Proceedings

DENDROLOGY IN THE EASTERN DECIDUOUS FOREST BIOME

Publication No. FWS-2-80
School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
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DENDROLOGY IN THE EASTERN DECIDUOUS FOREST BIOME

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Edited by

Peter P. Feret
Terry L. Sharik

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Department of Forestry
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FORWARD

These proceedings contain papers presented at the conference "Dendrology in the Eastern Deciduous Forest Biome" held September 11, 12 and 13 on the Virginia Tech. Campus. The conference theme was designed to elicit a response to the question "What is the current state of dendrology research and teaching in the biome; and what is the future of dendrology as a science in the biome?"

The papers presented indicate a considerable breadth of opinion as to 1) what dendrology is and what it should be, 2) research needs in taxonomy of woody plants in the biome, 3) definitions of what constitutes rare and local trees and what should be done with respect to management and research and 4) how and why dendrology should be taught as a course.

We hope these proceedings will serve as a catalyst for more creative research in dendrology and will stimulate creative teaching of the subject.

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TABLE OF CONTENTS

Page

ORIGINS OF THE EASTERN DECIDUOUS FOREST

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SUMMARY

The history of the vegetation of eastern North America has been drastically revised in the past two decades. The oldest and most archaic angiosperms known, discovered in Virginia a century ago and recently redescribed, were a minor element in the mid-Cretaceous forest of gymnosperms and ferns. By the end of the Cretaceous period the angiosperms predominated, but not until the early Tertiary were most tree genera that characterize today's deciduous forest represented in the vegetation. During the mid-Eocene, temperate trees coexisted with many subtropical and tropical taxa which later became extinct during the cooling trend that culminated in the Pleistocene. Much of the Pleistocene is poorly documented for the North American continent, but at the time of the last glacial maximum the upper slopes of the central Appalachians supported tundra, and jack pine-spruce forests were widespread at lower elevations of the unglaciated Southeast. The location of glacial refugia and the differential migration rates of woody genera had a major influence on the composition of the transitory forest communities of late glacial and early postglacial time. The present interglacial interval may be nearing its end, and within a few centuries or millenia, tundra and boreal forests may again extend hundreds of kilometers south of their present limits.

Additional key words: Paleobotany, angiosperms, paleoecology, forests, Quaternary Period, North America (east).

INTRODUCTION

The history of the eastern deciduous forest was summarized less than three decades ago by Braun (1950). She described a formation that had changed only slowly and undramatically in the 100 million years between the first appearance of flowering plants in eastern North America and the recession of the last ice sheet less than 15,000 years ago. In 1950, paleobotany was a relatively inactive field, although the increasing use of fossil pollen as a paleobotanical tool was beginning to raise questions about vegetational changes in the recent past.

Since 1950, and particularly in the past 15 years, radical changes in paleobotany and geology have brought about major reinterpretations of plant history, and few elements of Braun's historical reconstruction remain intact. The validation of continental drift has revolutionized historical plant geography, and the explosive growth of information from fossil pollen and spore analysis has caused many aspects of plant history to be rewritten, from the origin of the angiosperms to the nature of plant communities at the end of the Pleistocene. This paper reviews what is currently known about the vegetation of eastern North America at three important stages in its history: (1) about 100 million years ago during the mid-Cretaceous, when angiosperms first appear in the fossil record; (2) about 50 million years ago during the early Tertiary, before the start of the progressive cooling that culminated in the Pleistocene; (3) the past 100 thousand years or so--before, during, and after the last glacial period. Finally, I speculate about what the vegetation of eastern North America might be like 10,000 years from now.

100 MILLION YEARS AGO

In 1879 Charles Darwin, in a frequently quoted letter to J. D. Hooker, described the origin of flowering plants as "an abominable mystery" (Darwin and Seward, 1903, p. 20), and until the past decade there was little reason to challenge this pessimistic view. Darwin referred to the fact that angiosperms were already abundant, diverse, and often remarkably modern-looking at the time of their first appearance in Cretaceous rocks.

In the same year, University of Virginia professor of geology and natural history William M. Fontaine first noted a series of fossil leaves that he had found in a Mesozoic deposit near Fredericksburg (Fontaine, 1879). Despite their reticulate venation and generally angiospermous appearance, he hesitated to label them angiosperms because the flora of which they were a minor element seemed to be much older than the oldest angiosperm fossil floras known from other parts of the world. It was a typically "Upper Jurassic" flora, dominated by conifers, cycads, and ferns. In the following decade, Fontaine made extensive collections of macrofossils in outcrops of the Potomac Group, a series of flood plain and deltaic sediments that span 15-30 million years of mid-Cretaceous time (Doyle, 1977a). The Potomac Group extends along the western edge of the Atlantic coastal plain in a broken arc from the James River near Richmond, Virginia, through Washington and Baltimore, to Wilmington, Delaware. Fontaine collected fossils at several sites in Virginia, but the oldest deposits in which he found appreciable numbers of angiosperms were at Fredericksburg and a site on the James River.

Fontaine was fully aware of the importance of these ancient floras to an understanding of angiosperm evolution. In his descriptions of them (Fontaine, 1889, 1905), he recognized that the earliest angiosperm remains were generalized, archaic types remote from living genera, "very few in species and very rare in specimens," with leaves that sometimes had irregular, disorganized venation and poorly differentiated midrib and lateral veins. These fossils are now assigned to Zone I of Brenner's (1963) pollen-based stratigraphic classification of the Potomac Group sediments. In the later floras that Fontaine studied (Brenner's Zone II), the angiosperms showed essential continuity with the earlier fossils, but they were more numerous, the more abundant forms were more modern in appearance, and the archaic types had mostly disappeared. Commenting on this sequence, Fontaine (1889) observed that "the apparently sudden advent of this type of plants [the angiosperms] in predominating numbers is not to be taken as indicating their true mode of appearance."

Although the significance of these early angiosperms was recognized by Fontaine's contemporaries (Knowlton, 1889; Ward, 1888), through an unfortunate circumstance his work has had little impact on paleobotany. In a revision of the Potomac floras published early in his career, E. W. Berry (1911) questioned that Fontaine's "archaic" leaves were angiosperms at all, and thought they might be ferns or Gnetales. Berry, one of the most prolific of American paleobotanists, dominated the field in the early part of this century, and his assessment of Fontaine's fossils was widely accepted as authoritative (e.g., Hughes, 1961; Brenner, 1963) until the past few years.

Fontaine's fossils--now recognized as the richest known assemblage of primitive angiosperms--were not reinvestigated until a nearly complete record of fossil pollen and spores of the Potomac Group had been worked out by Brenner (1963), Doyle (1969, 1973), Doyle and Hickey (1976), and others. Angiosperm pollen first appears at the same level as the most archaic angiosperm leaves. Like the macrofossils, the pollen is limited in morphological diversity and greatly outnumbered by fern spores and gymnosperm pollen. In its structure and sculpturing, much of the pollen is a generalized type represented in both the magnoliid group of dicotyledons and the monocotyledons, and one pollen type has features that are now restricted to monocotyledons (Doyle, 1973). Similar types of angiosperm pollen appear in England at about the same time (Doyle, 1977b).

The macrofossils collected by Fontaine and his contemporaries, augmented by new collections, have been restudied by Wolfe (1972), Wolfe _et al._ (1975), Doyle and Hickey (1976), and Dilcher (1979). Angiosperm remains are fragmentary at the lowest level (lower Zone I of Brenner, 1963), but about five species can be distinguished. One of them, first collected by Fontaine on the James River, has a venation pattern similar to that of monocotyledons, although it exhibits the same disorganization as the dicotyledonous leaves in this assemblage. Most of these species are also represented in the somewhat later Fredericksburg flora (the upper part of Brenner's Zone I), which includes nine or ten dicotyledons. All of the leaves are apparently simple, and most are ovate, obovate, or elliptical in shape, with pinnate venation. One species has reniform leaves with venation that approaches the palmate. Most have small leaves (less than 5 cm long), but one species with more highly organized venation has leaves that may exceed 20 cm. In some species the blade and petiole are poorly demarcated, and at the base of the blade the midrib consists of more than one discrete vascular strand. The venation is generally highly irregular, with poorly differentiated vein orders.

The leaf characteristics of Zone I angiosperms, together with their restriction to relatively coarse, inclined sediments, led Doyle and Hickey (1976) and Doyle (1977a, 1978) to infer that they may have been opportunistic pioneer species with a shrubby, semiherbaceous, or perhaps herbaceous growth habit, occupying underexploited habitats such as unstable stream margins. In adjacent sediments that may have been deposited in more stable swamp environments, only gymnosperms and ferns are represented.

The fossils collected by Fontaine at Fredericksburg also include what are believed to be the oldest known angiosperm reproductive structures (Dilcher, 1979). These are clusters of 3-8 carpels borne on a flattish receptacle. Possible scars below the carpels are the only indication of other floral appendages. These flowers, unlike the pollen and leaves of Zone I plants, do not conform to the magnoliid prototype of the primitive angiosperm, inferred from the comparative morphology of living angiosperms.

A hiatus of perhaps a few million years (Doyle, 1977a) separates Zone I from the later (Zone 2) deposits sampled by Fontaine. During this break in the macrofossil record, angiosperm pollen shows a steadily increasing diversity, including the first appearance of a structural type that is now restricted to the non-magnoliid dicotyledons.

Conifers and ferns still dominate the vegetation in Subzone IIB, near the end of the early Cretaceous, but angiosperm macrofossils are more numerous than in Zone I (about 36 kinds in the subzone: Doyle and Hickey, 1976), and occasionally are locally dominant. Simple leaves with poorly organized venation persist and diversify, and serrate leaf margins are more varied. Lobed and deeply cordate leaves are common, and peltate leaves are suggestive of aquatics growing in ponds (Doyle and Hickey, 1976). Pinnately and palmately lobed leaves with irregular venation are locally abundant, and opposite leaves first appear in these sediments. Later in the zone, pinnately compound leaves also make their first appearance. At this level, palmately lobed "platanoid" leaves are present in abundance. These leaves are up to 10-20 cm long, with 3-7 lobes, and better organized, more rigid venation. Doyle (1978) has suggested that the "platanoid" complex may have been riparian trees. The possible presence of Platanus-like fruiting heads in this zone, and their somewhat later occurrence in central North America and central Europe (Dilcher, 1979), support the possibility that the monotypic Platanaceae is an extremely ancient lineage. Platanus is known from macrofossil evidence to have been widely distributed at the beginning of the Tertiary (Wolfe, 1975), but unfortunately the pollen cannot be reliably identified (Muller, 1970).

In addition to the presence of these Platanus-like macrofossils in mid-Cretaceous rocks, there is other evidence that wind pollination originated early in angiosperm evolution. Female catkins of several types and possible male catkins have been found in Kansas rocks that date to the earliest Late Cretaceous (Dilcher, 1979).

During the Late Cretaceous (a period of 30-45 million years), angiosperm pollen was increasingly diverse and abundant, although only toward the end of the Cretaceous did it consistently outnumber gymnosperm pollen and fern spores (Muller, 1970). During this period, the location of shallow epicontinental seas may have been partly responsible for the increasing provincialism of the world's pollen and spore floras. A broad seaway separating eastern and western North America delimited two northern hemisphere provinces. In the province that included eastern North America and Europe, the pollen assemblages are dominated by the "Normapolles," a group with elaborately structured pollen that reached its maximum diversity at the end of the Cretaceous and died out in the early Tertiary. Similarities in pollen structure suggest that the Normapolles group may be ancestral to several families of "Amentiferae," possibly including Juglandaceae, Betulaceae, and Ulmaceae (Muller, 1970; Wolfe, 1973). By the end of the Cretaceous, a few pollen types can be positively identified with living arborescent taxa, including Aquifoliaceae (Ilex), Betulaceae (Alnus), and Fagaceae (Muller, 1970).

50 MILLION YEARS AGO

The most extensive fossil record of the early Tertiary in eastern North America is in sediments laid down around the Mississippi Embayment, an intermittent extension of the Gulf of Mexico along the axis of the Mississippi River. The extensive macrofossil floras of these sediments were described by E. W. Berry several decades ago (e.g., Berry, 1930). Many of his determinations are now considered incorrect (Dilcher, 1971), and reidentification of these rich assemblages has only begun in the past 15 years. These sediments also provide a diverse, continuous pollen and spore record through much of the early Tertiary, with more than 370 pollen taxa represented in the Eocene rocks of this region (Tschudy, 1973).

Macrofossils of the mid-Eocene Claiborne formation are particularly abundant and well-preserved in commercially mined clays of western Tennessee, which are believed to have been deposited in oxbow lakes (Dilcher, 1971). The mid-Eocene macrofossils that have been redescribed are listed in Table 1 (summaries in Dilcher, 1971, 1973; also Crepet, 1978, 1979; Daghlian, 1978; Dilcher et al.,1976; Manchester and Dilcher, 1979; Roth, 1979; Zavada and Crepet, 1979), together with those pollen types whose identification reflects some degree of consensus among palynologists (Elsik, 1974; Gray, 1960; Tschudy, 1973). Dilcher's (1971) estimate that at least 60 percent of Berry's determinations are incorrect at the genus or family level appears to be exaggerated; many of the genera and 23 of the 28 angiosperm families in Table 1 are also listed by Berry in his last comprehensive treatment of these Eocene floras (Berry, 1930).

TABLE 1. Families and genera of seed plants in mid-Eocene floras of the Mississippi Embayment.

Family	Genus	Macrofossils	Pollen
Gymnosperms			
Ephedraceae			
	Ephedra		x
Podocarpaceae			
	Podocarpus	x	
Pinaceae			
	Pinus		x
Monocotyledons			
Araceae			
	Philodendron	x	
	1 extinct	x	
Gramineae			x
Palmae			x
	Sabal	x	
	4 extinct	x	
Restionaceae			x
Dicotyledons			
Apocynaceae		x	
Aquifoliaceae			
	Ilex		x
Araliaceae			
	Dendropanax	x	
Betulaceae			
	Alnus		x
Dilleniaceae		x	
Euphorbiaceae			
	Hura	x	
	2 extinct	x	
Fagaceae			
	Quercus		x
	Castanea		x
	Dryophyllum (extinct)	x	
	1 or more extinct	x	

TABLE 1. (cont)

Family	Genus	Macrofossils	Pollen
Hamamelidaceae			x
Juglandaceae			
	Juglans		x
	Carya		x
	Platycarya		x
	Engelhardia-Oreomunnea-Alfaroa	x	x
	2 extinct	x	
Lauraceae			
	Ocotea	x	
	Nectandra	x	
Leguminosae			x
Mimosoideae		x	
Loranthaceae			x
Magnoliaceae			x
Moraceae			x
	Ficus	x	
Myricaceae		x	
Myrtaceae			x
Nyssaceae			
	Nyssa	x	x
Onagraceae			x
Rubiaceae		x	
Sapindaceae		x	x
Sapotaceae			x
Symplocaceae			x
Tiliaceae			
	Tilia		x
Ulmaceae			
	Ulmus		x
	1 extinct	x	
Unknown	Knightiophyllum (extinct))	x	

It is generally agreed that the Eocene was warmer than those epochs that preceded and followed it (Elsik, 1974; Wolfe, 1975). Many of the identified families and genera in the Claiborne formation are now mostly or entirely restricted to subtropical and tropical climates. All of the families still occur in North America (including the West Indies) except Restionaceae, a southern hemisphere family of herbaceous monocotyledons with a single species in southern South America.

Despite this dominant tropical character, the well-documented occurrence in the Claiborne flora of temperate families like Betulaceae, Fagaceae, Juglandaceae, and Ulmaceae indicates that the vegetation was not the moist tropical forest suggested by the presence of genera like Philodendron. Gray (1960), who first identified the pollen of many temperate woody genera in Claiborne sediments, speculated that the pollen of these taxa might have been wind-transported from deciduous hardwood forests in the Appalachians. This view was supported by their low frequency in the sediments she studied, but more extensive sampling of other Claiborne deposits (Elsik, 1974) shows frequencies of Castanea, Quercus, and Engelhardia-Oreomunnea-Alfaroa pollens that are much too high to be accounted for by long-distance transport. Also, some of the temperate taxa are represented by macrofossils as well as pollen (table 1), and must have grown near deposition sites in forest associations that have no modern equivalents.

Another set of paleoecological indicators--leaf size and form--emphasizes the difficulty of extrapolating from modern floras and vegetation to their Eocene counterparts. The Claiborne leaf flora has the high percentage of entire margins that characterizes wet tropical or subtropical forests, but the near absence of drip-tips and high frequency of small leaves suggests a cooler or drier climate (Dilcher, 1973; Wolfe, 1975). Dilcher described the mid-Eocene climate as seasonally dry to slightly moist and warm-temperate to cool-subtropical; from the same data Wolfe inferred a dry tropical climate.

The Claiborne flora includes a majority of the elements that dominate the contemporary eastern deciduous forest. Following a major climatic deterioration in the Oligocene (Wolfe, 1975), many of the tropical and subtropical taxa in the Claiborne flora were eliminated from continental North America north of Mexico. During the late Tertiary, the temperate elements were increasingly restricted to regions of equable climate, including eastern North America and eastern Asia. In other parts of the northern hemisphere, regional extinction of these temperate woody taxa was widespread at middle and upper latitudes. It is best documented for the now impoverished woody flora of northwestern Europe (van der Hammen et al.,1971). Castanopsis and Engelhardia, among others, were eliminated during the Miocene; Aesculus, Liquidambar, and Nyssa in the Pliocene; and Magnolia, Carya, Castanea, Juglans, Pterocarya, and Celtis during the Pleistocene. These widespread extinctions in the late Cenozoic are responsible for the striking and well-known floristic similarities of the forests of the eastern United States, eastern Asia, and to a lesser extent southeastern Europe and adjacent western Asia, and for the "Tertiary relict" character of these contemporary forests.

THE PAST 100,000 YEARS

Braun's (1950) view that the eastern deciduous forest was largely unaffected by the periodic glaciations of the Pleistocene has now been almost universally abandoned. The opposite view, based on modern dating techniques and an increasingly detailed knowledge of Pleistocene climatic and vegetational change, was expressed by West (1964): "we may conclude that our present plant communities have no long history in the Quaternary, but are merely temporary aggregations under given conditions of climate, other environmental factors, and historical factors." West referred to Europe, which now has detailed pollen sequences for the past 500,000 years and broken sequences covering several million years (van der Hammen et al, 1971), but his conclusion also applies to the late Pleistocene and Holocene vegetation of eastern North America. Davis (1976) has described the species-rich deciduous forest communities of the southern Appalachians as "a recent, chance conglomeration of species of trees that have immigrated into the area from different directions."

The last interglacial interval, which ended more than 100,000 years ago, is poorly documented in eastern North America, but the few available pollen sequences suggest a climate warmer than at present, with Liquidambar growing in southern Ontario (Wright, 1971). The more complete pollen record of northwestern Europe shows a forest sequence from boreal to temperate, and near the end of the interval a return to boreal forest (van der Hammen et al, 1971). Superimposed on this generalized interglacial cycle are unpredictable shifts in forest composition related to the arrival of tree taxa migrating at different rates for varying distances from different full-glacial refugia (Davis, 1976).

The last glacial interval reached a maximum 18,000 years ago in eastern North America, and the pollen sequences covering this period indicate that the vegetation south of the ice was very different than it is today. Reconstructions of the full-glacial vegetation by Brunnschweiler (1962) and Whitehead (1973) show bands of tundra, boreal woodland, and boreal forest occupying most of the unglaciated East, with deciduous communities restricted to the Gulf and southern Atlantic coastal plains and Florida. These full-glacial communities were, however, often quite unlike their closest modern counterparts, as Whitehead pointed out. Boreal forest was present at less than 1000 ft elevation in northwestern Georgia (Watts, 1970). It was dominated by jack pine (Pinus banksiana) and lesser amounts of spruce, both represented by macrofossils (needles) as well as pollen. But pollen of a few deciduous hardwoods (Quercus, Carya, Ostrya-Carpinus) is also present in small amounts; these trees may have been intermingled with the boreal species in small numbers or grown on sheltered sites nearby. Spruce and probably jack pine also occurred in central Tennessee (Delcourt, 1977) and on the Atlantic coastal plain at least as far south as southeastern North Carolina (Whitehead, 1973). Tundra was present at 2700 ft in western Maryland, and persisted there until 12,700 years ago (Maxwell and Davis, 1972).

Most late glacial and early postglacial communities also differed from contemporary communities in composition, relative species-abundance, or both (Wright, 1971; Davis, 1976). The late glacial spruce forest in Minnesota, for example, lacked pine, which was rare or absent in the Great Lakes region until the beginning of the Holocene 10,000 years ago, but included Fraxinus, Quercus, and Ulmus--trees that are present only near the southern margins of the boreal forest today.

The location of glacial refugia and the migration rates of tree taxa had a major influence on the composition of these transitory forest communities. Not much is known about the location of glacial refugia, although the pines of the Great Lakes region are believed to have immigrated there in the past 10,000 or 11,000 years from refugia to the east (Wright, 1968). The migratory rates of several eastern tree species and genera have been estimated from the pollen record by Davis (1976) and others. The migration rate of jack pine is variously estimated at 350-500 m per year (Davis, 1976) and 1 km per year (Bernabo and Webb, 1977). Beech (Fagus grandifolia), despite its heavy seeds, migrated at a rate of 250-300 m per year (Davis, 1976). Chestnut and hickory were much slower--about 100 m per year for chestnut. Davis did not estimate the migration rate of oak in eastern North America, but in Russia oak migrated 2400 km in 5000 years (Leopold, 1967)--a remarkable 480 m per year! Due to these and other factors, most forest communities did not achieve their present character until the past few thousand years, and migration may still be influencing forest composition at the margins of the eastern deciduous forest.

10,000 YEARS FROM NOW

Although the geological time scale conveys the reassuring notion that the Pleistocene ended about 10,000 years ago, most students of global climatic change agree that the Holocene is only the most recent in a long series of relatively short interglacials separated by much longer glacial intervals (Kukla et al.,1972). The present interglacial is thought to have passed its warmest peak about 6000-7000 years ago (the "altithermal" or "temperature optimum"), and the present climatic trend is one of slow oscillatory cooling. The most recent interglacials are estimated to have lasted about 10,000 years, so the present warm interval may be nearing its end. Within the next few millenia or even the next few centuries, Canada and the northern United States may be covered by glacial ice, as they have been during most of the past 2 million years. With tundra again in the higher Appalachians and jack pine-spruce forests on the Georgia piedmont and the Atlantic coastal plain, many tree species that are now common elements of the eastern deciduous forest may once more be "rare and endangered species, [surviving] in small areas of favorable climate." (Davis, 1976).

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WOODY PLANT TAXONOMY IN THE EASTERN UNITED STATES: SOME INTRODUCTORY REMARKS

By

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Many dendrologists undoubtedly feel that there is little taxonomic work left to be accomplished on forest trees, especially those which are economically important. However, a look through some of the recent taxonomic literature on the woody plants of the Eastern U.S. indicates that this supposition is not true.

In 1968, the English plant taxonomist Vernon Heywood wrote: "The history of the development of taxonomy is very largely a reflection of the history of development of techniques which have a taxonomic application." (Heywood 1968, p. 4). As newer types of data are utilized, a more precise taxonomy should result. Some of the more recent sources of taxonomic evidence that have proved most useful are chemical and numerical studies and micromorphological studies utilizing the electron microscope.

Examples of these types of studies on southeastern woody taxa are Clarkson and Fairbrothers' (1970) serological and electrophoretic investigation of *Abies*; Giannasi's (1978) paper utilizing flavonoid chemistry to investigate generic relationships in the Ulmaceae; Thein, Heimermann, and Holman's (1975) use of gas chromatography and mass spectrometry on floral chemicals of *Liriodendron* and *Magnolia*; Hickock and Anway's (1972) paper combining a chromatographic analysis of flavonoid variation with a statistical analysis of morphological variation in *Tilia*; and Thomson and Mohlenbrock's (1979) heavy reliance on the scanning electron microscope in examining leaf trichomes in *Quercus*.

This is not to play down the more classical approaches to taxonomy. I, myself, have utilized the most classical method of all, comparative morphology, in my paper on *Zanthoxylum* in North America (Porter, 1976). Likewise has our first speaker, Dr. Hardin (1975), in his interesting and useful study on hybridization and introgression in *Quercus alba* L. His paper today, however, focuses on the use of the scanning electron microscope.

The point of all this is to indicate that as long as new data become available, or as long as there are new ways to look at old data, taxonomic change is inevitable. Although many people are wont to look on taxonomy as the most static of the sciences, indeed today it is one of the most dynamic.

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MODERN DENDROLOGY AND SEM-SYSTEMATICS[1]

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SUMMARY

The dendrology of the past concentrated on alpha taxonomy, autecology, revisionary studies, inter- and intra-specific variation, hybridization, and practical aspects of silvical characteristics and tree improvement. Modern dendrology of the future should emphasize the adaptive significance of characters and character states, ecological life histories, and evolutionary, genetic, and ecological principles that govern the dynamics of woody plant populations. One relatively new and very powerful tool available to the modern dendrologist is the scanning electron microscope. This has opened up a whole new dimension of analytic and synthetic micromorphological characters but at the same time it brings new problems of phytography. SEM-systematic studies of foliar surfaces indicate an overuse of the term "stellate" and a lack of adequate terminology for micro-relief features due to epidermal contours, cuticular patterns, epicuticular wax deposits, and protuberances on trichomes. New terminologies and a refinement of old definitions will have to be made to describe the myriad of differences in foliar surface features as seen with the SEM.

Additional key words: scanning electron microscopy, trichomes, cuticular patterns, epicuticular wax.

INTRODUCTION

For this session on "Woody Plant Taxonomy in the Biome", I want to first review briefly the past taxonomic research on woody plants, indicate the kinds of research which I think are needed for the future, and then present some examples of the need for new and redefined terminologies to keep pace with new micro-structural characters coming from scanning electron microscopy of foliar surfaces.

DENDROLOGY OF THE PAST

The research in woody plant taxonomy prior to 1950 dealt primarily with alpha taxonomy--classification, nomenclature, floristic inventories, descriptive autecology, and species distributional patterns. These

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early efforts demonstrated the tremendous species diversity and endemism which exist in the Biome, the geographically fascinating floristic affinities which exist with many other parts of the world, the various distributional patterns which reflect past migrations, relicts, or reticulate evolution, and a fairly good picture of the dynamics of the flora during the past 50 million years. In short, we generally know the what, where and in some cases the when, how, and why, and we have a reasonably workable classification and nomenclature for the woody taxa. For all of this invaluable information we are indebted to botanists such as John and William Bartram, André and François Michaux, Rafinesque, Nuttall, Gray, Gattinger, Sargent, Ashe, Britton, Harbison, Small, Fernald, Harper, Cain, Shanks, E. Lucy Braun, and numerous others (Core, 1970). Their explorations, collections, careful observations, and field studies form the basis for the botanical excitement in this region.

During the past 30 years there has been an explosion of research and publications on the woody plants of our area, some purely taxonomic and ecological, and others practical in terms of forest genetics, management, and tree improvement. In taxonomy, there has been a nearly complete standardization of the nomenclature and a mapping of the distributional ranges of the trees thanks to Dr. Elbert Little (1953, 1971, 1977, 1979).

Revisionary studies of a number of woody genera have led to a more realistic, or at least different (!), classification and taxonomic interpretation. Examples are Prunus (McVaugh, 1951), Aesculus (Hardin, 1957c), Cyrilla (Thomas, 1960), Asimina (Kral, 1960), Rhododendron sect. Rhododendron (Duncan and Pullen, 1962), Nyssa (Eyde, 1963), Calycanthus (Nicely, 1965), Clethra (Wilbur and Hespenheide, 1967), Diervilla (Hardin, 1968), Tilia (Jones, 1968), Leiophyllum (Wilbur and Racine, 1971), Aronia (Hardin, 1973), Kalmia (Southall and Hardin, 1974; Ebinger, 1974), Populus (Eckenwalder, 1977), and Alnus (Furlow, 1979).

Investigations of evolutionary relationships and adaptive significance of structural modifications, such as in the Juglandaceae (Stone, 1963, 1973; Whitehead, 1965; Stone et al., 1969), and studies of floral biology as in Magnolia (Thien, 1974) have been most interesting and useful--but all too few.

Analyses of individual species such as Acer saccharum (Desmarais, 1952), Juniperus virginiana (Hall, 1952: Flake et al., 1969, 1978), Liquidambar styraciflua (Duncan, 1959), Symplocos tinctoria (Hardin, 1966), Pinus pungens (Zobel, 1969), Quercus alba (Baranski, 1975; Braham, 1977), and Fagus grandifolia (Cooper and Mercer, 1977) have indicated fascinating and often quite different patterns of intraspecific variation. Analyses of natural hybridization and introgression have led to a better understanding of variability in trees such as Aesculus (Hardin, 1957a, 1957b), Quercus (Cooperrider, 1957; Silliman and Leisner, 1958; Ledig et al., 1969; Hardin, 1975; Jensen and Eshbaugh, 1976,), Picea (Wright, 1955; Morgerstern and Farrar, 1964;

Nienstaedt and Teich, 1971), and Betula (Grant and Thompson, 1975).

Much of this type of taxonomic information has been summarized in a series of publications during the past 20 years under the general title of the "Generic Flora of the Southeastern United States" published in the Journal of the Arnold Arboretum. The first dealt with the genera of the Ranales (Wood, 1958) and one of the most recent ones dealing with woody plants was on the Caesalpinioideae (Robertson and Lee, 1976). This continuing project is valuable in indicating the present state of our knowledge and identifying the current taxonomic problems and gaps in our information.

The forestry literature during the past 30 years is replete with studies dealing with silvical characteristics, hybrids, genetics of individual species, tree improvement, pollination, reproduction, variation and provenance analyses, and ecology--all having important taxonomic implications. Much of this forestry literature has been summarized by Miller (1967, 1974), and two USDA publications (1965, 1974).

During the remaining two decades of this century we should certainly continue to fill in the gaps with floristic studies. Such publications as the "Woody vines of the Southeastern States" (Duncan, 1967), "The Woody Plants of Alabama" (Clark, 1971), the second edition of the "Flora of West Virginia" (Strausbaugh and Core, 1978), the proposed "Vascular Flora of the Southeastern United States" (Radford et al., 1967) and the now revitalized "Flora North America" project (see announcement in Brittonia 31:124. 1979) are extremely important. It is also very necessary that we continue revisionary and monographic studies (Stuessy, 1975) for there are still genera and species complexes of woody plants in the Biome which are poorly understood and with debatable nomenclature.

MODERN DENDROLOGY

I believe, though, that we are now at a stage where the emphasis will shift to inter-and intra-specific variation; the adaptive significance of anatomical, morphological, chemical, and cytological differences; ecological life histories; evolutionary relationships among families, genera, and species; population biology; and the discovery of evolutionary, genetic, and ecological principles that govern the dynamics of woody plant populations. Call it "modern dendrology".

There are numerous questions which need to be asked of the modern dendrologist. For instance, what do we really know about the function and importance of the individual or species population in an ecosystem? What do we know about plant demography, ecological life history, reproductive biology, or autecology of most of our woody species? What do we know about the extent or dimension of gene exchange in and between populations or even the effective size of a breeding population?

The recent concern for endangered species has brought these questions into embarrassingly sharp focus. What do we know of the details of interspecific competition, plant-plant interactions, speciation, ecophenic vs. ecotypic vs. clinal variation? Has a wide-ranging species undergone ecotypic differentiation or does it have a highly plastic "general purpose genotype"? How is the degree of genetic variability correlated with life history and reproductive strategies? What do we really know of the nature of the effective reproductive barriers that maintain the morphological/ecological units that we call species? Does introgression in forest trees occur as much as we have thought, or could the apparent introgression owe its origin to some other cause (Heiser, 1973)? Is the introgressive hybridization that does exist merely "evolutionary noise", as has been suggested (Wagner, 1970), or could it be a consistent feature of the adaptive system of many plant species or a syngameon, and necessary for continued ecological exploitation and future progressive evolution or even actual survival (Raven, 1976)? The modern dendrologist faces exciting problems for future research.

SEM-SYSTEMATICS

There are several relatively new techniques and new research directions (Raven, 1976, 1977) which are gaining in popularity and which can be of importance to the modern dendrologist. One involves electrophoretic methods which indicate relative genetic variability through allozyme analysis. The analyses thus far indicate that woody plants, particularly wind pollinated ones, have among the highest levels of genetic variability (Gottlieb, 1977; Hamrick, 1979; Brown, 1979). The population geneticists need to get this type of information while the natural species populations still exist or before the interbreeding populations are fragmented by man's eradication of more and more natural habitats.

A second very fascinating technique is the use of the scanning electron microscope. Ten years ago it was called the most exciting and significant tool so far produced (Heywood, 1969) and it certainly continues today as a very powerful technique (Cole and Behnke, 1975) which has opened up a whole new dimension of analytic and synthetic micro-morphological characters for comparative studies. Significant SEM studies have been made of pollen (Stone and Broome, 1975; Walker and Doyle, 1975), seed coats (Brisson and Peterson, 1976), and foliar surfaces (Faust and Jones, 1973; Dayanandan and Kaufman, 1976; Hardin, 1976, 1979).

The history of taxonomy reveals successive waves of excitement, each based upon a new methodology before it became a routine taxonomic technique. Thus we have had the periods of "cyto-taxonomy", "bio-systematics", and "chemo-systematics". With an increased use and interest in SEM now, maybe we should call the present period that of "SEM-systematics".

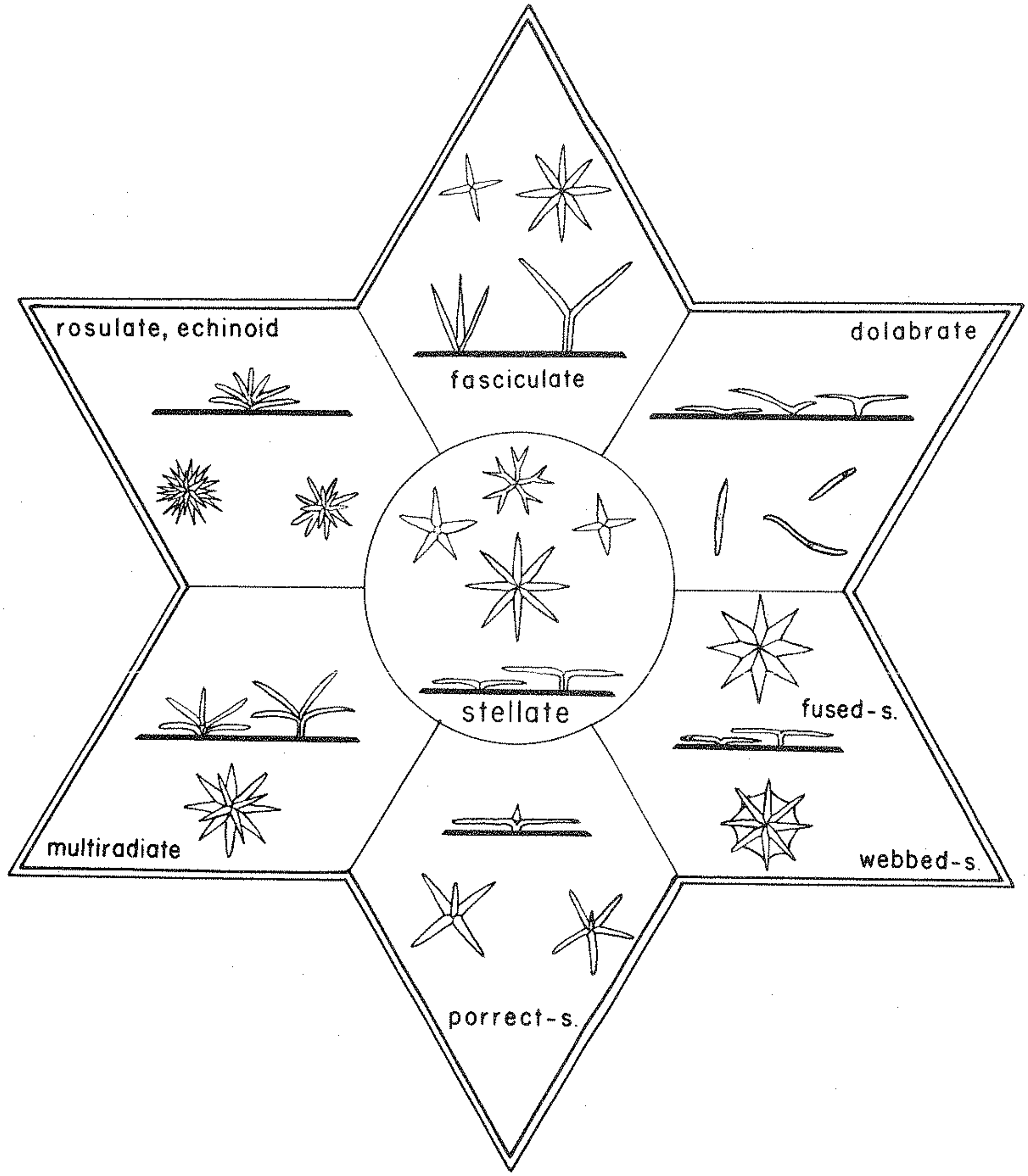


Fig. 1. Stellate and "para-stellate" trichome types.

As may be expected, new characters from SEM-systematic studies bring new problems of phytography--the descriptive terminology of plant structure. Previous terminology, developed through the resolution of light microscopy, is now not exact enough for critical comparisons and characterizations using SEM. This necessitates a corresponding increase in refinement of terminologies and explicit definitions and sometimes additional terms.

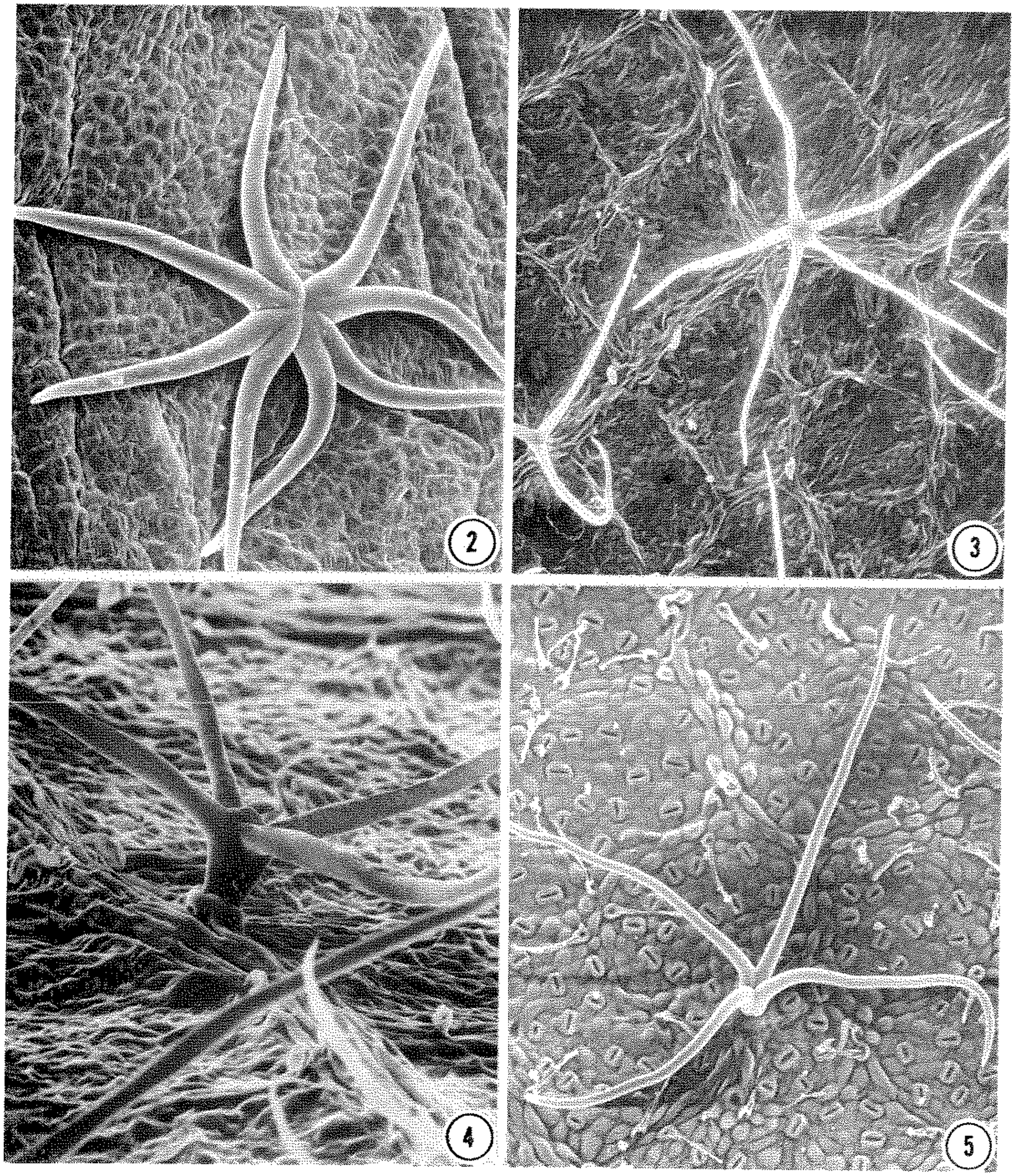
For example, the existing terminology associated with foliar surface features is full of synonyms, quasi-synonyms, generalized and ambiguous definitions, poor illustrations, and in some cases completely lacking. Twenty-five years ago, Rickett (1954) pointed out the ambiguity of the terms glabrate, glabrescent, pubescent, and others due to multiple meanings. These terms are still being misused today. In looking at a number of trichome types with SEM, I have become concerned with another example of misuse or overuse--that with the term stellate. This word is being used and defined entirely too broadly to include almost any branched trichome with radiating, star-like rays, and in addition, as a type of vestiture composed of star-like trichomes. Such broad usage leads to confusion, and descriptions too vague and ambiguous for purposes of critical comparisons. This is not good science.

The term stellate should be restricted to a trichome type, and described as having a single set of radiating, slender rays projecting horizontally from a common center (Figs. 1-4). It may either be sessile (Fig. 2) or stipitate (Fig. 4), and may have a varying number of rays. The distinguishing feature is the single set of rays held horizontally to the epidermis. In some cases the rays may be secondarily branched as in the Brassicaceae (Rollins and Banerjee, 1975).

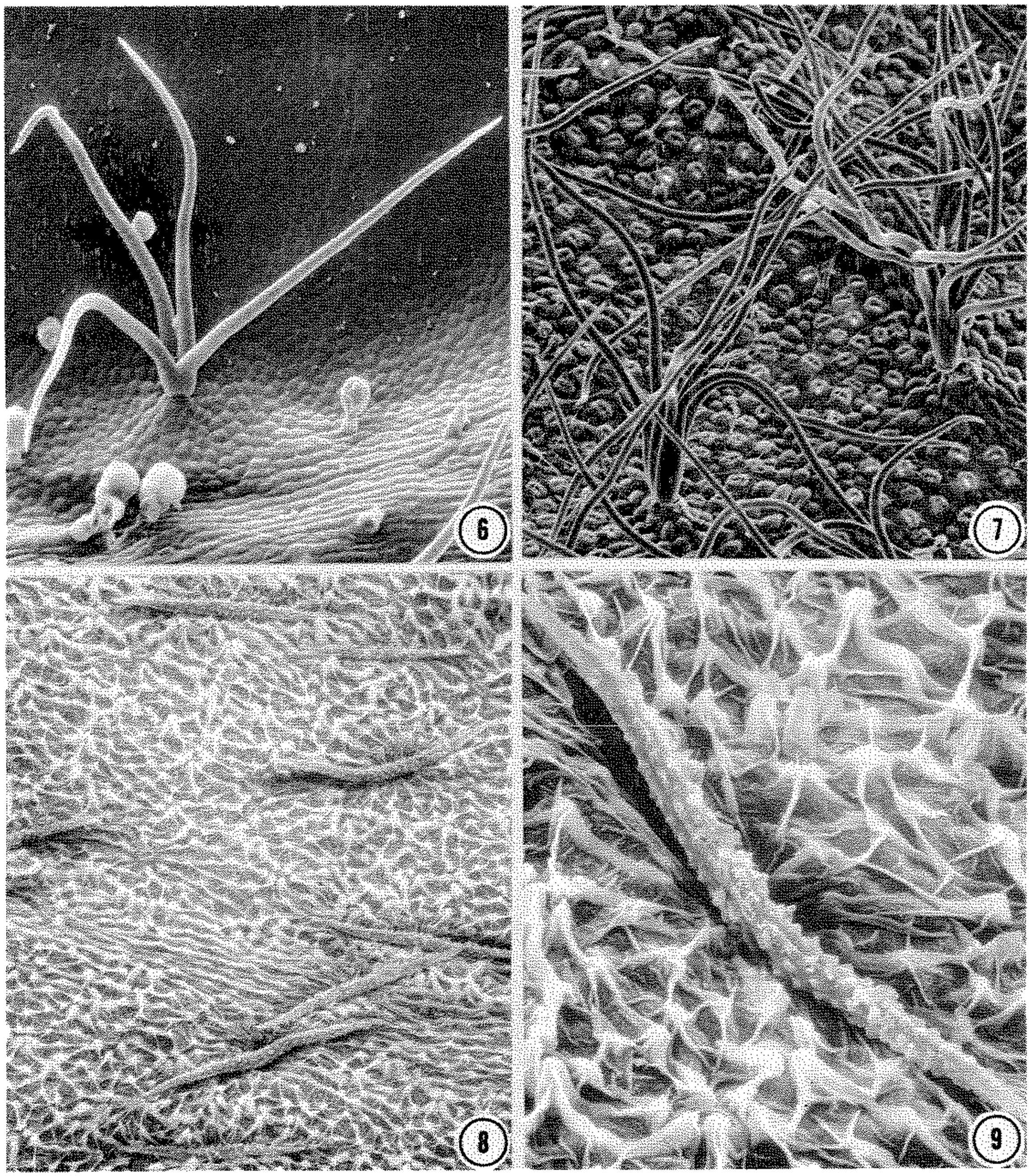
Several other types are somewhat similar, at least with light microscopy and in face view, and have been called "stellate" by various authors. They together may be thought of as pseudo-stellate or para-stellate (Fig. 1), but actually they should have their own specific term. One of these is fasciculate (Figs. 1, 5-7). In face view it has a stellate form (Fig. 5), but in side view it is obviously different with the rays held more or less erect (Fig. 6) rather than horizontal. This type may be sessile, stipitate, and also pedestaled (Fig. 7).

A very different and distinctive type has only two opposing rays and is known as dolabrate but has also been variously called "anvil", "malpighiaceous", "T-shaped", or twinned" (Figs. 1, 8, 9). The rays are parallel to the surface and it may be either sessile or raised on a central stalk cell. It certainly lacks the radial symmetry and should not be considered stellate. Somewhat similar is the three-rayed type also called "3-armed" or "Y-shaped" (Fig. 10). This also lacks the symmetry of the stellate form.

Two modifications of the stellate type are due to either fusion of the rays or webbing between the rays. The fused-stellate form has the



Figs. 2-5. 2. Sessile stellate trichome, X500 (Quercus sinuata). 3. Stellate trichomes, X110 (Tilia heterophylla). 4. Stipitate stellate trichome, X270 (Tilia heterophylla). 5. Fasciculate trichome, X200 (Quercus alba X lyrata).



Figs. 6-9. 6. Fasciculate trichome, X190 (Quercus stellata). 7. Pedastaled, stipitate, fasciculate trichomes, X100 (Quercus margaretta). 8. Dolabrate trichomes, X150 (Cornus florida). 9. Dolabrate trichome, X600 (Cornus florida).

rays fused together from the center to two-thirds their length (Figs. 1, 11). In the webbed-stellate type there is an obvious thin webbing between the rays as seen in some Brassicaceae (Rollins and Banerjee, 1975). Fusion or webbing beyond two-thirds the ray lengths leads to the peltate scale (lepide or squamate trichome) (Fig. 12).

The porrect-stellate type differs from the typical stellate by having one or two central erect rays in addition to the series of horizontal ones (Figs. 1, 13, 14). There is an obvious distinction between the erect and horizontal rays, unlike the condition in the next two types.

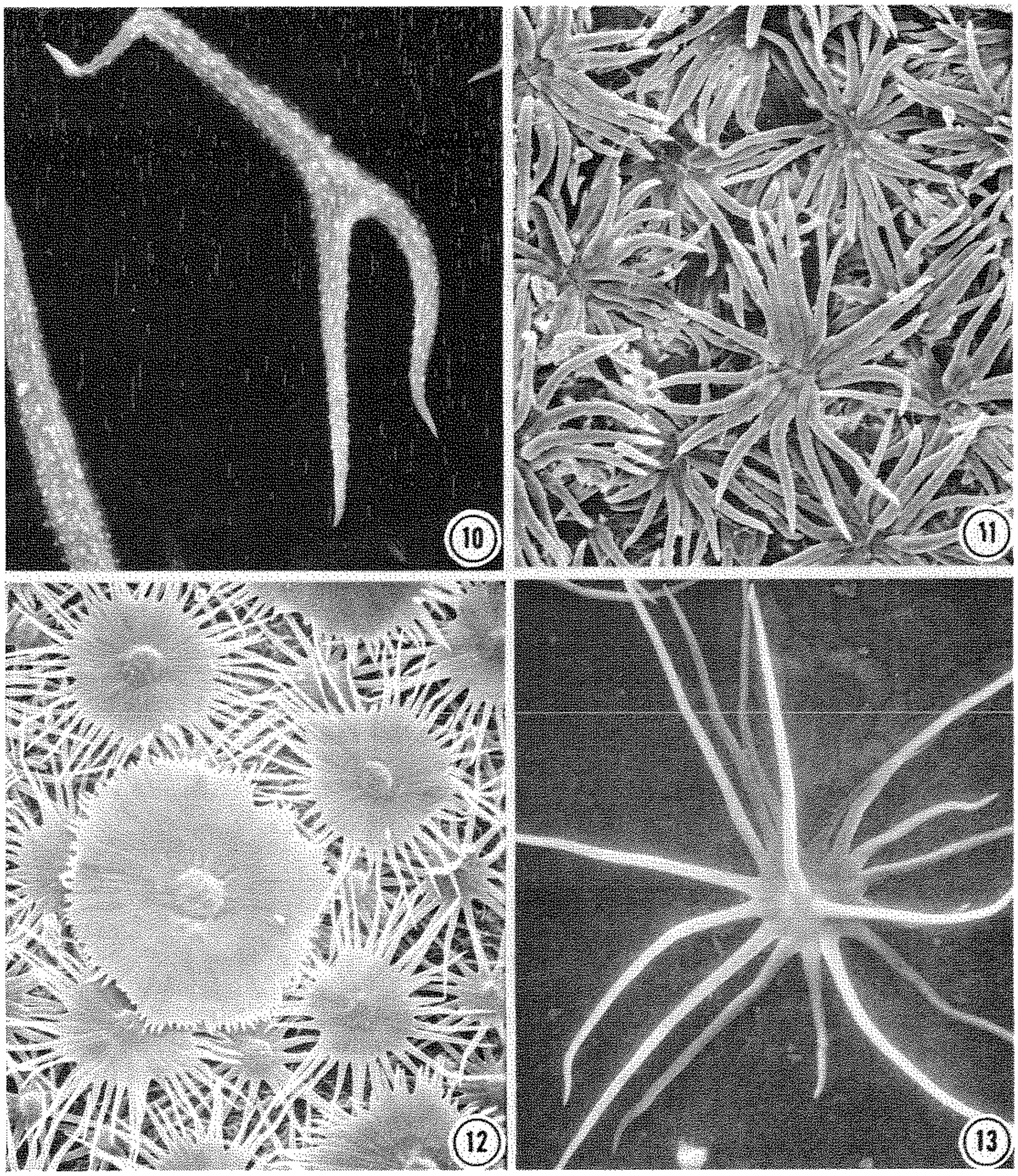
Multiradiate types have two or more levels of radiating and erect rays rather than just the single series of the true stellate form (Figs. 1, 15, 16). In *Quercus* they are thick-walled and the rays are tapered. The rosulate (echinate or tufted) type (Figs. 1, 17) has the same form but it is usually smaller and the rays thinner-walled, at least in *Quercus* (Hardin, 1976). The distinction between multiradiate and rosulate is not always clear and the terms multangulate, multiradiate, echinate, rosulate, and tufted have been generally quite loosely used and need to be re-defined.

Vestiture types with stellate or para-stellate trichomes should not be called simply "stellate". If the vestiture is composed only of stellate types, then a combined term to indicate relative density could be used; *e.g.*, stellate-tomentose or stellate-floccose, etc. In most cases, however, there is a mixture of trichome types, and the simple vestiture term is best.

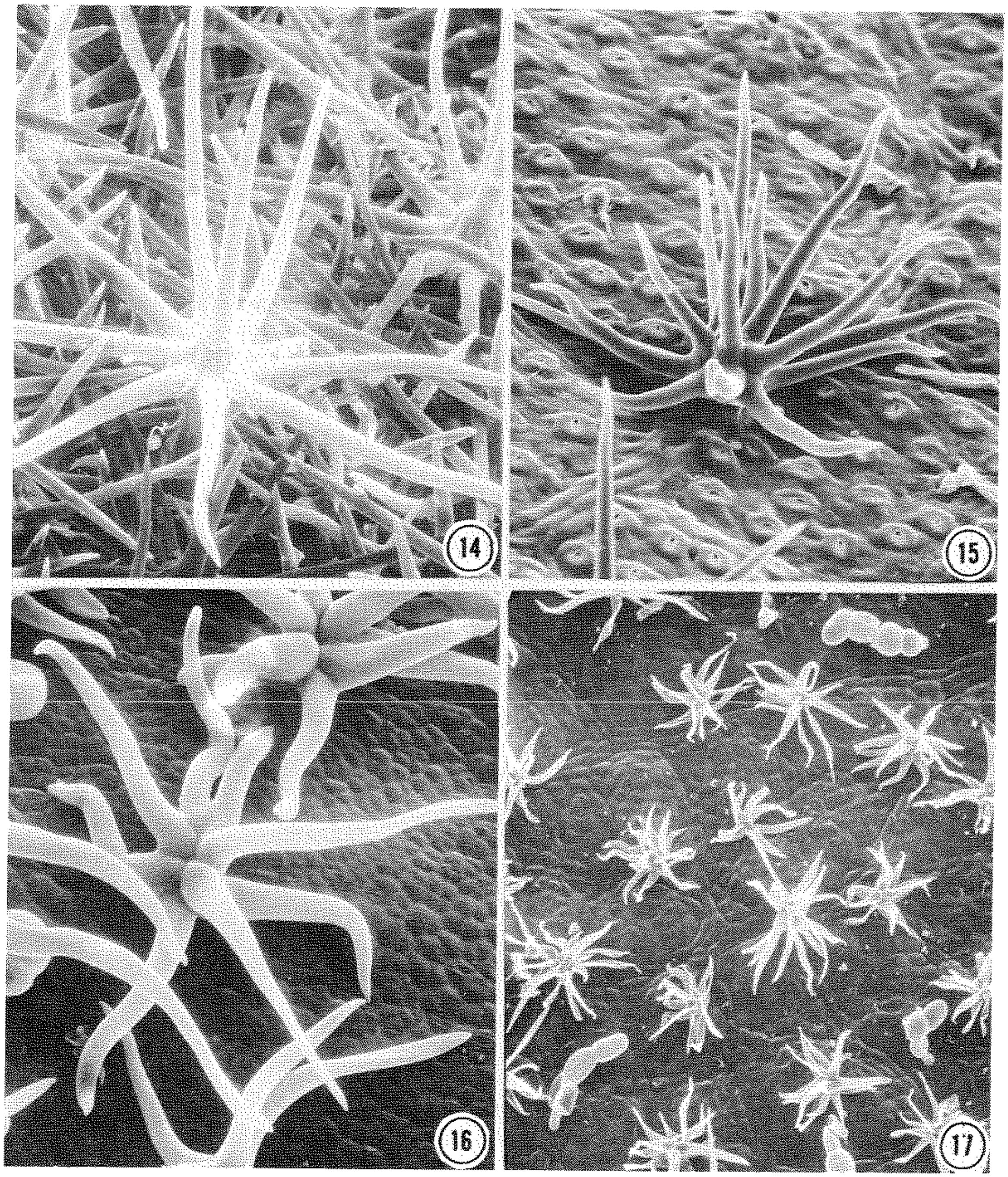
An example of the usefulness of exact trichome characterization comes from a recent study of the oaks of eastern North America (Hardin, 1979). There are eight different trichome types among the species and each species possesses a definite complement of types. Certain trichomes are characteristic of subgenera and series. For example stellate forms are found only among the white oaks, the fused-stellate type is only in the live oaks, and the rosulate and multiradiate types are only in the black and red oaks. In addition to such phylogenetic implications, the oak trichomes can serve as a fairly reliable clue to hybridization and introgression.

It is obvious that very exact characterizations and standardized, descriptive terminology, based upon SEM-systematic studies as a supplement to light microscopy, are needed for trichomes. Only with well illustrated and precisely worded glossaries will we be able to use these characters and communicate with equal exactness and understanding.

Additional foliar surface features, which are intriguing and of potential SEM-systematic use, involve micro-relief features due to epidermal cells and guard cells, cuticular patterns, epicuticular wax



Figs. 10-13. 10. Y-shaped or 3-rayed trichome, X400 (Erysimum sp.). 11. Fused-stellate trichomes, X300 (Quercus virginiana). 12. Squamate trichomes or peltate scales, X100 (Elaeagnus umbellata). 13. Porrect-stellate trichome, X300 (Elaeagnus angustifolia).



Figs. 14-17. 14. Porrect stellate trichome, X170 (Solanum eleagnifolium). 15. Multiradiate trichome, X400 (Quercus arkansana). 16. Multiradiate trichomes, X500 (Quercus ilicifolia). 17. Rosulate trichomes, X100 (Quercus incana).

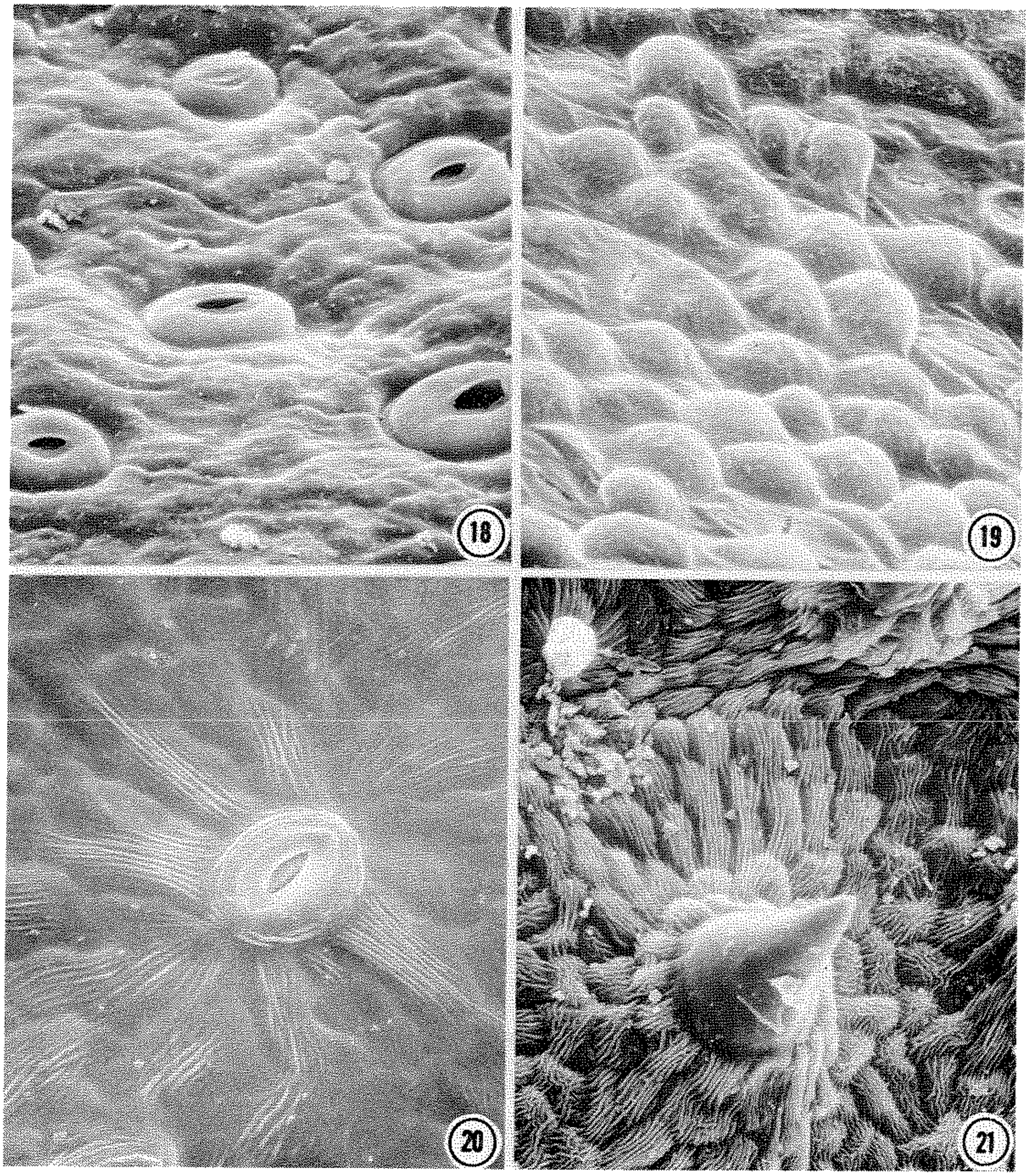
(Amelunxen et al., 1967; Lange, 1969), and protuberances on trichomes. As with trichome types, there is a lack of adequate descriptive terminology by which these features may be precisely described.

Primary relief due to epidermal cells varies from flat to rounded or papillose. Guard cells may be either even, protruding, or sunken with respect to the surrounding epidermal cells. The epidermal cells over veins or around trichome bases are also quite often different in outer contour.

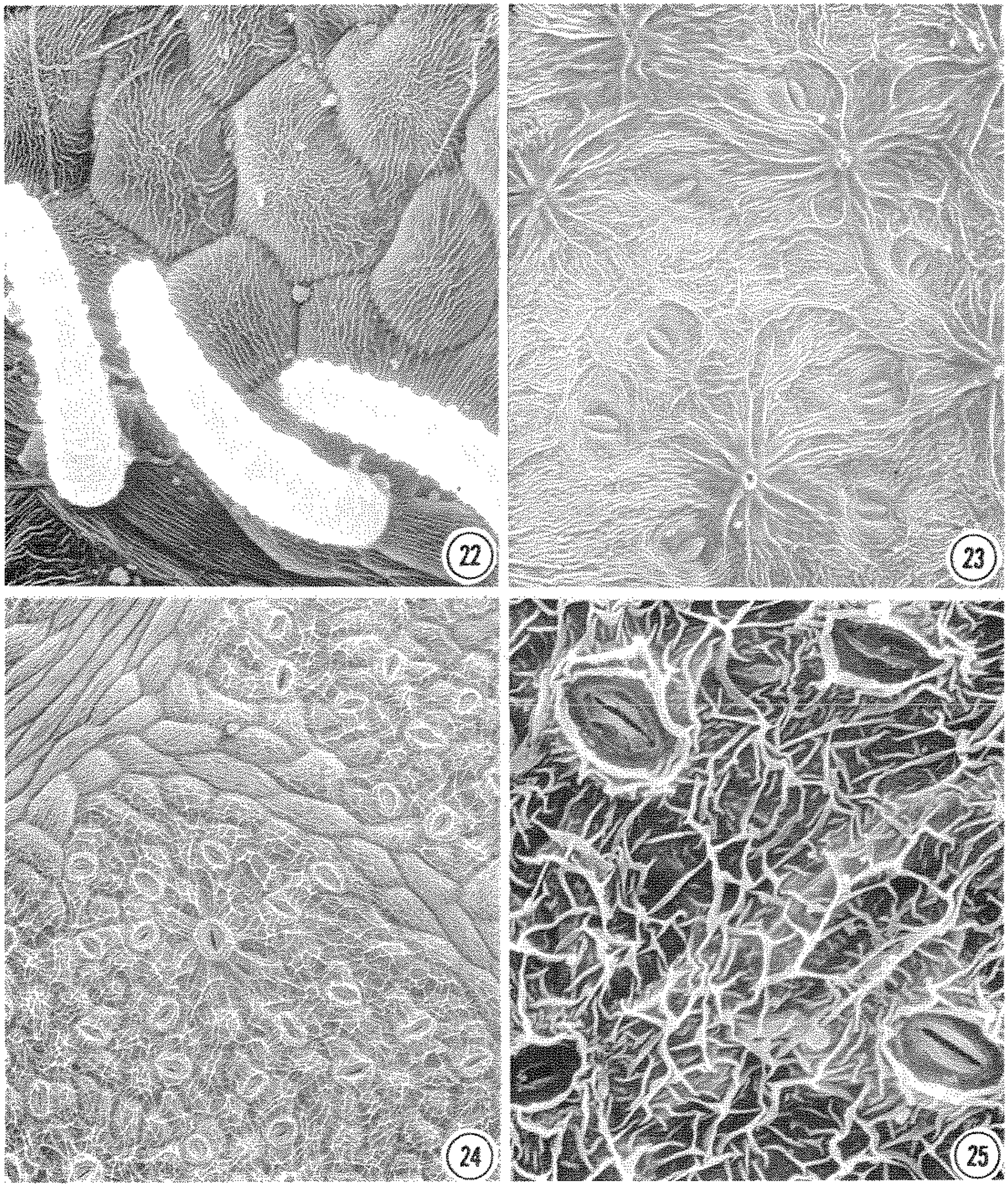
Secondary relief due to the cuticle is by no means a new taxonomic character, but the SEM gives a clearer picture and without the distortion sometimes accompanying the plastic peel technique. The cuticle may be thin and follow the contour of the epidermal and guard cells as in Buxus (Fig. 18) and Liriodendron (Fig. 19), or form a more or less flat surface and obscure the pattern of the cells as in Nyssa (Fig. 20). Cuticular ridges often form distinct patterns around guard cells as found in Nyssa (Fig. 20), around trichomes, or throughout as in Broussonetia (Fig. 21), Hydrangea arborescens (Fig. 22), Salix babylonica (Fig. 23), and Diospyros virginiana (Figs. 24, 25). Very prominent, erect protrusions with irregular interconnecting ridges are found in Cornus florida (Fig. 26) and Fraxinus americana (Fig. 27). How do we describe the intricate details and differences among all these cuticular patterns? I know of no specific terminology.

Tertiary relief may be formed by epicuticular wax deposits. It may be a relatively smooth crust or slightly flaky as in Magnolia virginiana (Fig. 28) and Sassafras albidum (Fig. 29), or distinctly roughened by scales or platelets as found in Acer saccharinum (Fig. 30), Quercus michauxii (Fig. 31), and Q. alba (Fig. 32), or roughened by rods or granules in other species (Martin and Juniper, 1970). This wax can be removed by xylene before dehydration to distinguish the three levels of relief. In this way, the cellular relief, or papillose condition becomes obvious in Quercus alba (Fig. 33). Similar treatments of Cornus and Fraxinus show that the protrusions are actually cuticular rather than deposited wax (Figs. 26, 27). White ash (Fig. 27) is obviously not papillose as in white oak (Figs. 32, 33), although sometimes called papillose. Can papillae be cuticular as well as cellular projections?

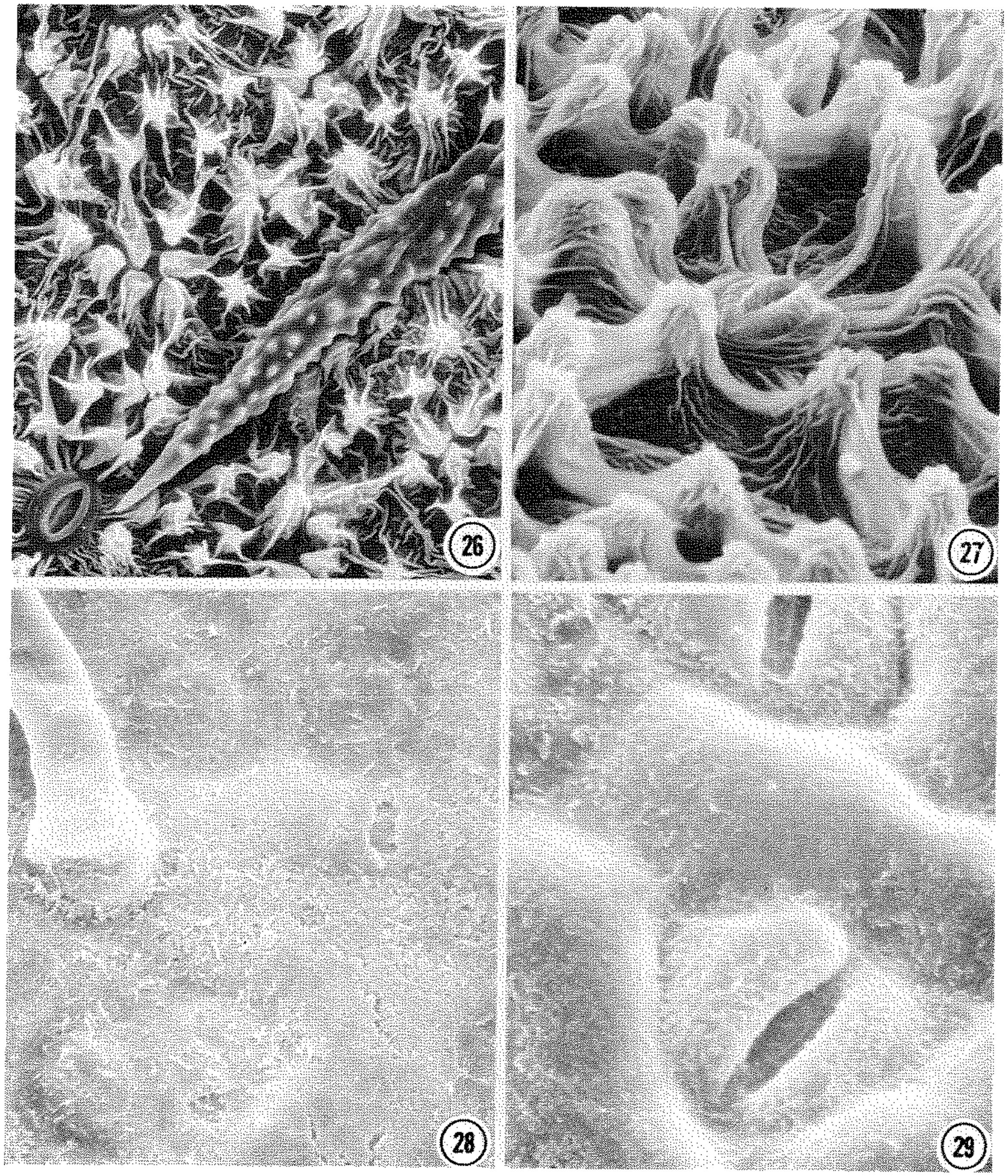
It may have become obvious that most of the examples given here for this discussion of micro-relief are those woody plants with pale, whitish, or glaucous backs of leaves. This is a good example of how plants can respond in different ways and through different genetic pathways to a given selection pressure. An adaptive shift, such as an increased foliar reflectance, can be accomplished in any one of several different ways; i.e., either increased cell wall relief, raised cuticular patterns, epicuticular wax deposition, or white vestiture. We therefore need to be very careful of the use of the terms glaucous or glaucescent which refer only to the presence of a wax bloom.



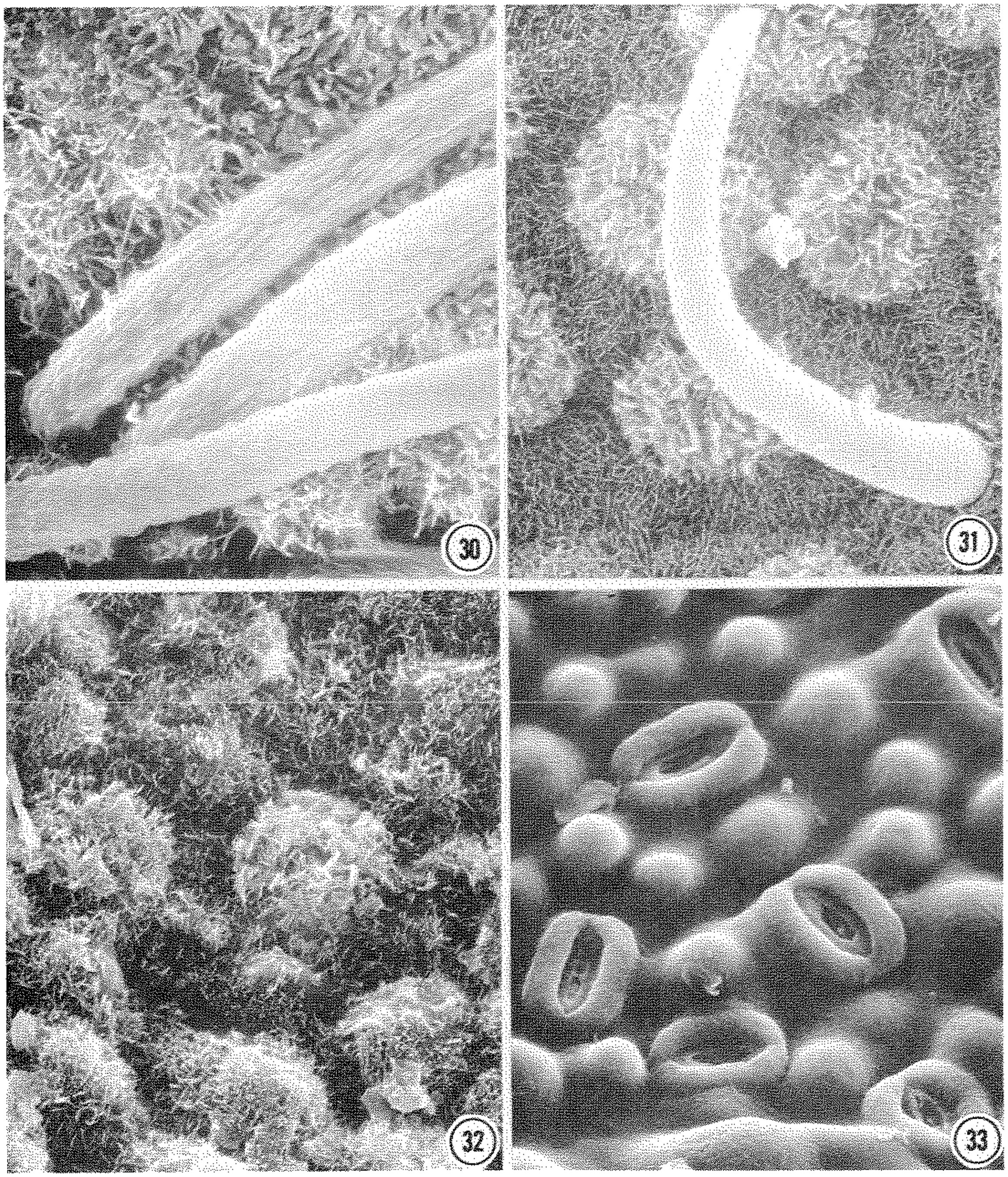
Figs. 18-21. 18. Thin cuticle, X900 (Buxus sempervirens). 19. Thin cuticle, X900 (Liriodendron tulipifera). 20. Thick cuticle with cuticular ridges around stoma, X900 (Nyssa sylvatica). 21. Cuticular ridges throughout, X500 (Broussonetia papyrifera).



Figs. 22-25. 22. Cuticular ridges throughout and protuberances on trichome, X600 (Hydrangea arborescens). 23. Cuticular ridges throughout, X200 (Salix babylonica). 24. Cuticular ridges throughout, X200 (Diospyros virginiana). 25. Cuticular ridges throughout, X1000 (Diospyros virginiana).



Figs. 26-29. 26. Cuticular protrusions and ridges, and protuberances on trichome, X600 (Cornus florida). 27. Cuticular protrusions and ridges, X1000 (Fraxinus americana). 28. Slightly flaky epicuticular wax, X900 (Magnolia virginiana). 29. Slightly flaky epicuticular wax, X2600 (Sassafras albidum).



Figs. 30-33. 30. Scaly epicuticular wax and protuberances on trichome, X2000 (Acer saccharinum). 31. Scaly epicuticular wax, X1400 (Quercus michauxii). 32. Scaly epicuticular wax, X1500 (Quercus alba). 33. Naked papillae after wax removed with xylene, X1300 (Quercus alba).

Trichome surfaces are generally smooth. However, protuberances of various forms occur on the trichomes of certain species and appear to be quite constant and of potential taxonomic importance. For example, they are obvious and also quite different among leaves of *Hydrangea*, *Cornus*, and *Acer* (Figs. 22, 26, 30). Again there is a lack of adequate descriptive terminology with which to describe and distinguish these various trichome surfaces.

All of these SEM-systematic features add tremendously to our knowledge of structural diversity in plants and are very exciting new characters for the modern dendrologist. None of these micromorphological features are expected to alter our present classifications and nomenclature, but they will undoubtedly aid in resolving some taxonomies constructed using other more traditional characters. As botanists we should also be concerned with the adaptive significance of these diverse forms--not only as a logical outgrowth from the purely descriptive phase of our studies, but also to give us better insight into the evolution of the species in this Eastern Deciduous Forest Biome.

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SOME TAXONOMIC PROBLEMS IN WOODY PLANTS OF ALABAMA AND MIDDLE TENNESSEE

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SUMMARY

The diverse climate, geology and soils expressed in the area known as Alabama and middle Tennessee are reflected in a substantial and equally diverse flora. Therefore it is not surprising that, in the woody component of this flora, there remain taxonomic problems. Time and space allowed, plus the inadequacies of this reporter, make it impossible to cite all the problem areas, but an attempt is made here to state several, essentially in the familial order of Engler and Prantl.

INTRODUCTION

A Manual of the Flora of Alabama and Middle Tennessee has been in progress since 1965, with field work toward this being supported by NSF from 1965 through 1972. A basis for such a Flora, known to be large and varied and at the same time largely systematically unsampled, has been pretty evident. Good basic listings of the flora have been available in the form of the works of Dr. Augustin Gattinger (1901) and Dr. Charles Mohr (1901), both reflective of sound academic foundation, considerable field experience with plants, and careful reporting of the then known components of the plant life of Tennessee and Alabama, respectively. Since the activity of Gattinger and Mohr, many more capable botanists, both amateur and professional, have contributed to our knowledge of the area. In Alabama, Dr. Mohr's successor with the Geological Survey of Alabama, Dr. Roland Harper, was definitely one of the most notable. The most significant contribution to our knowledge, in a modern sense, of the woody flora of Alabama has been that made by Dr. Ross C. Clark (1971), whose energy in the field and whose ability to express this information well is acclaimed by any who work with that flora. In Tennessee the work of Gattinger, whose active base was largely middle Tennessee, has been carried forward by a large number of botanists, past and present, at the University of Tennessee, where the State Herbarium is located. Undaunted by the tragic fire of the 1930's in which the Herbarium was destroyed, botanists such as Drs. Sharp, Shanks, Underwood (to mention only a few!) worked diligently to provide specimens to support a Flora of Tennessee. This led to a "Preliminary Checklist of Monocots and Dicots of Tennessee" and finally to the ongoing floristic work being done by Drs. Evans, Wofford, and others at the University. The National Environmental Policy Act and subsequent endangered species legislation has led to further effort toward definitive flora work in both Alabama and Tennessee, with the ambitious (often replicative) efforts of newly created agencies within the Forest Service and the Department of the Interior, Tennessee Valley Authority, Soil Conservation Service, etc., providing impetus through the funding or employment of botanists. In short, much floristic activity goes forward in Alabama and Tennessee and many young, highly capable botanists have entered the picture there since I first began my own studies of the area.

I will now deal directly with the topic. The problems taken up are only some that presently occur to me. Some are related to unusual distribution, some to problems in identification.

PROBLEMS AND QUESTIONS

Pinaceae. Some distributional information on Pinus in Alabama-middle Tennessee is provocative. A search for P. rigida Mill. in middle Tennessee goes on but with no success thus far, despite the fact that there are outliers far west in neighboring Kentucky. What are the factors influencing the present rarity of P. serotina Michx. in Alabama? According to Harper (1928), its occurrence there was unknown to Mohr, which gives a little historical perspective. Some specimens from southeastern Alabama near Georgia show characteristics that are intermediate to P. taeda L. and more observations of these putative hybrids might be of interest. The distribution of P. strobus L. is also interesting in that it is abundant northward in the Cumberland Plateau of Tennessee, has an outlier in middle Tennessee west of Nashville, yet is absent from what appears to be suitable habitat in northern Alabama.

Artificial hybrids have been gotten between most species of southern yellow pine. Natural hybrids are not much commented on in Alabama but in rugged northern areas of the state where P. palustris, P. echinata, P. taeda come together are extremes (in addition to the well-known hybrid between P. palustris and P. taeda) that appear to indicate frequent hybridization.

Taxodiaceae. What will the final assessment be of pond cypress (Taxodium ascendens Brongn. or T. distichum (L.) Rich var nutans (Ait.) Sweet) as related to bald cypress (T. distichum)? Both entities are key species in two very different forest types and have very different life history patterns. Is all the evidence now in?

Cupressaceae. Is Juniperus silicicola (Small) Bailey (J. barbadensis L. of auth.; Sabina silicicola Small) merely an ecological variant of J. virginiana L.? The former has what appears to be a distinctive habit and habitat but is distinguished morphologically on the sort of characters that might tend to "blur" when placed in the total pattern of variability within the latter. What treatment for a flora is most consistent with current taxonomy of the genus?

Taxaceae. The recent discovery of Taxus canadensis (L.) Carr. by Dr. G. Gonsoulin in the northern Cumberland Plateau of middle Tennessee adds a family to my Flora and further proof of the necessity for more field work before a truly definitive Flora is available.

Salicaceae. Salix and Populus species are not many in our area, yet poor distributional information may conceal real problems. In non-arborescent willows Salix humilis Marsh and S. tristis Ait. are consistently distinguishable and thus a case could be made in our area for treating them as distinct. A careful study of populations of the two is in order. Populus heterophylla L., often an integral part of the Cypress-Tupelo type over much of its range, is considered rare in the river swamps of Alabama; in middle Tennessee it is locally abundant in another type, namely pin oak and black gum flats, and is not uncommon in such stands northward in Kentucky according to Mr. Raymond Athey (pers. comm.).

Juglandaceae. It is often the job of floristicians to note advent or loss of species in their study areas. *Juglans cinerea* L. presents such a case. This species, formerly abundant locally along the small streams of much of middle Tennessee, is becoming so rare through ravages of canker dieback that collection and sight records of it from even a few years back are becoming historical evidence. Fruiting specimens are now nearly non-existent, and it is to be expected that a modern map of its distribution would show a definite contraction of known range. The species was never abundant in Alabama and soon may be totally absent. Is its destruction irreversible?

Definition of species in *Carya* awaits the sort of careful studies being done by Dr. Don Stone. I have done a treatment of the species for my Flora which differs somewhat from that rendered by some other students today. Within my area *Carya carolinaeseptentrionalis* (Ashe) Engler & Graebner behaves as a distinct species, at least in its character as distinguishable from *C. ovata* (Mill.) K. Koch, as is *C. laciniosa* (Michx.f.) Loud. The *Carya glabra* (Mill.) Sweet "complex" presents a greater difficulty, with *C. leiodermis* Sarg, *C. glabra* var. *megacarpa* Sarg. remaining mystery trees, and *C. ovalis* (Mill.) Koch appearing to be a demonstrable species. As stated above, true rank of the entities in this genus awaits the kind of proofs to be provided by Dr. Stone.

Fagaceae. The problems with working up treatments of this family in my area still are large, although we are getting much more insight on how to solve them thanks to interesting work being done by men such as Dr. Jim Hardin. While there are not many taxa of *Castanea* to be dealt with, *Endothia* is still taking its toll, making it ever more difficult to find fruiting material. Trichomal and epidermal studies such as are being done now with the oaks may be instrumental in clarifying the *C. pumila* "complex." I have no workable treatment at present.

In *Quercus*, some of the problems I see are:

(a) What constitutes the *Q. stellata* Wang. complex? Most have restored *Q. margaretta* Ashe as a species. The rest of the complex, including its proper limits, appears to be up for grabs. In our area, difficulties center around morphologies called *Q. boyntonii* Beadle, *Q. similis* Ashe, and a perplexing series of forms that appear to grade over into what has been called *Q. austrina* Small, which then involves *Q. sinuata* Walt. (*Q. durandii* Buckl?). SEM studies such as done by Hardin (1979, 1976) of trichomes are clarifying concepts here and elsewhere in the genus but some question must exist as to what rank to assign to "trichomal" taxa.

(b.) The "willow" oak complex. If Q. nigra L. and Q. hemisphaerica Batr. are included, there are 8 recognizable taxa in the Alabama-Tennessee area and Q. arkansana Sarg., Q. georgiana Curtis somehow involved. Perhaps most of the difficulty here centers on those taxa found in or along bottoms, namely Q. nigra L., Q. laurifolia Michx., Q. hemisphaerica, and Q. phellos L. Such are easily distinguished in the field but provide trouble for writers of keys and descriptions. Biometric analysis of the willow oaks may prove useful.

A difficulty I have in working up treatments of oaks comes from my own tendency to stress morphologies with which I am most familiar in the field, the resulting taxonomy being too expedient and anecdotal.

Ulmaceae. Problems in our area with Ulmus are largely distributional. The discovery by Dr. McDaniel of U. crassifolia Nutt. in northern Florida, when in the Gulf South it was previously thought to extend eastward only into Mississippi, has whetted the collecting appetites of Alabama botanists. Why are there not intermediate stations for it in Coastal Plain Alabama? All the old Forest Service records for Tennessee of U. thomasii Sarg. appear to be U. serotina Sarg., this last appearing to be more resistant to introduced diseases of elm.

In Celtis, three strong taxa emerge for our area with, additionally, Celtis iguanea (Jacq.) Sarg. rare on the Alabama coast. C. occidentalis L. and C. laevigata Willd. are not as clear as one might wish. In middle Tennessee and northern Alabama the two have blended to form a giant swarm of intermediates. This situation poses a problem ripe for expression and solution by a population biologist. The shrubby C. tenuifolia Nutt. appears not to be involved.

Magnoliaceae. Two questions arise for the dendrologist working with magnolias in Alabama. First, is there such a thing as M. cordata Michx.? Some maintain that the true M. cordata is a narrow endemic and essentially shrubby; others expand the range and morphology to include yellow-flowered arborescent extremes that may be found as far west as Louisiana. Still others call all these M. acuminata L. Secondly, what is M. pyramidata Bartr. ex Pursh? This small tree is separable from M. fraseri Walt. by several quantitative characters. Substantial spatial isolation exists, with no instances of sympatry known to me.

Lauraceae. Problems remaining here are primarily those of reestablishing old records, notably one for Lindera melissaefolium (Walt.) Blume, found in the bottoms of Wilcox County, Alabama, by Buckley over 100 years ago and not since then, and in determining if Litsea aestivalis (L.) Fern. actually grows in Alabama. No real record for the latter is available for the state, but much suitable habitat exists for it there. In the genus Persea the studies made by Dr. E. Wofford (1973) support the presence of two taxa in Alabama: P. borbonia (L.) Spreng. and P. palustris (Raf.) Sarg.

Saxifragaceae. Difficulties with identification of woody Saxifragaceae in Alabama and Tennessee involve only Philadelphus, a center of variation being middle Tennessee. The study by Hu (1954-1956) was an herbarium study and is helpful but points to the need for further revision based on study of living populations.

Rosaceae. While variation in Crataegus in our area is perhaps not to the baffling degree found in the glaciated area northward, or in the Gulf Coastal Plain westward, it is still sufficient to perplex this writer. I am looking for someone to contribute a treatment for our flora, and am inclined to hope that such a treatment would be conservative in light of the degree of apomixis reported for the genus. My treatment of chokeberries and apples is to refer them to Aronia and Malus respectively, rather than to include them in Pyrus (see Hardin, 1973). As Clark (1971) has indicated, the wild crabapples require more study. Distributionally, Neviusia alabamensis Gray, a monotypic genus of the Interior Highlands and southern Appalachian systems of North America, is of interest first because of its rarity and to some extent because of its disjunctive distribution. The disjunction is becoming less in that it has recently been discovered in Tennessee and Mississippi. Prunus remains a problem genus for Alabama-Tennessee. The "Padus" types involve some interesting morphology and a biosystematic assay may reveal a higher rank than subspecies is appropriate for P. serotina Ehrh. ssp. hirsuta (Ell.) McVaugh (1951) in any treatment where consistency is sought. The true plums involve at least six species for our area, with the problem of what constitute real differences between P. americana Marsh and P. mexicana Wats being paramount. Rubus abounds in riddles and I seek someone to contribute this genus to my Flora, again hoping for a treatment similar to that sought for Crataegus.

Leguminosae. The problem woody genera for Alabama-Tennessee remain Amorpha, Robinia, and Wisteria. In the case of Amorpha, the recent treatment by Wilbur (1975) appears to be inconsistent for our area, with the widespread A. fruticosa L. blurring the picture. In the case of Robinia there is still the problem of the low-growing, pinkish flowered taxa (most of which develop large clones but no fruit!!) for which I have no sensible treatment available. In Wisteria, Alabama-Tennessee material shows a clear break existing between W. frutescens (L.) Poir and W. macrostachya Nutt. though it would appear that the latter species requires redefinition.

Cyrillaceae. Some controversy should exist as to the number of taxa of Cyrilla in Alabama. In that Cyrilla produce gigantic clones, conventional sampling is difficult; however, in addition to the C. racemiflora L. a smaller and rounder-leaved, smaller-flowered and rounder-fruited entity does appear to emerge, this answering the description of C. parvifolia Raf. This is the opinion also of Dr. R. K. Godfrey (pers. comm.). though it runs contrary to that of Dr. J. Thomas, who studied the family.

Aquifoliaceae. The hollies are sufficiently controversial to daunt writers of state and regional floras, perhaps because excursions by taxonomists into their convoluted morphology, genetics, and nomenclature have as yet been without the aim of a general treatment. This has led to inconsistent taxonomy and much shuttling around of names. My own treatment (over that used in the Flora of the Carolinas (Radford et al., 1968) and approaching that used in Gray's Manual (Feinald, 1950) and Small's Manual (Small, 1933) would be to restore I. monticola Gray at least to rank of subspecies under I. ambiqua (Michx.) Torr. Ilex myrtifolia Walt. is morphologically and ecologically very distinct, is a co-dominant in a yet-to-be-described forest type in northwest Florida, and should not be combined in any way with I. cassine.

Aceraceae. In the genus Acer, the southern sugar maples are still problematic, and nowhere are they of more interest than in Alabama. The chalk maple and the southern sugar maple may both be deserving of specific rank in any consistent treatment. In the Coastal Plain and Piedmont of Alabama both often occur in large, mixed populations along small streams, and though there is considerable leaf variation within each, there appears to be little evidence of real intergradation. I am treating each as a species, namely A. leucoderme Small and A. barbatum Michx. A wider problem within the complex involves the northern sugar maple A. saccharum Marsh and A. nigrum Michx. Further study may reveal a taxonomy close to that suggested by Desmarais (1952).

Anyone who has seen pure populations of the Drummond maple, A. drummondii Hook. & Arn., is struck first by what appears to be an ideal F1 between A. rubrum L. and A. saccharinum L., even though this may not be the case. Whatever the case, a proper disposition of A. drummondii should not be as a variety of A. rubrum L. The problem is clouded by the very considerable range of variation within the latter, this sufficient to lead sometimes to erroneous reports of the distribution of A. drummondii.

Tiliaceae. The basswoods are given an adequate treatment by Dr. Jones (1968), at least one that admits much of the "blurring" that exists in the genus. However, one cannot fault the conservative treatment given the Alabama lindens by Dr. Clark (1971), who considers all as "T. americana L. complex."

Nyssaceae. The long-standing problem here is what status Nyssa biflora Walt. (including N. ursina Small) should have; this decision should rest more properly on a revision of the genus worldwide. I treat it expediently as a species, rather than as a variety or ecotype of N. sylvatica Marsh. in that it holds together well on the basis of several quantitative characters and in that it is silvically distinct. In fact, it is important in a distinct forest type that excludes N. sylvatica.

Ericaceae. The two most difficult genera for Alabama-Tennessee in this exclusively woody family are, not surprisingly, Vaccinium and Rhododendron. In the case of the former, the treatment of Camp (1945), who recognized the significance of the hybrids, has to be consulted, together with a more modern diagnosis of the situation such as is presently being made by Dr. McDaniel. In the case of Rhododendron there is still no clear solution available to me, perhaps because as yet no general view of the genus has been provided by anyone with an outlook such as that of Camp, perhaps because of some taxonomy being obscured by horticulturists. Thirteen taxa are in the area, if a conservative view of species is taken, but the number of hybrid examples is very great and makes necessary the description of some of the more common ones.

Oleaceae. A key based on fruiting material of Fraxinus for the area is not difficult to construct, but difficulties arise when one has much sterile material in collections. I have found the work of Gertrude Miller (1955) extremely helpful, not only for the problems it solves but for the questions it poses. Problems remain, it would appear, with determining the true rank and position of Biltmore ash, and with real parameters for pumpkin ash.

Caprifoliaceae-Viburnum remains the major woody plant problem in this family for our area. Complexes within it have been assigned as graduate level studies both at the University of Tennessee and the University of North Carolina and the published results of these are awaited with interest. The paucity of collections from within Alabama compound the difficulty of interpreting what may, or may not, be anomalies. For example, treatments of other state floras vary widely in regard to entities variously identified as V. nudum L., V. cassinoides L. or V. nudum vars., and with the V. dentatum L. complex. Many, confronted with a problem that looks too much like Tilia, have included in synonymy entities that are deserving further study. V. bracteatum Rehd. and V. molle Michx. in the "dentata" complex are cases in point. I have searched limestone bluffs along the Coosa in Alabama and Georgia for populations of V. bracteatum and have found material agreeing with the type and that shows sufficient integrity to warrant further work by someone. Material in our area answering V. molle is of interest because of character variations that are not explained in available literature. I have specimens from the Black Belt of Alabama that fit V. lentago L. exactly; this is curious in part because of the unlikely habitat and partly because of the considerable geographic disjunction. Such finds indicate the need for more field work in the whole area to test the known distribution patterns and point to the potential for biosystematic study of the genus in North America.

I have presented what, to me, a hopeful author of a Flora for Alabama and middle Tennessee, appear to be some problem groups of woody plants. Some of these problems, placed in context of a broader geographic view, may be minor. However, they bother me. I do believe, nonetheless, that a considerable basis for revisional work exists within an area that Flora North America editors have thought well worked already.

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THE REVISED FOREST SERVICE "CHECKLIST OF UNITED STATES TREES"

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SUMMARY

The revised Forest Service "Checklist of United States Trees (Native and Naturalized)" compiles the accepted scientific names and current synonyms, approved common names and others in use, and the geographic ranges. Eight appendices have much new information. Native trees total approximately 679 species in 216 genera and 73 plant families. Naturalized trees add 69 species, 28 genera, and 3 families. A brief review of the accomplishments of the dendrology project begins with George Bishop Sudworth in 1886 and ends with the present author 93 years later. Future research work in dendrology is of low priority and is specialized. It could be postponed and done by local specialists. Some suggestions are offered.

Key words: United States, trees, names, checklist, plant distribution.

INTRODUCTION

Several new features, as well as updated information, are contained in the revised "Checklist of United States Trees (Native and Naturalized)" (Little 1979). Publication of this compilation provides an opportunity to review past work of the dendrology project and to offer suggestions for future studies.

The fourth in a series, the 1979 Checklist retains the general plan of the third (Little 1953) and the earlier preliminary mimeographed draft by the same compiler (U.S. Forest Service 1944). It follows the first two checklists by George B. Sudworth (1898, 1927) and his "Nomenclature of the Arborescent Flora" (1897).

These compiled checklists have three main parts: (1) accepted scientific names with current synonyms; (2) approved common names and others in use; and (3) geographic ranges. Coverage is the native and naturalized trees of continental United States, including Alaska. Hawaii, which became a State in 1959, is omitted because its unique or endemic tropical trees are listed in special references.

THE 1979 CHECKLIST

Arrangement of the 1979 Checklist is alphabetical by accepted scientific name, with cross references of common synonyms in large genera. At the end is the detailed Index of Common Names. One new feature is insertion of accents to indicate pronunciation of accepted scientific names.

Eight appendixes with much new information are: (1) Condensed checklist--alphabetical by scientific names; (2) Condensed checklist--alphabetical by common names; (3) New scientific names of United States trees, 1951-77; (4) Authors of accepted scientific names; (5) Commercial names for lumber; (6) Guiding principles for common names of United States trees; (7) Botanical index of plant families and genera; and (8) Summary of changed specific names. Appendixes 5, 6, and 7 are revisions of similar subjects in the 1953 Checklist.

The taxonomic treatment is conservative in acceptance of species and varieties. Checklists are references primarily for foresters rather than specialists, who may distinguish additional variations by name as needed.

According to the Statistical Summary, numbers of accepted species and varieties are slightly fewer than in the 1953 Checklist. Native trees total approximately 679 species in 216 genera and 73 plant families, reduced from 787 species in 221 genera. Naturalized trees add 69 species, 28 genera, and 3 families. About 85 additional species, mostly introduced trees or native shrubs reported to reach tree size, are mentioned in notes. The number of varieties accepted is 49, not counting 35 typical varieties. The genus Crataegus, hawthorn, has been reduced to 35 from 149 (also 40 local species or probable hybrids mentioned in notes).

The scientific nomenclature of native trees is approaching stability. Very few important tree species are affected by changes in scientific names. For giant sequoia, the generic segregate Sequoiadendron giganteum (Lindl.) Buchholz, which has become widely adopted, even on postage stamps, replaces Sequoia gigantea (Lindl.) Decne. For yellowwood, Cladrastis kentukea (Dum.-Cours.) Rudd, based on an obscure name, has priority over C. lutea (Michx. f.) K. Koch. The proposed generic segregate involving incense-cedar, Libocedrus decurrens Torr., has not been taken up. To agree with usage, 2 segregate families of Pinaceae, pine family, have been accepted: Cupressaceae, cypress family, and Taxodiaceae, redwood family.

Commonly used synonyms (but not all) are cited. Omitted older synonyms may be found in the 1953 Checklist and the compilations by Sudworth (1897, 1927), Sargent (1891-1902), and others. Scientific and common names are correlated with those of the 1953 and 1927 Checklist by means of symbols.

Common names have been reviewed and revised by the Forest Service Tree and Range Plant Name Committee. Other common names in use are listed and indexed.

The range of each native tree species has been thoroughly revised and compiled in greater detail with increased accuracy from the recently completed 6-volume "Atlas of United States Trees" (Little 1971). These large maps for the United States and, where needed, for North America, are cited by number. Occurrence outside the United States has been expanded. No maps are included, but small maps of 180 important tree species reduced from the Atlas are available in concise form in a smaller handbook (Little 1978).

Revision of references for genera and species involves the citation of new publications, such as monographs, notes on nomenclature, and related taxonomic studies. The Introduction is followed by an expanded list of general References.

Natural interspecific hybrids are mentioned less prominently than in previous checklists and without common names or recorded ranges. These hybrids are cited under both parent species, and if named formally, the binomial is added in parentheses.

Number of species and distribution is a new feature for each genus of native trees. Species totals include numbers of native and naturalized trees, any native shrubs, estimates for other geographic regions, and worldwide. These figures of generic distribution in other parts of the world may have useful applications, for example, in suggesting sources of foreign species for tree planting and tree breeding programs.

THE DENDROLOGY PROJECT

A brief review of the accomplishments of the dendrology project may be appropriate. The oldest research project of the Forest Service, it antedates by about 19 years the establishment of that agency in 1905. The historical sketch of botanical activities in the Forest Service by Dayton (1955) embraced dendrology.

In 1886, the young botanist George Bishop Sudworth (1864-1927) began work with the Division of Forestry (later Bureau), United States Department of Agriculture, in Washington, D.C. He was the first assistant of Bernhard E. Fernow, the German forester who became the chief the same year. (Earlier, in 1876, Franklin B.

Hough had served as the first forestry agent and then chief.) Sudworth continued work on the dendrology project until his death, almost 41 years. Thus, in years of service, he was the oldest official of the Forest Servce and predecessor agencies and was recognized as the dean of the forestry profession in this country.

Sudworth's numerous publications included several early forest survey reports as well as the checklists previously mentioned. His classic "Forest Trees of the Pacific Slope" (Sudworth 1908) was well illustrated by excellent line drawings and has been reprinted by a large publisher of paperbacks. The first of a planned series of four regional manuals, it was followed by five shorter bulletins forming an incomplete reference on Rocky Mountain trees. He began the preparation of a "Forest Atlas" with maps of each native tree species. However, only "Part 1, Pines" (Sudworth 1913) was published. Some years later, his maps of important forest trees were published in slightly revised form by Munns (1938).

The dendrology project was less active for several years after Sudworth's death, as no successor was appointed. However, related work was continued by others.

William Willard Ashe (1872-1932), another dendrologist, was an authority on the woody plants of the Southeast. He was forester with the North Carolina Geological Survey and did special work for the Bureau of Forestry. From 1909 until his death, he was employed by the Forest Service as forest inspector and later as assistant district forester, mainly in acquisition of national forest lands.

Ashe's dendrology studies were made apparently in addition to duties as forester. He became a member of the Forest Service Tree Name Committee in 1928 and its chairman in 1930. This "indefatigable observer, collector, and annotator of plants" wrote numerous articles in this field, not mentioning his employer. His new botanical names totaled 510, including 177 in *Crataegus*, 60 in *Hicoria* (*Carya*), 43 in *Quercus*, and 15 in *Castanea*, but the type specimens were not deposited in the Forest Service Herbarium or National Herbarium. Many of these mostly minor variations have not been recognized by others. *Betula uber* (Virginia roundleaf birch) was one of his discoveries. The University of North Carolina at Chapel Hill has part of his private herbarium.

William Adams Dayton (1885-1958) included dendrology in his career with Forest Service beginning in 1910 as plant ecologist and continuing in retirement as collaborator, as total of 48 years. He founded the Forest Service Herbarium and assembled there the largest collection of western range plants. From 1942 until 1955, he was principal dendrologist and director of the Division of Dendrology and Range Forage Investigations. Upon his retirement, that office ended with a reorganization.

Dayton (1955) prepared several publications about trees, for example, a bibliography on dendrology as well as a definition (Dayton, 1952, 1945). He completed Sudworth's posthumous bulletin, "Poplars, Principal Tree Willows and Walnuts of the Rocky Mountain Region" (1934). He was coauthor of the second edition of "Standardized Plant Names" (Kelsey and Dayton 1942), which contained many thousand tree names. His contribution to the revision of common names for the 1953 Checklist was very helpful.

The present author began research work with the Forest Service in January 1934 and for eight years was forest ecologist in Arizona and New Mexico. The research projects were in range, watershed, and timber management, the last four years on pinyon. Afterwards he wrote "Southwestern Trees" (Little 1950). In January 1942 he was transferred to Washington, D.C., as dendrologist under Dayton. Upon retirement in 1975, he continued another year under a temporary appointment and as a volunteer through 1978, a total of 45 years. Besides the checklists, he wrote many technical and popular publications and articles in the field of dendrology. His tree handbooks extended beyond contiguous United States to Alaska, Hawaii, and Puerto Rico and the Virgin Islands. Also, he prepared the 6-volume "Atlas of United States Trees" (Little 1971). With coauthors he published tree lists for five experimental forests.

Thus, the dendrology project on the classification, nomenclature, identification, and distribution of United States trees has been brought to a close after 93 years through the lifetime careers of two dendrologists and parttime work by others. The basic general research on the forest trees, their names and ranges, has been accomplished.

REFERENCES FOR IDENTIFICATION

Progress of work in the field of dendrology, or tree indentification, is summarized in a current bibliography (Little and Honkala 1976). This bibliography lists more than 470 titles of selected references for identification of wild and cultivated trees, shrubs, and woody vines of the United States. General references, those for special geographic regions, and others on all fifty States are cited for the interval from 1950 to 1975, as well as many older titles. Additional or new references would be useful for some areas.

FUTURE WORK

Future research work in dendrology, or tree identification, in the United States is of low priority and is specialized and could be postponed as an economy measure. When needed, research could be done by local specialists as time and funds permit. Various monies, grants, and foreign currency programs are available. Some suggestions for future studies are offered here.

Tree identification. References can be updated and improved as needed. Illustrations, especially color photographs, can be assembled, and keys can be improved.

Ranges. Geographic ranges in some parts of the country are known in less detail than in others. More detailed published maps of tree species would be useful for some States. Range extensions should be recorded and documented by herbarium specimens for future revisions of the maps.

Local lists. Inventories of trees or woody plants (or also local floras of seed plants including herbs) are useful for experimental forests, natural areas, parks, and related preserves. Annotated lists describe the present vegetation, aid in management, and provide records for measuring future changes. The accompanying herbarium specimens serve for vouchers, reference, and training.

Natural areas. Tree identification is basic in management of natural areas and in the selection of new ones.

Rare and endangered species. More studies on rare and endangered tree species are desired for protection and management. Some additional preserves may be needed. Seeds can be collected and distributed.

Hawaii. Distribution maps of the native trees could be prepared to complete the "Atlas of United States Trees." The rare and endangered trees merit further studies, including their habitats and collection and distribution of seeds.

Flora of North America project. This new flora project of international scope provides opportunities for taxonomic work on plant families and genera containing trees.

Monographs. A few native tree genera lack up-to-date taxonomic treatments.

Naming of cultivated varieties. As improved cultivated varieties (cultivars) of forest trees are developed, English names will be needed under the International Code of Nomenclature for Cultivated Plants (Gilmour *et al*., 1969).

Special techniques. Various new tools and methods are available or will be developed to improve plant classification and aid identification. Examples are the scanning electron microscope, computers, chemical taxonomy, numerical taxonomy, card keys, etc.

Chromosome counts. For native tree species and varieties, at least those of economic importance, additional chromosome counts would be helpful. Where the number varies within a species, detailed geographic studies would be useful. This basic information is of value in forest genetics programs and hybridization tests and may aid in refinement of the classification.

Chemical screening. Collection of representative material will assist searches for useful chemicals, particularly in medicine.

Worldwide monographs. Up-to-date generic mongraphs involving important United States trees will be helpful in programs of introduction of foreign species. Foreign currency funds may be available.

Maps of foreign trees. Maps of foreign tree species in genera important in the United States will aid in obtaining seed of the best adapted germplasm for introduction in forestry and horticulture.

Trees of temperate East Asia. Introduction of additional seeds or germplasm of trees of temperate East Asia, especially of genera represented in the United States, will be useful in forestry and horticulture. China has a rich flora still imperfectly known and not assessible in recent years. Japan has species meriting further introduction.

Wood identification. Improvement of wood identification would be useful, especially in tropical timbers. Collection of wood samples and herbarium specimens from the same tree is basic to correlation of unknown woods.

Tropical dendrology. Much basic work in tree identification is needed in many developing countries of tropical America. A small percentage of tropical trees awaits discovery and lacks scientific names. Difficulties are increased by the great number of species and the large size of many indviduals. Additional collections could be made along new highways before the forests are destroyed. References for tree identification are inadequate in many tropical regions.

Shrubs. Finally, native shrubs, including woody vines, comprise several times as many species as trees and merit similar studies where needed information is lacking.

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RESEARCH AND MANAGEMENT OF RARE AND LOCAL TREE POPULATIONS: AN OVERVIEW

by

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In these introductory remarks I wish to highlight the major components of the job of conserving rare and local tree species--and in so doing set the stage for the detailed consideration of some of them by our speakers. The first of these components is a description of the resource. On this count we are fortunate in having Elbert Little's definitive work which has resulted in up-to-date distributional information on endemics, rare species, disjunct populations, and unusual range extensions. His paper will provide foundation to our discussion of the management problems inherent in these patterns of distribution.

From this point on, we move to the realm of hypotheses--about genetic relationships and population characteristics which will be so important in conserving, not just some specimens, but a representative sample of germ plasm, a set of biological information. While we have essentially no data on the population genetics of rare and local species, we do have, in Gene Namkoong, a good population geneticist on the program who will bring his skills and knowledge to bear on the problem of conserving genetic material and designing the necessary genetic research should a combination of investigative interest, enlightened foresight and money ever present itself. In the course of these discussions of distribution and population biology, it would be profitable for us to keep in mind the possible relationships of these species to the forest ecosystems of which they are a part. It is this area of information to which we must turn for guidance in gene conservation.

Even without all the information essential to an enlightened management policy for rare and local species, current wildland management policy will be the major component of conservation programs and the central issue in our discussion. The questions are: (1) What will be the predominant management philosophies on public and private lands; and (2) How will rare and local species be treated under the resulting management systems, either by plan or happenstance. We see the beginnings of a constructive policy in, for example, the new U.S. Forest Service management regulations which for the first time specifically require efforts to maintain diversity and protect endangered and threatened species. This new emphasis on conservation of natural systems is also partly the consequence of the Endangered Species Act of 1973, the implications of which LaVerne Smith will discuss in her paper. While this act and other recent legislation should have a positive effect on public land management, it is still uncertain whether private wildland management will consciously assume the necessary breadth to preserve species diversity given the generally narrow and unstable goals of private ownership. We should consider how and where this lack of policy for private lands will affect natural systems and their rare and special components.

Though it is encouraging to now see some attention given to rare and local trees and other wildland plants, it is significant I think, that with a few exceptions, the effort in resource management circles seems to be mostly one of reaction to the pressure of botanists and interested lay people, not one of leadership by professional wildland managers. In my opinion, one of the basic reasons for this is that the training of most wildland managers still does not impart an adequate knowledge of taxonomy, a lasting interest in biological diversity, and an awareness of its fundamental importance. The other reason is that most bureaucracies are reactive, not creative, organizations. Perhaps this will change as "minor" species assume new value because of special management considerations. For example, the Federal Surface Mine Control and Reclamation Act of 1977 encourages revegetation systems incorporating a wide array of native plant species, and the economics of reclamation will increasingly encourage use of species mixes which will reduce nitrogen and phosphorous fertilization requirements. These and other needs should provide incentives to protect and expand material such as the less common nitrogen fixers.

In light of these new policy and management considerations and needs, where do we stand in research on rare and local species? Terry Sharik, one of the country's three or four birch experts, will review activity surrounding the rediscovery of and research on *Betula uber*, the only officially "endangered" tree species. There is much to be learned from this case history. While we hope that research on other species will be forthcoming, there is at present little evidence to suggest that such is the case. There are several reasons for this: First, our initial endangered species legislation was couched mostly in prohibitive terms; it notes what cannot be done rather than mandating positive programs. However, some recent amendments may eventually provide for research programs. Second, there is presently little money for research on rare and local trees because these species do not have an effective constituency. Third, most "on-the-ground" wildland managers still are not terribly interested in rare, endangered, and threatened species, for reasons which I have already noted.

I do see evidence that this situation may change for the better. This conference and others like it are appropriate initial steps. Let us hope that they will lead to formal problem analyses and establishment of research and management priorities by appropriate public institutions. Another progressive development is, I believe, the renewal of interest in State native plant societies. In such organizations, I see the beginnings of the necessary broader, popular support for the intrinsic values of natural plant communities and their genetic diversity. A concern for rare and local flora is usually a policy centerpiece for these groups. I believe it is part of our professional responsibility as plant scientists to actively support, participate in, and help direct them. Only through such a botanical constituency will we realize the management policies and long-term research programs which we will be discussing today.

GENETIC CONSIDERATIONS IN THE MANAGEMENT OF RARE AND LOCAL TREE POPULATIONS

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INTRODUCTION

If dendrology is primarily concerned with the means and variances of tree species, what do genetic studies add except to partition the variation among causes? If species hybrids are found, do genetic studies add more than comfort to dendrologists that their parental species are indeed still properly defined as biological species? I suspect that for the central issues in dendrology, genetics is a very nice but essentially irrelevant science. Even in managing rare and local populations, interest must be focused on ecosystem management. Species must be considered in terms of commonly understood and fixed elements. Thus, though we may be aware of genetic variations, thought is concentrated on existing means and variances. From this view of species, gene sampling, conservation, and management are problems only to the extent that one wishes to maintain all features of the presently available stands. The solution can be as simple and cheap or as complicated and expensive as one can afford.

In this paper, I'd like to offer an alternate view which is based on evolutionary concepts of changeable species and which gives primacy to genetic evolution as a dynamic process we can influence. From this view, gene sampling, conservation, and management are designed to develop the genetic resource base and not to maintain frozen sets of features; dendrology is meant to study the present status of tree species evolution.

POPULATION GENETICS OF FOREST TREES

The basic driving forces in the genetics of trees and other organisms are mutation, drift, migration, and selection. While mutation is the initiating force which creates genetic variations, it is a slow, random process, less interesting than the others in shaping the kinds of population structures we are concerned with.

In terms of the dispersion of alleles or particular combinations of alleles over a species' range, the effect of drift is to increase differences among stands or subpopulations. Drift is caused by sampling variations in small populations which allow otherwise similar populations to diverge in allele frequency. Since this process is random, stands may vary without any discernable pattern, and rare alleles may disappear from many stands but exist at high frequencies in some. The average allele frequencies may stay the same for the species as a whole, over many generations, but local variations may become important. If inbreeding is frequent, or if stands are widely spaced and remain separate over several generations, differences in allele frequencies are likely to develop. On the other hand, genes do migrate by pollen and seed dispersal. If the effective migration distances are high, then migration of just a few individual gametes per generation can overcome even strong drift forces (Lewontin, 1974). While low frequency alleles may still disappear from some populations, the tendency for local populations to sharply diverge is assuaged by migration rates involving as few as one individual per generation.

Selection can also affect the pattern of allelic variations. Even in the absence of local drift, microsite selective forces can cause contiguous stands to diverge in allele frequencies. But selection can also maintain similar allele frequencies, even in the absence of migration. In the former case, climatic or elevational clines can exert such strong selective pressures that genes governing phenological events and temperature adaptabilities are segregated along easily recognized gradients. In spite of obvious pollen and seed dispersion over short distances along mountain slopes, Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco (Campbell, R., personal communication) and pitch pine (Pinus rigida Milla) (Ledig and Fryer, 1972) show strong localized clinic adaptabilities. Localized ecotypic variation is not well established for trees, but other plant species display genetic adaptabilities to localized soil variations (Antonovics, 1968) and similar patterns can reasonably be assumed to exist for trees. However, it is equally obvious that for other genes, selection can uniformly favor one allele over another and hence can fix certain alleles. If heterosis or epistasis is present, selection can fix certain intermediate allelic frequencies uniformaly for the whole species. These complications allow considerable genetic variation to exist within populations but often force the allelic frequencies to be identical for all populations.

If the interaction between the forces of selection and drift-migration balance, different kinds of gene action can cause a wide array of gene dispersion patterns to exist simultaneously. Population geneticists are concerned with the dynamics of these forces. They want to know how, for example, selection may favor more than one optimum set of allelic frequencies and how migration can limit the number of optima achieved. They are concerned with the changing face of selection and migration over generations, and how gradual shifts or quantum leaps in either can affect the genetic structure. They are concerned with the processes of evolution, and they consider populations to be in dynamic states of motion with different gene frequencies, population sizes, drift propensities, migration rates, and selection effects. These forces are viewed as creating diversity within and among populations which are geographically dispersed and which change over time. In forest trees, we have most experience with temperate-zone conifers, we know little of temperate hardwoods and we know even less of tropical hardwoods with small, dispersed populations. Even in this state of ignorance we can make a few suggestions for dendrologists, and can define common concerns.

POPULATION SAMPLING

Rare and local populations may represent the remnants of species which evolved under, and were adapted to, extensive areas or they may always have been rare and local. In the first case, some special efforts may be required to even maintain the species. In the latter case, the species may not adapt well to expanded establishment. In either case, the objective of management will dictate the methods of sampling and management. If the objective is to preserve the species for archives or for its museum value then we can essentially "freeze" a sample of the desired size with currently available techniques. An average can be defined, and a small sample of trees can be genetically frozen by clonal propagation, or by cryogenically storing pollen and seed.

If the objective is to exactly preserve not only the averages, but also, the variation patterns which presently exist, then the necessary sampling and storage is far more difficult. Several million trees are required to save the unique combinations of even common alleles at as few as 20 loci. On the other hand, just a few hundred trees are required to save rare alleles at many more loci, if we are only concerned that the alleles are present in our sample and not that all possible combinations are preserved. Thus, saving a museum piece is trivially simple, freezing the total possible population is impossible, but saving allelic samples is manageable.

For the last objective we are obviously not concerned with the preservationist mystique of defining what is best by what exists. We are concerned only with creating a potential for gene management. To do this, alleles must be saved in an initial collection. Some simple computations can guide our operations to assure that the rarer but potentially useful alleles can be saved. It is debatable that very rare alleles, say less than one per thousand alleles, are or ever will be very useful since they may be strongly selected against for good and enduring reasons. Rare alleles are the most expensive to save and hence require a managerial decision about costs and benefits.

SAMPLE SIZE

For a single genetic locus with an allele at $q = .05$, a random sample of 30 trees is sufficient to allow only a 5% chance that the allele will be missed, and a sample of 45 trees reduces the chance to only 1%. For a rarer allele (say $q = .01$), 230 trees will allow only a 1% chance of missing it. Since we are usually concerned with many loci, some of which have alleles at low frequency, we'd like to sample enough trees to keep a low loss probability for any of the alleles, at all loci. If we'd accept a loss of just 1 allele at any of say 50 loci, and if all 50 had an allele at $q = .01$ which we'd like to save, then a sample of 389 trees will be sufficient. For higher numbers of loci, or for rarer alleles at each locus, the numbers of trees required to allow for an average loss of 1 of those rare alleles is given in Table 1.

Table 1

Minimum Number of Trees Required
for an Average Loss of 1 Allele
at Any of the Loci

No. of Loci	Frequency of Rare Allele at Each Locus: .05	.01	.005	.001
10	45	227	455	2278
50	77	389	780	3906
100	90	458	919	4601

Note that an order of magnitude increase in the numbers of loci considered only doubles the number of trees required, while a similar decrease in average allele frequency increases the sample size by an order of magnitude. Thus, sample size is more strongly affected by the rarity of the alleles one wishes to save and cost-benefit analyses are critical. If we are concerned with many loci, however, it seems reasonable to expect that we may not be as concerned with all of the rarest alleles at each, and hence that sample sizes of several hundred or a few thousand will likely suffice.

We may wish to expand consideration to saving more than 1 allele per locus. Where as many as 4 rare alleles may exist at each of many loci and all are at the same frequencies as examined in Table 1, only modest increases in sample sizes are required to assure the average loss of only 1 of any of the multiple alleles at any of the loci (Table 2).

Table 2

Minimum Number of Trees Required
for an Average Loss of 1 Allele at any of the Loci

(4 Alleles per Locus)

No. of Loci	Frequency of Rare Alleles at Each Locus: .05	.01	.005	.001
10	72	367	735	3681
50	104	528	1057	5295
100	117	597	1196	5988

It can be seen that increasing the number of alleles at each locus for 10 loci increases the sample size by approximately 62% for all frequencies. It can also be seen that the increase in sample size for any increase in numbers of loci is exactly the same for 4 as for 1 allele. Thus, our general rules for sample size remain intact.

Finally, we may note that if the genes are dispersed into subpopulations with different gene frequencies, the total sampling sizes required for species-wide average frequencies are not affected. The distribution of samples is affected since we wish to assure that we sample subpopulations that contain the alleles, but since the frequencies differ, the sample size within the subpopulations with higher than average q can be similar. If, for example, $\bar{q} = .01$ for 1 allele at each of 50 loci, but the alleles are in 10 subpopulations with 9 at $q = 0.0$, and 1 at $q = .1$, we require a sample of 37 trees in each of the 10 subpopulations, for a total of 370 trees. If the species was broken into 28 subpopulations, we'd require 14 trees in each for a total of 350 trees to provide an expected loss of only 1 allele. Finer subdivisions of the species reduce the problem to random sampling, which is equivalent to our original computations given in Tables 1 and 2.

Samples can thus be manageably small even for many loci with low-frequency alleles, and the distribution of allele frequencies will not strongly affect sample size except for very low frequency alleles. The critical question is how rare an allele can be and still be worth the effort to save it. For 10 loci with alleles at $q = 10^{-5}$, a sample size of 277,911 is required to give an expected loss of 1 allele. I doubt that we are interested in alleles that rare, but we may be interested in the alleles at $q = 10^{-3}$ or 10^{-4}, which for 10 loci require a sample of 22,792.

These sample sizes can be reduced if we can identify the subpopulations where rare alleles are located and concentrate sampling in as many such populations as may exist. To determine sampling strategy, therefore, three basic questions must be answered: How are genes distributed in the species? What gene differences exist among subpopulations? How stable are those patterns? If we know these parameters and understand the forces which interact and which may stabilize or destabilize the system, we can sample from natural populations and create manageable systems to help assure the future evolution of a species.

POPULATION STRUCTURE

The more exactly we know the species, the easier the sampling can be designed. Obviously, if we could concentrate sampling in only the critical regions we could save even very low frequency alleles at more loci than otherwise. Our knowledge of population structure, however, largely derives from large populations of temperate zone conifers. The rare and local populations of concern in this session usually present more difficult problems. The evidence indicates that relatively fine subdivisions of even large conifer populations exist. However, the stability of these subdivisions is not secure. A study of loblolly pine (*Pinus taeda* L.) being conducted in my laboratory has demonstrated that differences in gene frequency which exist in one generation are obliterated in the next. Hence, we must conclude that if subpopulations exist in this species, their boundaries shift. Therefore, migration among subpopulations can frequently occur. If this is generally true, then we must indeed sample among several subpopulations and can expect that central populations will contain most of the alleles because migration provides wide allelic dispersal. In ponderosa pine (Pinus ponderosa Laws.) such "central" populations may well lie in the midelevation zones of optimum species adaptability (Namkoong and Conkle, 1976).

For more finely subdivided populations where intermating among subpopulations is more restricted, allelic dispersal is less. It is therefore more important to sample among environmental or locational extremes. For these species, alleles which are rare on a species-wide basis can occur at high frequency in clinally or ecotypically extreme populations. Hence, sampling at species margins is recommended for such species.

While research on the genetic dynamics of rare species would clearly be useful, our present state of ignorance forces us to be conservative in making assumptions about these populations. For more widespread species, efficiency is enhanced by sampling in ecologically central regions, but sampling in population extremes is also needed to capture locally distributed alleles.

GENE MANAGEMENT

What are we to do with the common and rare alleles we manage to save? If we wish to preserve them at this moment of their evolution we can save a representative sample by available techniques. We can probably meet this objective by saving just a few examples.

If, however, we perceive species as dynamic, evolving sets of organisms, then any one sample in time or space is a limited "snapshot" of the species history and potential, and any small sample picture is as valid as any other. I suggest that our interests are often in the continuing evolution of the biota as it changes to meet a changing world. The objective of genetic sampling and gene management then is to allow potential evolution to develop and to neither stop evolution nor to channel the species into unnecessarily restrictive developmental paths. By choosing a "natural area" environment or by choosing a silviculturally managed environment, we are choosing a particular path and the merits of alternate paths should be determined by their effect on evolution. Since any one path chosen can be as restrictive as any other, and since we are highly ignorant of present genetic population structure as well as future requirements, we must be conservative in managing evolutionary potential.

Clearly, the larger the total population, the better. There must be a commitment not only to initially sample a few thousand trees, but also to maintain similar population sizes over generations, even for the smallest of species populations. Some alleles will be lost no matter what we do, and we should be weighing costs against probable worth of lost alleles. Thus, the same kinds of considerations exist for gene management as for the gene sampling.

If we wish to guide the evolution of a species to maximize its potential value for human consumption, we have an additional problem in that some rare alleles may be quite valuable. Since our ignorance of allelic distributions is matched by our ignorance of which alleles will be useful in the future, we have a double problem of finding alleles of uncertain value and managing them in such a way that they can be efficiently used. I suggest a solution to this gene management problem which implies certain management strategies for rare and local populations. From whatever sample of trees we can get, I suggest that we create as many subdivisions of multiple populations as possible and keep them evolutionarily distinct. A reasonable way to start is to use presently existing subdivisions and to further subdivide according to diverse future potential values. To the extent that the future can be well predicted, fewer such subpopulations need be carried and selection can be directed to one or a few objectives. The greater the uncertainty about future values and needs, the more diversity should be maintained among subpopulations. Such a strategy will not only be more efficient for developing economic value from those populations, but with many smaller subpopulations, the alleles can be more easily identified and used in a conscious breeding program (Namkoong, 1976). There is a substantial need for conservation and for managing the evolution of tree species. I therefore suggest that multiple population conservation and multiple population breeding efforts can strongly overlap and that there is little need for separate conservation and breeding efforts.

If these evolutionary concepts of tree species are accepted and the evolutionary objectives of gene management adopted, then dendrology is not a study of immutable species with annoying genetic variations and conservation is not a freezing of the present state. Dendrology instead is a present view of the evolutionary process, and conservation is benign evolutionary guidance.

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THE ENDANGERED VIRGINIA ROUND-LEAF BIRCH (BETULA UBER (ASHE) FERNALD): A CHALLENGE TO THE MANAGEMENT OF RARE AND LOCAL TREE POPULATIONS

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INTRODUCTION

The Virginia round-leaf birch (*Betula uber* (Ashe) Fernald), officially listed as endangered on April 26, 1978 (U.S. Fish and Wildlife Service, 1978), is the only tree in North America recognized under the Endangered Species Act of 1973. Since its rediscovery in August 1975, which gained wide public attention (Kinkead, 1976a, 1976b; Preston, 1976), a considerable amount of effort has gone into protection and management. This effort has been coupled with limited research in the basic biology of *B. uber*. In spite of this effort, the species is closer to extinction than it was at the time of its rediscovery in 1975. This paper explores some of the reasons why this situation exists and examines the challenges in the management of *Betula uber* as a rare and local population.

HISTORICAL PERSPECTIVE

Original Discovery

B. uber was originally discovered by W. W. Ashe in 1914, presumably along the banks of Dickey Creek in Smyth County, Virginia (Mazzeo, 1974). Four years later, Ashe (1918) published a description of the taxon under the name *Betula lenta* var. *uber*. The taxon was considered to be very similar to the typical black or sweet birch (*B. lenta* L.), except in its foliage characteristics. No mention was made of the number or exact location of individuals in the population. M. L. Fernald (1945) later examined available voucher specimens and in 1945 elevated *B. uber* to the rank of species and transferred it from series *Costatae* (dark-barked tree birches) to series *Humiles* (shrub birches). A. G. Johnson (1954), who later visited the type locale of *B. uber*, was unsuccessful in locating the species. He concluded that Ashe's birch was probably an aberrant individual which had subsequently been eliminated and was not worthy of further consideration, at least as a species. Attempts by other botanists in the 1950's and 1960's at locating *B. uber* were likewise unsuccessful.

Rediscovery

In the early 1970's, P. M. Mazzeo (1971, 1973, 1974) became interested in B. uber as part of his studies of the Betulaceae in Virginia. In addition to the seven herbarium specimens collected by Ashe, Mazzeo discovered a previously uncited and undated specimen collected by H. B. Ayres bearing the location "Cressy Creek". Cressy Creek parallels Dickey Creek approximately 2 km to the east. Both creeks drain the Rye Valley and flow into the South Fork of the Holston River.

In his 1974 discussion of the B. uber problem, Mazzeo pointed out that no one had reportedly visited the Cressy Creek site. D. W. Ogle, a biologist and naturalist on the faculty of nearby Virginia Highlands Community College, became interested in B. uber upon reading Mazzeo'a accounts. He set out to locate the species and in August 1975 was successful in doing so along the banks of Cressy Creek (Ogle and Mazzeo, 1976). Some disagreement exists in crediting the rediscovery in that C. F. Reed (1975), a biologist from Coppin State College near Baltimore, claims to have done so one week prior to Ogle (Preston, 1976).

Eleven adult trees were located in the initial rediscovery. By September of the same year, subsequent searches had brought the total number of individuals to 34 (12 adults, 1 sapling, 21 seedlings). Additional searches have led to the conclusion that at least 40 individuals (14 adults, 26 seedlings/saplings) must have existed in 1975, ranging in age from approximately 3 to 45 years. All were apparently part of the same local population situated in a narrow band (60 m by 1 km) along Cressy Creek.

The B. uber population was divided among three contiguous properties, as follows: U.S.D.A. Forest Service (Jefferson National Forest), 1 adult tree, the largest in the population with a stem diameter (at 4 1/2 ft. above the ground) of 8 in. and 1 "sapling", the latter a sprout resulting from damage to a large individual cut back during routine transmission corridor maintenance; a private landowner, 1 adult tree and 24 seedling/saplings; and a second landowner, 12 adult trees and one sapling.

Intensive searches for B. uber along the same stream and in adjacent stream areas (including Dickey Creek) proved unsuccessful. Thus, there is no conclusive evidence that B. uber ever existed at any locale other than the existing Cressy Creek site. Ogle has suggested that Ashe may have erred in his original reference to the Dickey Creek locale (Preston, 1976).

As of July 1979 there were 20 individuals remaining in the natural population along Cressy Creek, with no recorded recruitment (reproduction) since prior to 1975. Most of the remaining individuals have had varying amounts of tissue removed for both well-intentioned, as well as (in view of some people) misguided and/or perhaps ill-intentioned purposes. Reasons for the nearly 50 percent reduction in the population and reduced vigor in a number of the surviving individuals, together with concurrent efforts at protection, management and research, are documented below.

Reduction in Numbers and Vigor of the Natural Population

The first documented reduction in the B. uber population occurred in September 1975, approximately one month after its rediscovery

(Ogle and Mazzeo, 1976). At that time four seedlings were taken to the U.S. National Arboretum to "preserve the germplasm, to provide living study material, and to attempt propagation" (Ogle and Mazzeo, 1976). One of the four seedlings was subsequently sent to the Botany Department at the University of Michigan. All four seedlings have been outplanted and are growing vigorously. One of the seedlings at the National Arboretum produced a few female aments in 1978 (Mazzeo, personal communication). Two additional seedlings were removed by National Arboretum personnel in September 1975 and sacrificed for voucher specimens. A seventh seedling was transplanted by Virginia Highlands Community College personnel in October 1975 to Grayson County where it still exists (Ogle, personal communication).

Two medium sized trees on private property failed to leaf-out in the 1977 growing season and were cut back to stump level in September 1977. These stumps failed to produce sprouts the following growing season. A massive flood in November 1977, probably the worst on record for the Cressy Creek drainage, claimed yet another small tree on private property. Three seedlings were removed from their native site in 1978 and transplanted to the yard of one of the private landowners on whose property the population resides. In 1979 a small, apparently suppressed, sapling on private property failed to leaf-out and is presumed dead.

Thus, it is possible to document the loss of 10 seedlings, 1 sapling, and 3 adults from the native population since 1975. Of these losses, four can be attributed to natural phenomena, while the remaining 10 are due to the activities of man.

There are six additional individuals, all seedlings, whose loss from the population cannot be fully documented. Ogle (personal communication) reports that one of the seedlings was probably removed in the fall of 1975. There is also some indication that road maintenance and ditching operations claimed several seedlings on private property, probably during the 1976 growing season. Curiosity on the part of informed persons may have caused the death of additional individuals during the same growing season.

Potential damage to the residual population, as evidenced by reduced vigor, can be attributed to several sources. Perhaps the most subtle of these are related to natural phenomena, principally the 1977 flood and normal reduction in vigor when intolerant trees are reduced to an understory position in competition with other plants. Alluvium has built up at the base of several adult individuals, in part the result of entrapment of materials by a fence erected to prevent grazing damage.

Additional damage to the residual population is associated with research efforts by the scientific community. All individuals have been pruned, some rather severely, in successive growing seasons for collection of branches, foliage and fruits. Bark and wood (increment cores) samples have also been taken. This material was to be used for taxonomic studies, propagation work, aging of the population and determinations of growth rates (and thus vigor).

Protection, Management and Research Efforts

Initial efforts at protection were made by the private landowners in early spring 1976 when they erected high fences around their individual segments of the population. The fences were designed mainly to prevent grazing damage, but also to reduce inadvertent damage by curious persons.

At about this same time, the U.S.D.A. Forest Service (Southeast Forest Experiment Station) attempted to obtain a co-operative agreement with the two private landowners to facilitate management of the B. uber population. The landowners refused the request, for reasons which are not entirely clear, but are apparently related to their general apprehension of government controls, the ambiguous wording of the agreement, and the way in which the landowners were approached (Ogle, personal communication).

In August 1976 the U.S. Forest Service (Jefferson National Forest) developed a protection plan for the two individuals of B. uber on public lands (Beaver and Brock, 1976). It called for: (1) constructing a chainlink fence (with gate and lock) around each of the two individuals, (2) developing methods for controlling erosion along Cressy Creek, (3) notifying public utilities of the location of trees in or near their rights-of-way and requiring approval of Forest Service personnel for maintenance work, (4) contacting adjacent landowners to make them aware of the importance of the trees and to caution them of the use of fire and chemicals in the area, (5) cessation of hatchery trout stocking in the stream to prevent damage by fishermen, (6) notifying a local munitions plant (then and now inactive) of the location and importance of the trees, (7) remarking Forest Service property boundary lines adjacent to the location of the trees, (8) submission of necessary information to request designation of the site as a Botanical Area, (9) covering the area with a Forest Supervisor's Closure Order, which in effect prevents trespass, (10) constructing visitor information facilities adjacent to the large tree on Forest Service property, and (11) conducting a meeting to determine the process for developing a detailed research plan.

Most of the above recommendations had already been carried out at the time the protection plan was released in late 1976. Furthermore, the Forest Service was already in the process of contacting professionals to assemble for development of a research plan.

Accordingly, a group of 10 persons including representatives of the U.S.D.A. Forest Service, U.S.D.I. Fish and Wildlife Service, U.S. National Arboretum, Virginia Highlands Community College, Virginia Polytechnic Institute and State University, and including the two private landowners, met during May 18-19, 1977 to develop a research plan. In its deliberations the group concluded that research efforts should be integrated with a general management plan. The group thus proceeded to outline a plan for preservation of B. uber, which included: (1) protection of the existing natural population, (2) propagation of the population and broadening the genetic base to the extent possible, (3) search for new populations, (4) basic research on species biology, (5) public relations, (6) solicitation of financial support for management and research, and (7) providing a mechanism for effective gene pool management.

The success of the group's efforts, relative to its recommendations, has been mixed. The last recommendation was met in part by creation of the Betula uber Protection, Management and Research Co-ordinating Committee. The Committee has met semi-annually since that date and membership has increased from the original 10 members to 14 persons, including representation by The Commonwealth of Virginia and the U.S.D.I. Office of Endangered Species.

Attendance at committee meetings has been good. However, the Committee has not met with total success. Leadership roles could be more clearly defined. The two private landowners, after having attended the first meeting of the Committee, have been absent from subsequent meetings. The reasons for their absences are not entirely clear, but stem from their discomfort with the highly technical and formal nature in which the first meeting was conducted (Ogle, personal communication). Furthermore, the landowners were apparently becoming increasingly alienated by the actions of scientists and land managers which resulted in the transplanting of some plants and damage to others (Ogle, personal communication).

Another important development in committee affairs was the recent decision of D. W. Ogle, the rediscoverer of B. uber, to remove himself from formal membership on the Committee. This occurred because he felt that management and research directions taken by the Committee were not in the best interests of the private landowners and the preservation of the species (Ogle, personal communication).

Protection of the existing natural population has been reasonably successful. Since formation of the Committee, three trees and one sapling have died of natural causes, as discussed earlier. Three seedlings have been transferred by one of the private landowners to his lawn area. No cases of undocumented removal of individuals have occurred since then and access to materials on public lands for research and propagation has been controlled.

It was generally agreed by the Committee that public viewing of B. uber would be discouraged on private lands. "No trespassing" signs were displayed. Public viewing and interpretation of the B. uber story thus focused on Forest Service lands, through construction of a viewing ramp and interpretive signs at the site, slide-tape programs presented at the Visitor Center and campfire talks given by naturalists at nearby Forest Service campgrounds. A sapling-sized rooted cutting was also made available for viewing at the Visitor Center.

A co-ordinated search effort for new populations during the summer of 1977, like earlier searches, yielded negative results (Ogle, personal communication).

Attempts at propagation of the population by National Arboretum personnel have met with limited success (Mazzeo, personal communication). Vegetative propagation was initiated in 1976 when 32 individuals (of 100 attempts) were produced from rooted cuttings of the three seedlings transferred to the National Arboretum in September 1975. An additional 14-18 individuals were produced from cuttings in 1977. Of the approximately 50 individuals of vegetative origin produced over a two year period, 40 remain at the National Arboretum. Ten individuals have been distributed to various locales, including West Germany (1), Belgium (1), Colonial Williamsburg (2), Blacksburg, Virginia (VPI & SU) (3), Mt. Rogers National Recreation Area (Jefferson National Forest) (1), and the residences of the two private landowners on whose property the natural population in part resides (1 each). In 1978 and 1979 attempts were made to graft cuttings from the 11 adult trees remaining in the natural population onto B. lenta or putatative B. uber (progeny of open-pollinated seed) rootstock. Of approximately 110 attempts at grafting, two (or possibly 3) have been successful.

Attempts at sexual propagation have been largely unsuccessful (Mazzeo personal communication). Greenhouse germination trials, using open-pollinated seed collected in the 1976 growing season resulted in about 1% germination for B. uber trials, compared to 50% or greater for B. lenta trials. Of the approximately 300 germinates produced from B. uber mother trees, three had the appearance of B. uber, while the remainder exhibited leaf attributes of B. lenta.

With regard to research on the basic biology of B. uber, the Committee in its meeting on May 18-19, 1977 recommended that a plan be developed to co-ordinate research efforts. Such a recommendation seemed prudent in that no less than 10 organizations and institutions, involving perhaps 20 researchers, had already initiated or were considering initiating research involving some facet of the biology of B. uber. Accordingly, on April 20-21, 1978 the B. uber Committee convened a group of seven biologists (3 additional persons were invited), most of whom had conducted basic research on some phase of the biology of birches, to develop a research plan for B. uber. Interestingly, B. uber had been officially listed as an endangered species under the Act approximately one month earlier.

The research advisory panel made two general recommendations. The first was that any ongoing preservation efforts in the original stand which might alter the natural ecology or result in further reduction of the B. uber gene pool should be postponed for at least a year and preferably for two years, until an accurate assessment of the existing population could be made. This recommendation was made under the assumption that the entire gene pool of large trees (11 individuals) had been preserved through grafting efforts at the National Arboretum. As reported earlier, the grafts subsequently failed. The second general recommendation of the advisory panel was that ongoing efforts in vegetative propagation be continued for the purposes of: (1) maintaining and preserving the entire gene pool, (2) providing materials for establishment of additional wild populations and (3) providing materials for studies of reproductive biology and genetics.

The research advisory panel outlined 3 top priority research projects to be initiated in 1978. These included the areas of population ecology, reproductive biology and systematic relationships. Studies of population ecology were to involve the complete life cycle (germination and establishment, maintenance, reproduction and dispersal) of B. uber and other taxa of dark-barked birches (B. lenta and B. alleghaniensis) occurring at the Cressy Creek site. Recent models proposed by Harper (1977) and Whitson and Massey (1979) were given as examples for developing a conceptual framework for such studies. The panel recommended that investigations of reproductive biology be based primarily on vegetatively propagated material in the laboratory, for reasons stated earlier. Elements of this study would include the cytogenetics of reproductive structures, pollen analysis (size, abortion, fertility, germinability, etc.) and analysis of controlled crosses involving B. uber and B. lenta, including development and morphology of progeny. It was suggested that crossability studies of B. uber with other birch species apparently unrelated to it and not native to the site should also be conducted to facilitate the third major area of investigation, systematic relationships. The latter would necessitate a comprehensive morphological description of B. uber and would include any other anatomical, biochemical, cytological, and genetic information that related to its similarity to other birch taxa. The fossil record would also be considered.

The research advisory panel also identified 16 scientists with demonstrated expertise in Betula who might contribute to the B. uber project. Finally, the committee outlined several sources of potential funding for research.

The limited strides made in research on the biology of B. uber since the advisory panel made its recommendations have in large part been influenced by the paucity of available funds. The U.S.D.A. Forest Service made available approximately $10,000 through a co-operative agreement with VPI & SU over a two year period (September 1978 - August 1980). The Endangered Species Office of the U.S. Fish and Wildlife Service contributed an additional $10,000 for a one year period (April 1979 - April 1980) through a second cooperative agreement with VPI & SU. The latter was to be used to develop a recovery plan for the species. A recovery plan is defined as "a guide that justifies, delineates, and schedules those actions required for restoring and securing an Endangered/Threatened species as a viable self-sustaining member of its ecosystem" (U.S. Fish and Wildlife Service, 1979). The plan is designed to co-ordinate long-term activities of numerous agencies which may have responsibility for conservation of the species.

Efforts on the part of the advisory panel at securing other sources of funding have met with little success. Home institutions of potential researchers have been unwilling to provide funds. The National Science Foundation has indicated that it is more interested in funding research aimed at developing population models of general utility and thus was not inclined to support research on rare populations.

Preservation efforts were attempted by one of the private landowners in the winter of 1978 when he removed several large sweet birches adjacent to his single adult B. uber. The reasons for this action stem from the owner's belief that the B. uber individual would respond to release from competing vegetation and from the notion that individuals of sweet birch were bastardizing the B. uber population.

Perhaps the greatest strides in research involving B. uber have occurred in the area of population ecology. The populations of dark-barked birches in the Cressy Creek area (20 B. uber, approximately 620 B. lenta, and 11 B. alleghaniensis) have been inventoried and mapped. Individuals have been aged and their structural dimensions obtained. Data on abundance and phenology of flowering and fruiting have been collected over the past two growing seasons. Seed dispersal studies will be conducted at the end of the current growing season. Inventories of plant associates and substrate conditions are presently being conducted. Germination and establishment has been studied on a limited scale, involving growth chamber studies and introduction of open-pollinated seeds in prepared seedbeds at several locations on public lands.

Research efforts in reproductive biology and systematic relationships have been very limited and those which have been conducted have been of limited success. The failure of grafted material, reported earlier, has curtailed crossability trials and studies of F1 progeny. Controlled crosses were made *in situ* in the spring of 1979 and fruits appear to be developing normally. However, the lack or paucity of flowers on all but one *B. uber* (in contrast to heavy flowering in the 1978 growing season) precluded making the *B. uber* x *uber* cross.

Morphological, anatomical, and biochemical studies are currently under way to determine the affinities among extant individuals of *B. uber* and its closest relative. These studies are likewise rather limited in scope. One group of researchers, dealing with chemosystematics, has even requested that it remain anonymous, apparently because of the controversies in working with endangered species. The evidence to date has revealed no substantial differences between *B. lenta* and *B. uber*, other than leaf dimensions.

DISCUSSION AND CONCLUSIONS

Management of *B. uber* is a multi-faceted problem and the challenges appear great in the face of an ever declining population. First, the extent to which *B. uber* is capable of maintaining itself as a viable population in nature is not well known. Thus, attempts at meeting the ultimate objective of the Endangered Species Act, i.e., recovery of the species, may not be within the realm of possibility. To determine the population's viability and integrity will require several years of intensive research in population ecology and genetics. Even attempts at defining the critical habitat of the species will be difficult given the long life cycle typical of woody plants. A species' niche has a time dimension as well as a space dimension (Stern & Roche, 1974) and accordingly the description of critical habitat will have to deal with both. The regeneration niche, which some consider to be of paramount importance in population biology (Grubb, 1977) will need to be experimentally recreated for *B. uber*, given the absence of recent recruitment.

B. uber, like *B. lenta*, is apparently an early successional stage species. Thus, the absence of recent recruitment may in part be a matter of the lack of proper conditions for germination and establishment. Likewise, growth and maintenance of the existing population may be related to competition for space. But to open up the present stand to release individuals which are obviously suppressed (according to growth ring analyses) could prove fatal at this late stage in stand development.

It does seem evident that *B. uber* is being influenced to a large degree by *B. lenta*, both in terms of competition for space and other resources, and with respect to gene flow. Thus, there is an obvious need to study the entire dark-barked birch gene complex in the region.

Furthermore, it is not clear that the existing natural population can withstand the levels of perturbation required to answer vital questions on population ecology and genetics. It seems inevitable that propagation and cultivation will play an important role in any recovery that occurs. Cultivation would also serve to reduce pressures arising from sources other than experimental manipulations (Zeedyk et al., 1978).

It is not clear that any private or public institution or agency is willing to finance an effort of the magnitude outlined above. The reasons for this are many, and are discussed by others in this conference and elsewhere (Farmer, 1979).

Protection of the existing population is exceedingly difficult given its small size, the diversity of ownerships, the limited protection afforded plants under the Endangered Species Act, and the limited knowledge of the biology of the species. The private landowners involved are not likely at this time to favor a cooperative agreement which would place their land under any form of governmental or quasi-public control. Such attempts would probably cause further alienation and may cause retaliation on the part of the landowners or others in the local community, which could take the form of destruction to the population. The Endangered Species Act provides no legal recourse for such actions.

The limited effectiveness of the B. uber Protection, Management and Research Coordinating Committee is testimony to the fact that current management of endangered species is largely management of people.

We do not really know what Betula uber is. It may be just another leaf mutation which appears briefly in the landscape, is unable to persist under strong competition with well-established species and then disappears. Under such conditions, it would be incapable of being preserved under all but the most artificial of conditions. We may never know what B. uber is or was. But one fact remains: its destiny will in large part be determined by the actions of man.

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PLANT CONSERVATION AND THE ENDANGERED SPECIES ACT

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SUMMARY

Plant conservation is an integral part of protecting natural diversity. It is a challenging and important effort which requires the involvement and interaction of the private sector, academia, and government. This paper primarily deals with the protection offered plants by the Endangered Species Act of 1973, but also briefly discusses the efforts of other groups. There is an emphasis on rare and local trees, but most of the comments apply to other plants and animals as well.

INTRODUCTION

Many of the other symposium speakers and certainly many authors have already noted the importance of conserving natural diversity. Plant conservation is an inextricable part of this larger goal. Our biotic diversity is especially vulnerable because its continued existence depends on a web of interrelationships. Any loss of diversity weakens the stability of this ecological system and reduces its resistance to diseases and pests. In terms of more direct benefits to humans, protecting natural diversity insures the continued availability of resources which may be of scientific, medicinal, cultural, and/or esthetic importance. A quote which seems to summarize these ideas well and which has been attributed to Aldo Leopold goes as follows: "The first prerequisite of intelligent tinkering is to save all the pieces."

Protection of natural diversity is a challenging goal which requires the involvement and interaction of the private sector, academia, and government (local, state, and federal). Plant conservation must be a multiagency effort based on cooperation and interaction, and be carried out with funding from many sources. If this effort is to be sucessful, it will require the support of the professional botanical community and private individuals. While Federal involvement alone will not insure plant conservation, several pieces of national legislation in the last decade have brought increased attention to its importance. This paper will primarily deal with the Endangered Species Act of 1973 with a few brief comments on the many contributions of other involved parties. Most of my comments will focus on plants and more specifically on rare and local trees.

ENDANGERED SPECIES ACT OF 1973

At the time of its passage, the Endangered Species Act of 1973 (Public Law 93-205) may have represented the strongest environmental legislation ever passed. The 1973 Act was also the first Federal endangered species legislation to include protection for plants. Previous national legislation had only affected animal species. The 1973 legislation provided a means for conservation of Endangered and Threatened species of fish, wildlife, and plants and the ecosystems upon which they depend. The 1973 Act authorized the Department of Interior to carry out the Act, and this responsiblity was delegated to the U.S. Fish and Wildlife Service (hereinafter referred to as the Service). Therefore, the Service's Office of Endangered Species is mandated to identify which plants and animals are Endangered and Threatened, and must then carry out programs for their conservation.

IDENTIFICATION OF ENDANGERED AND THREATENED SPECIES

The listing process through which Endangered and Threatened species are recognized for protection under the Act is a lengthy one, and one with which few people outside the Office of Endangered Species are truly familiar. The Act provides two possible categories for listing, Endangered and Threatened. These are defined in Section 3 of the Act as follows:

> Endangered--any species which is in danger of extinction throughout all or a significant portion of its range, and
>
> Threatened--any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Determination of whether a taxon is Endangered or Threatened is related to one or more of the factors set forth in Section 4(a)(1) of the Act which follow:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;

(2) overutilization for commercial, sporting, scientific, or educational purposes;

(3) disease or predation [including grazing];

(4) the inadequacy of existing regulatory mechanisms; or

(5) other natural or manmade factors affecting its continued existence.

The decision to list a species as Endangered or Threatened is made by the Director of the U.S. Fish and Wildlife Service under authority delegated by the Secretary of Interior.

The listing process usually begins either by internal initiative or by someone petitioning the Service to list specific taxa under Section 4(c)(2) of the Act. An initial consideration is made of the best available scientific and commercial data, and if the taxon appears to warrant further consideration, either a notice of review or a proposal to add the species to the list is prepared and published in the Federal Register. The procedures for both notices of review and proposals incorporate comment periods and encourage involvement of the affected states, federal agencies, and interested persons and organizations. After a plant is proposed, all comments are reviewed and summarized and a decision is made concerning whether a final rulemaking determining the taxon to be either Endangered or Threatened should be prepared. Designation of a species' Critical Habitat under the provisions of Section 7 of the Act follows basically the same procedures. After the Director determines species to be either Endangered or Threatened, the determinations are published in the Federal Register and the species are afforded the protection available under the Act.

The listing process, which has always been lengthy, was greatly affected by the Endangered Species Act Amendments of 1978. The most publicized effect of the amendments was the creation of the exemption process and the Endangered Species Committee. The amendments affect the listing process as well by requiring 1) that Critical Habitat, when prudent, be determined simultaneously with the species' status; 2) that economic and other impacts be considered in determining Critical Habitat; 3) that more thorough public notification procedures be employed; and 4) that proposals be withdrawn if not finalized after two years (proposals currently over 2 years old must be withdrawn in November 1979, the first anniversary of the passage of the amendments). These requirements have greatly slowed the listing process for native species.

Federal actions which resulted in plants being listed under the 1973 Act began with the Smithsonian's report to Congress in 1975 which was published by the Service as a notice of review on July 1, 1975 (U.S. Fish and Wildlife Service, 1975). As of October 2, 1979, these actions have resulted in 27 plants being listed (see Table 1) and two plants' Critical Habitats being determined (U.S. Fish and Wildlife Service, 1978b). A more detailed discussion of these actions and the listing process is presented by Smith (1980) and MacBryde (1979a). Certainly in the case of rare and local trees, much has already been written concerning which species are rare, endemic, and/or in need of protection. State lists and publications, and Dr. Elbert Little's works (Little, 1970, 1975a, 1975b, 1976, and 1977) all discuss and document which woody

Table 1. Endangered and Threatened Plants (Species listed as Endangered or Threatened pursuant to the Endangered Species Act of 1973 as of October 2, 1979). (U.S. Fish and Wildlife Service 1977, 1978a, 1978c, 1979a-e)

Scientific Name	Common Name	Known Distribution	Status	When Listed
Alismataceae-Water plantain family:				
Sagittaria fasciculata	bunched arrowhead	USA(NC & SC)	E	7/25/79
Asteraceae-Aster family				
Echinacea tennesseensis	Tennessee purple coneflower	USA(TN)	E	6/6/79
Betulaceae, Birch family:				
* *Betula uber*	Virginia round-leaf birch	USA(VA)	E	4/26/78
Brassicaceae, Mustard family:				
Arabis macdonaldiana	McDonald's rock cress	USA(CA)	E	9/28/78
Erysimum capitatum var. *angustatum*	Contra Costa wallflower	USA(CA)	E	4/26/78
Crassulaceae, Stonecrop family:				
Dudleya traskiae	Santa Barbara Island liveforever	USA(CA)	E	4/26/78
Ericaceae-Heath family:				
**Rhododendron champmanii*	Champman rhododendron	USA(FL)	E	4/24/79
Fabaceae, Pea family:				
Astragalus perianus	Rydberg milk-vetch	USA(UT)	T	4/26/78
Baptisia arachnifera	hairy rattleweed	USA(GA)	E	4/26/78
Lotus scoparius ssp. *traskiae*	San Clemente broom	USA(CA)	E	8/11/77
Vicia menziesii	Hawaiian wild broad-bean	USA(HI)	E	4/26/78
Hydrophyllaceae, Waterleaf family:				
Phacelia argillacea	phacelia	USA(UT)	E	9/28/78

Lamiaceae, Mint family:				
Pogogyne abramsii	San Diego pogogyne	USA(CA)	E	9/28/78
Liliaceae-Lily family:				
Harperocallis flava	Harper's beauty	USA(FL)	E	10/2/78
Trillium persistens	persistent trillium	USA(GA, SC)	E	4/26/78
Malvaceae, Mallow family:				
*Malacothamnus clementinus	San Clemente Island bushmallow	USA(CA)	E	8/11/77
Onagraceae, Evening-primrose family:				
Oenothera avita ssp. eurekensis	Eureka evening-primrose	USA(CA)	E	4/26/78
Oenothera deltoides ssp. howellii	Antioch Dunes primrose	USA(CA)	E	4/26/78
Poaceae, Grass family:				
Orcuttia mucronata	Crampton's Orcutt grass	USA(CA)	E	9/28/78
Swallenia alexandrae	Eureka dune grass	USA(CA)	E	4/26/78
Zizania texana	Texas wild-rice	USA(TX)	E	4/26/78
Ranunculaceae, Buttercup family:				
Aconitum noveboracense	northern wild monkshood	USA(IA,NY OH,WI)	T	4/26/78
Delphinium kinkiense	San Clemente Island larkspur	USA(CA)	E	8/11/79
Sarraceniaceae-Pitcherplant family:				
Sarracenia oreophila	green pitcher-plant	USA(ALA)	E	9/21/79
Scrophulariaceae, Snapdragon family:				
Castilleja grisea	San Clemente Island Indian paintbrush	USA(CA)	E	8/11/77
Cordylanthus maritimus ssp. maritimus	salt marsh bird's beak	USA(CA,MX)	F	9/28/78
Pedicularis furbishiae	Furbish lousewort	USA(ME), Canada (New Brunswick)	E	4/26/78

* Woody Species

plants are in need of protection. Of the 27 plants listed to date, only three of these are woody species (see Table 1). The other approximately 3,000 species which appeared in the July 1, 1975 notice of review remain candidates for listing. Numerous woody species were included in the notice, and several of these are high priority candidates for listing such as Torreya taxifolia (Florida torreya), Taxus floridana (Florida Yew) and Fraxinus gooddingii (Goodding's Ash).

PROTECTION AFTER LISTING

If plant conservation is to be achieved, we must certainly go beyond identification and listing of Endangered and Threatened species. A frequently asked question is: What protection is offered plants by the Endangered Species Act of 1973? The Endangered Species Act Amendments of 1978 included plants equally for the first time in sections 5 (land acquisition) and 6 (cooperative agreements) of the Act, both of which had previously applied only to animal species. The amendments also created a new section 4(g) (recovery plans) which equally covers plants and animals. These, and other sections which had previously offered protection to plants, require the Service to carry out protection measures for species once they are listed. These protective measures will be discussed in greater detail in the following paragraphs.

Section 6(c) of the Act, which provides for state cooperative agreements, enables the Service to give financial assistance to states to assist them in carrying out programs for conserving Endangered and Threatened species. Through cooperative agreements, funds are available to states to carry out research, management, and recovery efforts for Endangered species. Many states already have such agreements for animals and are receiving large amounts of funding. Now, the same is possible for plants! Botanists should urge their states to qualify for and to seek state cooperative agreements for plants.

Both plants and animals are equally covered under a new section 4(g) of the Act which requires the development and implementation of recovery plans for Endangered and Threatened species. A recovery plan is a guide to justify, delineate, and schedule actions to restore and secure Endangered and Threatened species as viable, self-sustaining members of their ecosystems. These plans outline the threats or limiting factors facing the species and form the basis for programming and budgeting endangered species recovery efforts, which include habitat protection and management, research, and law enforcement. Recovery plans are needed and used not only by the Service but also by other involved agencies and organizations.

Recovery plans may include recommendations for habitat protection through land acquisition, accomplished through section 5 of the

Act or through other agencies and organizations. Section 5 of the Act authorizes the Secretary of Interior and the Secretary of Agriculture (U.S. Forest Service) to acquire lands for the purpose of conserving fish, wildlife, and plants. Other methods may be used to protect the species' habitat such as appropriate easements and/or leases. Once the species' habitat has been protected from imminent destruction, appropriate management and protection plans must be developed to perpetuate the conditions necessary for the species' continued existence. These recovery plans often require additional species biology research in order to obtain information necessary for developing sound recovery plans. An example of a tree which has been federally listed as Endangered and for which recovery efforts are taking place is Betula uber. Dr. Sharik's paper will provide the details concerning Betula uber .

Section 9 of the Endangered Species Act, which prohibits the taking, possession of illegally taken, and commerce in Endangered fish and wildlife only prohibits interstate commerce, import, and export of Endangered plants. This discrepancy in the treatment of animals and plants severely limits the protection offered plants. When a plant occurs solely on privately owned lands, there is little federal agencies can do without the cooperation of the private landowners to protect its natural habitat. Fortunately many private landowners are willing to cooperate. Although plants are treated less restrictively than animals under the Act, substantial opportunities for research, management and conservation of plants and their natural habitats are provided by the Endangered Species Act of 1973.

Efforts of Other Agencies and Groups

The necessity of interaction and cooperation between various agencies in order to conserve plants was briefly mentioned earlier in this paper. A certain amount of interaction is required by the Endangered Species Act and other legislation. Section 7 of the Endangered Species Act requires all federal agencies, in consultation with the Service, to insure that their actions do not jeopardize the continued existence of any Endangered or Threatened plant or animal or result in the adverse modification of their critical habitat. Certainly other affected agencies play an important role in the development and implementation of recovery plans. Of special importance for plants has been section 12 of the Endangered Species Act, which instructed the Smithsonian Institution to compile a report on those plants threatened with extinction. As stated earlier, this report contained the names of over 3,100 plants. The Service's 1975 notice of review (U.S. Fish and Wildlife, 1975) and 1976 proposal (Fish and Wildlife Service, 1976), which were based primarily on this report, encouraged many agencies to begin gathering data on, monitoring, and providing protection for these candidate plant species while they were under consideration for final listing. Fortunately many agencies have gone beyond what is strictly required by the Endangered Species Act or other legislation.

Other programs which have been initiated by various agencies often use the presence of endangered, threatened, or rare species as criteria for designating or including areas under some form of protection or recognition. Examples include: the U.S. Forest Service's Research Natural Areas and Botanical Areas programs; the Heritage, Conservation, and Recreation Service's National Natural Landmark program; the National Park Service's Protected Natural Areas and Research Natural Areas programs; and others. Many state agencies are initiating state recognition and protection programs for endangered, threatened, and rare species and their habitats. A number of states have already passed state legislation requiring the protection of endangered, threatened and rare plants, and other states are in the process. In most states, lists of plants which are considered endangered, threatened, or rare within the state have been developed.

Many private conservation organizations are continuing to assist in and develop programs for plant conservation. One prime example is The Nature Conservancy which, besides assisting in the protection of large acreages each year independently and in cooperation with many state and Federal agencies, has also initiated many State Heritage Programs. These programs systematically conduct inventories in order to identify, locate, and develop protection plans for elements of natural diversity. These programs help to insure that the fullest possible spectrum of natural diversity is contained within the areas which are set aside. Many of these programs have already been incorporated into various state governments in order to insure maximum interaction in land-use planning at the state level. These programs also serve as an excellent source of reliable information.

Arboreta and botanical gardens are very important in carrying out research in propagation and cultivation. Through propagation and cultivation, material can be made available for educational purposes, for later reintroduction, and as a means of preserving a genetic resource, as has been the case for Franklinia. The availability of easily cultivated material should also reduce collection pressure on wild populations.

The role of academia in providing needed research and expertise is also very important. Extensive reliable information on endangered and threatened plants is needed in order to carry out plant conservation programs. A more detailed discussion of the information required to use the Endangered Species Act for plant conservation is presented by MacBryde (1979b) and Smith (1980). Status report outlines and information systems have been developed that researchers may follow in gathering information on Endangered and Threatened species. Several of these are presented in the symposium, "Geographical Data Organization for Rare Plant Conservation", proceedings (Morse and Henifin, 1979). The need for reliable data has prompted various federal and state agencies to initiate contracts for status surveys and needed research for recovery efforts. The data from these contracts, along with those available from interested botanists and conservationists who have given freely of their time and expertise for many years, have resulted in adequate data for a large number of species. The current increased interest in species' biology research has also provided extensive data on many species. For other species, necessary information is not available and further contracts and studies will be required.

CONCLUDING REMARKS

In addition to the continued efforts of federal and state agencies, academia, and the private sector, all those involved must also continue to encourage strong and effective state and federal legislation and must develop and implement effective education programs for the general public. These programs, interactions, and cooperation must continue and improve if the common goal of plant conservation is to be achieved.

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RARE AND LOCAL TREES IN THE EASTERN DECIDUOUS FOREST BIOME

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SUMMARY

Maps provide information for a comparison of the rare and local tree species of eastern United States. This region has 10 endemic tree genera and 9 others known also from eastern Asia. About 10 centers of endemism of trees in eastern United States have about 65 species (also 7 varieties) of local or slightly broader range. These centers, with numbers of tree species, are: Northeastern 1; Southern Appalachians, 13; Piedmont, 5; Coastal Plain, 15; Northwest Florida, 5; Central Florida, 6 (also 2 varieties); South Florida, no species (3 varieties); Ozark Plateau, 1; Southern Appalachians and Ozarks, 2; Ozark and Edwards Plateaus, 4; Edwards Plateau (and beyond), 10 (also 2 varieties); Southern Great Plains, 3. Notes on young and old endemics and on very rare trees are included.

INTRODUCTION

The rare and local tree species of eastern United States are compared here according to their present distribution. Trees are excellent subjects for biogeographical studies, because their ranges are fairly well known. Detailed species maps provide much informaton about relationships and history. Results from trees may apply also to other seed plants with similar distributional patterns.

This study of the eastern deciduous forest biome refers to the eastern half of the country west to the treeless grasslands and foothills of the Rocky Mountains and mentions conifers as well as hardwoods. It follows and continues an earlier article on the endemic, disjunct, and northern trees in the southern Appalachians (Little 1971b), which cited general references not repeated.

As noted previously, additional information is available from other branches of science outside the scope of this article. These include paleobotany or the fossil record, palynology or pollen analysis, cytology and genetics, and experimental taxonomy.

Lists of rare and local trees of eastern United States have been compiled from the "Atlas of United States Trees" (Little 1971a, 1977a, 1978) and from the revised Checklist (Little 1979), which summarizes the range of each species. The checklist is the source of the nomenclature and cites authors of scientific names. Maps are available in the Atlas and are omitted here.

Several studies involving rare and local eastern trees may be noted. The preliminary list of proposed endangered and threatened plant species compiled by the Smithsonian Institution (1975; Ayensu and De Filipps 1978) had approximately 15 species and 7 varieties of eastern trees (Little 1975b). Three conservation research reports (Little 1975a, 1976, 1977b) contain information about rare and local conifers, rare and local trees on the National Forests, and rare tropical trees of South Florida.

A key word in studying plant distribution is change, or dynamics. Just as all organisms end in death, all species become extinct or change into others by evolution. Likewise, the natural distribution of a species is slowly changing.

Time is another important term. A century ago Joseph F. James (1881, p.67) observed "that the time necessary for the distribution of our plants has been sufficiently long."

DEFINITIONS

Several definitions may be repeated (Little 1977b). A rare species has small numbers of individuals throughout its range, which may be restricted or widespread. A local species has relatively small range but is sufficiently common not to be called rare. Species classed here as local occupy areas mostly within a distance of 300 miles in three or fewer States.

An endemic species has range limited to a particular named area, usually small. A border or peripheral species reaches the limit of its natural range a short distance into the United States, where it may be classed also as rare or local. A disjunct species has a discontinuous range; that is, small populations are separated and isolated from the main areas.

Two administrative or legal definitions may be quoted from the Endangered Species Act. "The term 'endangered species' means any species which is in danger of extinction throughout all or a significant portion of its range. . . ." "The term 'threatened species' means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Survival of an endangered species requires assistance. When a species has small numbers of individuals, loss of or changes in habitat, overexploitation, competition, disease, or other factors could cause extinction.

Some rare and local tree species have been proposed as endangered and threatened species. However, border or peripheral species, which may be common in a neighboring country, generally are excluded by definition.

ENDEMIC TREE GENERA

Endemics, the taxonomic groups or taxa of restricted occurrence, are of special interest in an analysis of geographic distribution. Several groups are sufficiently distinct to be classed as separate genera. Eastern United States has 10 endemic tree genera.

The United States has one endemic plant family of trees, Leitneriaceae, corkwood family, an interesting relic of very obscure affinities. The lone species, Leitneria floridana (corkwood), is a shrub or small tree rare and local in the southeastern Coastal Plain in Georgia, Florida, and Texas and up the Misssissippi Valley in Arkansas and Missouri. A fossil species of Miocene age has been named from Oregon, and others have been reported from Siberia.

One addition to the 9 endemic tree genera mentioned earlier (Little 1971b) is Nemopanthus (mountain-holly), long known from a single species, a large shrub or rarely small tree of northeastern United States and adjacent Canada, Nemopanthus mucronatus (L.) Trel. The genus now has a second species, Nemopanthus collinus, a shrub or small tree rare and local in mountains of West Virginia, western Virginia, and western North Carolina. It was transferred from Ilex (holly) by Clark (1974).

Eight of the 10 tree genera endemic to eastern United States are monotypic, that is, represented by only 1 living species. These endemic tree genera mostly confined to the southeastern Coastal Plain, with their tree species and families, are:

Asimina, A. triloba (pawpaw), widespread; A. obovata (bigflower pawpaw), Florida; A. parviflora (smallflower pawpaw), southeastern Coastal Plain (Annonaceae); also several shrub species.

Cliftonia, C. monophylla (buckwheat-tree; Cyrillaceae).

Elliottia, E. racemosa (elliottia; Ericaceae).

Franklinia, F. alatamaha (franklinia; Theaceae), extinct except in cultivation.

Leitneria, L. floridana (corkwood; Leitneriaceae).

Nemopanthus, N. collinus (mountain-holly), southern Appalachians; N. mucronatus, widespread in northeast (Aquifoliaceae).

Oxydendrum, O. arboreum (sourwood; Ericaceae), centering in southern Appalachians.

Pinckneya, *P. pubens* (pinckneya; Rubiaceae).

Planera, *P. aquatica* (water-elm or planertree; Ulmaceae).

Serenoa, *S. repens* (saw-palmetto; Palmae).

Four of the above genera have fossil records indicating much broader past distribution and great age. *Elliottia* has a close relative (*Tripetaleia* with 2 species) in Japan, which is sometimes placed in the same genus. *Serenoa*, of the southeastern Coastal Plain mainly in Florida, may be relatively young. *Franklinia* at one time was united with *Gordonia*.

GENERA KNOWN ALSO FROM EASTERN ASIA

Many plant genera of eastern United States have persisted from the Arcto-Tertiary flora of uniform forests widespread across North America and Eurasia in late Mesozoic and early Cenozoic eras. Eastern North America is one of the four centers of survival, also called refugia, where some genera remained after climatic and other changes. Disjunct genera of the ancient flora now surviving in eastern Asia and eastern North America have been listed by various workers beginning with Asa Gray in 1889 (Li, 1952). The 9 tree genera confined to temperate portions of these two distant regions are listed below, slightly revised from the earlier compilation (Little 1971b). Two genera reappear southward in mountains of Mexico. These ancient tree genera obviously are stable and have a slow rate of evolution.

Carya (hickory), 11 species in eastern North America, 3 of these and 1 other in mountains of Mexico, and 4 in eastern Asia.

Chionanthus (fringetree), 1 in eastern North America, 1 shrub in central Florida, and 1 in east Asia.

Cladrastis (yellowwood), 1 in southern Appalachians and Ozarks and 3 in east Asia.

Gymnocladus (coffeetree), 1 in eastern North America and 3 in southeast Asia.

Halesia (silverbell), 3 in southeastern United States (1 mostly in southern Appalachians and Ozarks and 2 mostly in Coastal Plain) and 3 in east Asia.

Hamamelis (witch-hazel), 1 in eastern North America and northeastern Mexico, 1 shrub in Ozarks, 1 in Mexico, and 3 in east Asia.

Liriodendron (yellow-poplar), 1 in eastern North America and 1 in east Asia.

Sassafras (sassafras), 1 in eastern North America and 2 in east Asia.

Stewartia (stewartia), 2 in southeastern United States (1 in southern Appalachians and 1 in Coastal Plain) and about 8 in east Asia.

CENTERS OF ENDEMISM

About 65 tree species (also 7 varieties) native in eastern United States can be classed as local or slightly broader in range. These can be grouped geographically in about 10 areas or centers of endemism. Less than half of these species are very local and classed also as rare. (For comparison, the total number of tree species in this region is about 300, not including about 100 tropical species of South Florida.) Most of the centers of endemism have obvious natural geographic limits, based upon topography, bedrock, and geological history. These centers of endemism with their species are listed below.

The genus Crataegus (hawthorn) is often excluded from geographic studies because of the very large number of named local species and the taxonomic difficulties. In the 1979 Checklist, the number of eastern species is reduced to 30, of which 9 are cited here as local.

Northeastern, 1 species. Only 1 local species is confined to the glaciated region, Crataegus dilatata (broadleaf hawthorn), of New England, New York, and adjacent Canada. Though not a precise center, the glaciated region with a single endemic tree species merits mention.

Southern Appalachians, 13 species. This natural geographic mountainous region may be classed as a center of endemism, though large. It extends from central Pennsylvania southeast to Alabama, mainly above 2,000 feet altitude, about 700 miles long and 150 miles wide. Three tree species are rare and local: Betula uber (Virginia roundleaf birch), southwestern Virginia, classed as endangered; Prunus alleghaniensis (Allegheny plum), mostly Pennsylvania and West Virginia, proposed as threatened; and Nemopanthus collinus (mountain-holly), West Virginia to North Carolina.

These 10 endemic species of wider range in the southern Appalachians were listed earlier (Little 1971b): Abies fraseri (Fraser fir); Pinus pungens (Table Mountain pine); Tsuga caroliniana (Carolina hemlock); Aesculus octandra (yellow buckeye); Clethra acuminata (cinnamon clethra); Magnolia fraseri (Fraser magnolia);

Rhododendron catawbiense (Catawba rhododendron), also Piedmont; *Robinia kelseyi* (Kelsey locust); *Robinia viscosa* (clammy locust); *Stewartia ovata* (mountain stewartia).

Piedmont, 5 species. *Quercus georgiana* (Georgia oak), on granite and sandstone hills, proposed as threatened; *Quercus oglethorpensis* (Oglethorpe oak), proposed as threatened; *Aesculus sylvatica* (painted buckeye); *Crataegus harbisonii* (Harbison hawthorn); *Crataegus triflora* (three-flower hawthorn).

Coastal Plain, 15 species. Species with a relatively limited or scattered distribution are grouped here. *Aesculus parviflora* (bottle-brush buckeye); *Alnus maritima* (seaside alder), also local in southern Oklahoma, proposed as threatened; *Catalpa bignonioides* (southern catalpa), the original range uncertain; *Cliftonia monophylla* (buckwheat-tree); *Crataegus texana* (Texas hawthorn); *Elliottia racemosa* (elliottia), very rare and local, proposed as endangered; *Franklinia alatamaha* (franklinia), extinct except in cultivation; *Halesia parviflora* (little silverbell); *Illicium floridanum* (Florida anise-tree), also northeastern Mexico; *Leitneria floridana* (corkwood), much scattered; *Myrica inodora* (odorless bayberry); *Pinckneya pubens* (pinckneya), proposed as threatened; *Quercus arkansana*, (Arkansas oak); *Salix floridana* (Florida willow), proposed as endangered; *Yucca gloriosa* (moundlily yucca).

Northwest Florida, 5 species. The bluffs and other rock outcrops have 2 well-known very rare endemics, both proposed as endangered: *Taxus floridana* (Florida yew), and *Torreya taxifolia* (Florida torreya), almost extinct in wild state because of a fungal disease. Others are: *Crataegus lacrimata* (Pensacola hawthorn); *Crataegus pulcherrima* (beautiful hawthorn); *Magnolia ashei* (Ashe magnolia).

Central Florida, 6 species (also 2 varieties). The sandhill area with scrub vegetation of evergreen oaks and sand pine has several endemic trees: *Carya floridana* (scrub hickory); *Illicium parviflorum* (yellow anise-tree), proposed as threatened; *Pinus clausa* (sand pine), common and widespread but centering here; *Lyonia ferruginia* (tree lyonia), also adjacent States; *Quercus chapmanii* (Chapman oak); *Quercus myrtifolia* (myrtle oak). Varieties: *Ilex opaca* var. *arenicola* (dune holly), proposed as threatened; *Persea borbonia* var. *humilis* (silkbay), proposed as threatened.

South Florida, no species (3 varieties). The 101 native tropical tree species all are found beyond in the West Indies or also southward and are classed as border species (Little 1976). The 3 endemic tree varieties are: *Cereus robinii* var. *deeringii* (Deering tree-cactus), very rare on Upper Florida keys and proposed as endangered. Also, *Cereus robinii* var. *robinii* (key tree-cactus, typical), very rare on Lower Florida Keys but also rare in Cuba, has been proposed as endangered. (According to Ward (1979), the typical variety is extinct in Florida, and the plants of Big Pine Key belong to the other variety.) Myrcianthes fragrans var. simpsonii (Simpson stopper), rare and local on mainland, proposed as threatened and protected by State law (as Eugenia simpsonii). The typical variety, Myrcianthes fragrans var. fragrans, has wider range in South Florida and tropical America. Pinus elliottii var. densa (South Florida slash pine), common in pine forests of southern Florida. The typical variety, Pinus elliottii var. elliottii (slash pine), is widespread in the Coastal Plain from central Florida northward.

Ozark Plateau, 1 species. The only endemic tree species in this upland region of plateaus and mountains in southern Missouri, Arkansas, and eastern Oklahoma, is Castanea ozarkensis (Ozark chinkapin). An endemic large shrub is Hamamelis vernalis Sarg. (Ozark witch-hazel).

Southern Appalachians and Ozarks, 2 species. Cladrastis kentukea (yellowwood); Ulmus serotina (September elm). Eight other species of wider distribution in these two regions were noted earlier (Little 1971b).

Ozark and Edwards Plateaus, 4 species. A few tree species have their ranges mainly in these two upland regions or slightly beyond. Carya texana (black hickory); Cotinus obovatus (American smoke tree), also in mountains of southeastern Tennessee and northern Alabama; Crataegus reverchonii (Reverchon hawthorn); Juniperus ashei (Ashe juniper), also northeastern Mexico.

Edwards Plateau (and beyond), 10 species (also 2 varieties). This ancient land mass has a few endemic tree species and others extending south into northeastern Mexico. These do not reach Mexico: Fraxinus texensis (Texas ash), also southern Oklahoma; Sophora affinis (Texas sophora), also adjacent States; Styrax platanifolius (sycamore-leaf snowbell); Acer grandidentatum var. sinuosum (Uvalde canyon maple), proposed as threatened; Pinus cembroides var. remota (Texas pinyon).

These 7 species of the Edwards Plateau continue south into Mexico: Arbutus texana (Texas madrone), also Trans-Pecos Texas; Celtis lindheimeri (Lindheimer hackberry); Crataegus greggiana (Gregg Hawthorn); Crataegus tracyi (Tracy hawthorn), also Trans-Pecos Texas; Leucaena retusa (littleleaf leadtree), also to southern New Mexico; Pistacia texana (Texas pistache); Quercus glaucoides (Lacey oak).

Southern Great Plains, 3 species. These species have ranges centering in the Texas panhandle, though perhaps too broad to be classed as local: Juniperus pinchotii (Pinchot juniper); Quercus havardii (Harvard oak); Quercus mohriana (Mohr oak).

Chisos Mountains, in Trans-Pecos Texas, may be mentioned though better classed as a western center of endemism. Two rare tree species known only from Chisos Mountains are: Ostrya chisosensis (Chisos hophornbeam) and Quercus tardifolia (lateleaf oak), both proposed as threatened. Quercus graciliforms (Chisos oak), proposed as threatened, is also on a nearby Mexican peak. Others have broader range in Trans-Pecos Texas and northeastern Mexico.

YOUNG AND OLD ENDEMICS

Species distribution patterns give some indication of the relative age of rare local tree species in the absence of fossil record. However, as various workers have observed, area alone is not reliable. A species with small range could be young and spreading its range or old and contracting.

A compact and mostly continuous range with large populations indicates a young species of expanding area. A discontinuous range with disjunct or isolated small populations suggests an old species of decreasing area.

Distributions of closely related species offer further clues. For example, a local species whose small range borders the greater range of another may have been derived from the latter. A tree species whose nearest relatives are in a distant continent probably is old.

Several pairs of related eastern tree species with mostly different but adjacent ranges may be noted, as in the previous study. The local species, on the left in the list below, may have been derived from the related species of broader range, on the right, or both might have evolved from the same extinct ancestor.

Abies fraseri	Abies balsamea
Pinus clausa	Pinus virginiana
Aesculus sylvatica	Aesculus octandra
Betula uber	Betula lenta
Carya floridana	Carya glabra
Castanea ozarkensis	Castanea pumila
Magnolia ashei	Magnolia macrophylla
Magnolia fraseri	Magnolia pyramidata
Nemopanthus collinus	Nemopanthus mucronatus
Rhododendron catawbiense	Rhododendron maximum
Robinia kelseyi, R. viscosa	Robinia pseudoacacia
Stewartia ovata	Stewartia malacodendron

Crataegus dilatata (broadleaf hawthorn) apparently is a young or new endemic, as its range is confined to the glaciated region in the northeast. Its nearest relative is C. coccinioides (Kansas hawthorn), of southern Illinois to northeastern Oklahoma.

BETULA UBER

As a result of recent publicity, Betula uber (Ashe) Fern. (Virginia roundleaf birch) has become one of the best known rare trees. It was discovered near Marion in Smyth County, southwestern Virginia, in 1914, named as a variety in 1918 by W. W. Ashe, and elevated to a species in 1945 by M. L. Fernald. The 1953 Forest Service Checklist accepted it as "a poorly known local variety meriting additional study."

After unsuccessful searches, it was placed on the list of proposed extinct species. Soon afterwards, in 1975, about 15 trees, plus seedlings, were found along Cressy Creek on private land near houses. Two other trees were located later nearby on the adjacent Jefferson National Forest. Thus, this rare birch became the first tree of the United States to be classed officially as endangered (April 26, 1978).

Obviously, Betula uber is very rare and very local, now known from about 20 plants of various sizes. The largest tree is about 45 feet high, 8 inches in trunk diameter, and about 50 years old. Perhaps not mature, but larger trees may have been cut earlier. This species apparently is a young endemic.

The habitat, a broad valley of a small stream, is not distinctive but is an open cutover deciduous forest with exposed stream banks and disturbed areas. The lands now are in farm woodlots near houses. Betula lenta (sweet birch) and B. alleghaniensis (yellow birch) are associated trees.

The leaf shape of Betula uber is distinctive, small, rounded, dentate, with few spreading sunken lateral veins and slightly resembling shrubby birches of northern regions. In form the leaf differs more from leaves of two associated tree birches than their leaves do from one another. A few plants with intermediate, long-pointed leaves have been observed.

During maximum glaciation in the Wisconsin glacial stage (Pleistocene epoch), the climate of this locality was colder. The border of the ice sheet at its nearest point, in southern Ohio, was about 225 miles away. Vegetation here apparently was spruce-fir forest, as zones shifted down the mountains as much as 3,000 feet in altitude.

One explanation proposed for the origin of Betula uber is derivation from Betula lenta through mutations and recombinations of genes. Another is that it may be a natural hybrid with the more northern shrub Betula pumila L. var. glandulifera Regel (low birch). Or, a planted artificial hybrid.

Investigations in progress by the National Arboretum and Virginia Polytechnic Institute and State University should provide additional information. In the meantime, Betula uber is worthy of further propagation and wider distribution as an ornamental.

VERY RARE EASTERN TREES

Very rare tree species of eastern United States now in danger of extinction apparently are very few. In some details of distribution, trees are unlike herbs. Lists of proposed endangered species contain numerous examples of herbs known only from one or few collections or colonies or confined to a very local habitat such as a mountain peak or peculiar rock formation.

In eastern United States, these 3 tree species qualify as both very rare and very local in their original natural ranges: Betula uber (Virginia roundleaf birch), Taxus floridana (Florida yew), and Torreya taxifolia (Florida torreya). Other endemic eastern trees are represented by more and larger populations. However, some populations and their habitats are subject to damage and destruction. Thus, other species may need assistance if they are to survive.

A few minor variations of eastern trees, such as varieties, might qualify as both very rare and very local. However, agreement on details of classification and need for protection may be lacking. Western United States, with greater differences in habitats, has a larger number of very rare and very local tree species.

Of the contemporaneous (geologically recent) tree species native in eastern United States, none is known to have become extinct. Franklinia alatamaha (franklinia), found at one locality in southeastern Georgia in 1765 and not seen wild since 1790, fortunately survives in cultivation. Perhaps transplanting was the cause of the disappearance.

NEW SPECIES

No tree species of eastern United States new to science has been accepted in recent years, and very few tree species have been published as new (Little 1979, p. 321-322). The most recently named tree species of this broad region accepted in the 1979 Checklist is Nemopanthus collinus (Alexander) Clark (mountain-holly). It dates from 1941, as Ilex collinus Alexander. However, a few varieties described later are recognized. Binomials for natural interspecific hybrids are not counted as species.

FLORIDA TREES

The number of tree species endemic to Florida is only 5 (also 5 varieties; Little, 1976, p. 3-4; 1978): Carya floridana, Crataegus lacrimata, Illicium parviflorum, Magnolia ashei, and Taxus floridana. However, a few others including Pinus clausa and Torreya taxifolia extend barely into a second state. All other tree species proposed as new have been reduced to synonyms or varieties.

A recent detailed report on the rare and endangered plants of Florida accepts only about 25 tree species as endangered, threatened, and rare (Ward 1979). About half of those trees are tropical species omitted in this article as border or peripheral, and one-fourth are common northern species rare at their southern limits in that State. Five also cited in this article are: Leitneria floridana, Magnolia ashei, Salix floridana, Taxus floridana, and Torreya taxifolia.

The three centers of endemism in Florida have been mentioned. C. W. James (1961) noted that the highest altitudes of Florida could have remained above the maximum rise of sea (about 250 feet) in the Pleiostocene epoch. Scattered Pliocene land areas or islands could have remained available to plants as Pleistocene refugia. These areas, shown on maps, are parts of the Marianna Hills, the Apalachicola Bluffs, and the Tallahassee Hills of northwest Florida (panhandle) and segments of Trail Ridge, the Brooksville Ridge, and the Lake Wales Ridge of central Florida.

Long and Lakela (1971, p. 15; Long, Lakela, and Broome 1969) stated that more than 300 endemic flowering plant species were recorded for Florida, mostly in the Lake District of the central part, with a second area of concentration in southern Florida and the Florida Keys. They noted that about 9% of the flora of tropical Florida is endemic to the State, the majority herbaceous dicotyledons presumably of recent origin.

The native trees of South Florida are mostly evergreens of tropical forests. The previous study listed 101, of which 60 were classed as rare. All are border or peripheral species native in the West Indies or beyond. Not one is endemic, but there are 3 endemic varieties, as noted above.

An explanation for the absence of endemic tree species in South Florida is apparent. The peninsula and Florida Keys are relatively young geologically, having been submerged repeatedly in interglacial times. Northward, freezing winter temperatures serve as a climatic barrier from the continent. The narrow water barrier southward may not be effective, however. Seeds could be carried by air, especially in hurricanes. At the time of last maximum glaciation, the sea level was as much as 200 feet lower and the land massess of the Bahamas, particularly the Grand Banks, several times larger.

In the future, endemic tree species may be expected to appear in South Florida. The 3 endemic varieties mentioned above suggest that some evolution is in progress. One observation is that the rate of evolution of tree species there seems to be slower than that of herbs. Generations of herbs are much shorter. A mutant herb would have a greater chance of reaching maturity and bearing seeds than a tree because of the shorter life cycle and reduced competition with larger individuals.

MIGRATION

Every area has many plant species with ranges continuing in different directions, several near range limits, and often a few local. Current species could have arrived from various directions over long periods of time. Obviously, the fossil record is the best evidence of past history and migration.

The tree species of the northern coniferous forests have migrated northward at a relatively rapid rate following melting and retreat of the last ice sheet. However, a few hardwood species, ancient and with disjunct patterns, apparently have advanced more slowly. Very few tree species centering in the southern Appalachians have ranges northward into the glaciated area. Several extended farther north in interglacial stages than at present, according to fossil evidence. Thus, more time may be needed for recovery.

A few species of the Ozarks and scattered localities eastward are absent or nearly so from the southern Appalachians. Examples are Cotinus obovatus (American smoketree), Cladrastis kentukea (yellowwood), and the shrub Neviusia alabamensis Gray (snow-wreath). Their distribution patterns suggest that they may have retreated from the mountains and have not advanced afterwards. Some isolated populations may be very old and may have persisted during stages of ice advance.

Naturally, tree species have migrated and vegetation zones have shifted in various directions with fluctuations of climate. Besides the colder periods of glaciation and warmer interglacial stages, there have been east-west changes such as xerothermic periods.

Evidence from pollen analyses of peat deposits and from packrat nests or middens indicates that vegetation zones in mountains of western North America moved downward as much as 3,000 feet. Thus, timberlines in the southern Rocky Mountains, now about 11,500 feet, may have shifted to 8,500 feet or lower. However, there is no evidence of a timberline or alpine flora in the southern Appalachians of lower altitude, now 6,684 feet on Mount Mitchell in North Carolina. (A report of glacial striations was based upon markings made by logging cables.)

Much progress has been made in reconstructing shifts of past vegetation in eastern North America pollen records at many sites. Paul A. and Hazel R. Delcourt (1979) have prepared vegetation maps at intervals from the present back to 40,000 years.

DISJUNCT DISTRIBUTION

Some tree species have more or less continuous distributions, while others have disjunct or discontinuous ranges. Species of high altitudes in mountains commonly have irregular ranges because of the topography of peaks and ridges. For example, an earlier study (Little 1971b) listed 16 northern tree species continuous to the southern Appalachians and 14 northern tree species disjunct in the southern Appalachians. Also, 10 tree species of the southern Appalachians reappear in the Ozarks. The disjunct populations of rare and local eastern tree speices merit further study.

Many tree species have disjunct populations at borders of their ranges. These isolated colonies may be of special importance, for example, in the selection of seeds for introduction to extreme conditions such as a cold or dry region or site. The species maps show many of these localities, though the unit of mapping in some eastern States is no smaller than the county. The sites generally are similar to those of larger populations. Further information often can be obtained from local specialists or from herbarium labels.

The irregular distribution of a few tree species seems to defy explanation. *Alnus maritima* (seaside alder), proposed as threatened, is local in five counties of Maryland's Eastern Shore and one in southern Delaware. About a century ago it was discovered far inland in a second area, rare along a stream in two counties of south central Oklahoma, more than 1,150 miles to the southwest! No other tree species confined wholly within the contiguous United States has a greater distance between its disjunct areas, though a few reappear in other countries, for example, in mountains of Mexico. No explanation has been offered for this mystery of plant migration. However, the time has been sufficiently long for accidental migration.

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PROBLEMS AND POTENTIALS IN DECIDUOUS FOREST TREE-RING STUDIES

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SUMMARY

Tree rings from several species in the deciduous forest region have been successfully dated, and show promise for dendrochronological applications. Though methods developed in the Southwest have been applied to eastern collections, modifications of techniques are needed to deal with common conditions such as arise from crowding and release. As new collections are completed for local studies in the East, it is anticipated that they will also be in demand for use in regional estimations of past climatic and hydrologic conditions.

Additional key words: Dendrochronology, dendroclimatology.

The methods and techniques of dendrochronology have been known for more than 50 years (Fritts, 1976). The world leader in developing and applying these techniques has been the Laboratory of Tree-ring Research at the University of Arizona. At about the time that Harold Fritts began his concerted efforts in dendroclimatology about 17 years ago (Fritts, 1962) the Laboratory had on hand nearly a thousand collections of tree-ring material from living trees. Each collection included two samples each from at least ten trees. Drawing heavily from these collections and by adding new collections, Fritts and his colleagues were able to put together a network of collections for western North America. By adapting and applying various multivariate techniques to the tree-ring work, they have been able to estimate or reconstruct on a seasonal basis for much of North America, past air pressure, temperature, precipitation, and an index of drought severity (Stockton and Jacoby, 1976, and Blasing and Fritts, 1976). Their significant developments in dendroclimatology have attracted considerable attention, and they are responsible for generating a great deal of new interest in tree-ring studies in general.

Traditionally, eastern botanists have considered the application of dendrochronology mainly limited to the Southwest where water is such a precious commodity. Moreover, it was not difficult to find time series of tree rings which bore resemblance to time series of rainfall for this region. At the same time the eastern deciduous forest was perhaps written off as too complex to be of much value in studies involving dendrochronology. Too many environmental factors and too many nonclimatic factors seemed to limit growth.

Owing to the success that dendrochronology has had in the West, workers have begun to reexamine the potential of dendrochronology in eastern forests. The deciduous forest appears to hold great potential for tree-ring studies. Eastern forests are influenced by many environmental factors, some climatic, some non-climatic. By careful selection dateable tree rings can be found, and the data do contain an extractable climatic signal (Cleaveland, 1975, Cook and Jacoby, 1977, Phipps and others, 1979). We now have dated collections of more than a dozen species in the deciduous forest region. Because of current interest in climate and the significant progress made by the University of Arizona, the greatest potential for dendrochronology in the East would seem to be in dendroclimatology. Those who have worked with western material to estimate climate for all of North America point out that a whole new generation of estimations will be possible when eastern collections are available for use as predictors (Fritts, personal communication, 1978). At the same time, dendrochronologists in Europe are also following the lead of Arizona's Tree-Ring Laboratory. They are interested in our deciduous forest dendroclimatology since a component of their weather comes across the North Atlantic from eastern North America. Thus we have the unique opportunity of interfacing with the work of both western North America and western Europe.

Work of the magnitude needed to reconstruct climate of eastern North America from eastern collections requires a large quantity of high quality data. More specifically, it requires a systematic network of collections which we do not have. We do not even know what species to use or what are the best collection sites. We are collecting, and we are learning, so the quality of our collections is improving. We have a long way to go.

A prime ingredient in developing precisely dated tree-ring collections in the East is a good, solid working knowledge of the techniques of dendrochronology. There are probably less than a dozen qualified dendrochronologists (some might say no more than two or three) working in the eastern deciduous forest. I know of no eastern University which offers formal training in dendrochronology, though the University of Arizona continues to produce graduates capable of teaching the subject.

The deciduous forest is typified by closed, mixed-aged stands. Generally, trees of great age do not exist as in the West, and the growth of most eastern trees is often influenced as much by neighboring trees as by climate. Thus, methods developed in the West for standardizing tree rings of ancient, open-grown trees do not always fully lend themselves to tree rings of eastern trees. Standardization is the procedure of removing the non-climatic time trend from tree-ring data, thus creating a time series of indices which retain the climatic information. Intuition tells us to proceed with methods already developed, but good sense tells us that climatic reconstructions may be limited until we develop new methods of extracting the climatic signal from eastern tree rings.

The time-honored parameter of growth utilized in dendrochronology is tree-ring width. Recent work has shown that image density data from x-ray or gamma ray radiographs contain climatic information (Parker and Meleskie, 1970). This work has suggested the potential for working with parameters of intra-annual growth variation. Evidence has been presented which indicates that x-ray analysis may be particularly helpful in studies of trees on more mesic sites (Cleaveland, 1975).

Those of us working in the deciduous forest region need to determine where to collect, what to collect, and then to get it collected, dated, measured and standardized. Once this is done we can calibrate the tree-ring data with climatic or hydrologic data, and then use the regression weights in calibration to estimate, or reconstruct, past conditions from tree rings (Fritts and others, 1971). No one laboratory can hope to develop a complete data network for all of eastern North America within a reasonable length of time. One solution is to encourage small, local forest studies. Each of these studies adds to our pool of knowledge and contributes more tree-ring data from a greater range of the deciduous forest. Once data are made available they may be utilized by any number of investigators in numerous applications. Judging from the inquiries reaching the Survey laboratory, it appears that increasing interest is being generated in the possibility of using tree rings to solve local or regional time-related problems. For example, problems encountered have included determination of the construction dates of colonial buildings (Stahle, 1978), reconstruction of past variations in lake levels, estimation of the recurrence intervals of local droughts of a certain magnitude, determination of the areal extent of a given hydrologic change that predated local records, and investigations of the influences of local air pollution on tree growth. Perhaps the traditional concept of tree-ring complexities in the East had some truth to it, but it appears that as we unravel the complexities we increase the number of kinds of information which may be gleaned from tree rings in the deciduous forest.

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HOW CLIMATOLOGISTS USE TREE RING DATA

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ABSTRACT

If some feature of climate is limiting to tree growth, then the time series of annual growth increments, or ring widths, provides an indicator of past variations in that climatic feature. Stands of old trees showing replicated, year-to-year, ring width departures from the longer-term non-climatic growth trends can thus be used to provide information about climatic conditions before conventional weather records were kept. While records of climatic conditions at a single location are interesting in themselves, it is when a number of such records from different locations are analyzed in a spatial context (map) that they become most useful to the climatologist. Year-to-year records of Palmer Drought Index, inferred from ring width chronologies at several locations throughout the western United States, have been summarized as year-to-year maps of drought conditions since 1700 (Stockton and Meko, 1975). Year-to-year variations in large-scale precipitation patterns, obtained from such summaries of tree ring data, can provide information about large-scale spatial shifts in the generalized locations of storm tracks, and thus provide information on past variations in the general circulation of the atmosphere and several related climatic variables. Such information is useful for testing hypotheses about causes of climatic change, as well as for investigating the nature and extent of climatic variations on long time scales. Frequencies of extremely cold winters in various parts of North America, or of widespread drought in the western United States, have been inferred by such methods, and the accuracy of these estimates of past climate has been documented. Some of these analyses indicate that cold winters, by 20th century standards, in the northern plains and northeast United States occurred more frequently in the 18th and 19th centuries than since 1900 (Blasing and Fritts, 1976), and that the 1930's drought in the western United States was spatially the most extensive drought in that region for at least 275 years (Stockton and Meko, 1975). The eastern United States appears to be a region of considerable, untapped, potential for dendroclimatological studies.

ACKNOWLEDGMENTS

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DATING TREE RINGS IN THE EASTERN UNITED STATES

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SUMMARY

Because tree-ring series may contain errors in the form of missing and false rings, it is important that they be dated for many applications, not merely counted. Knowledge of the wood anatomy of both gymnosperms and angiosperms is essential for the dendrochronologist working in the East. False rings can often be detected by microscopic examination of cells within rings. Missing rings can only be detected by comparing and crossdating many samples from each site, and crossdating between different sites. The best technique for crossdating eastern tree-ring series is skeleton plotting, a means of comparing patterns of relatively narrow rings and other characteristic features. Other methods of crossdating, such as correlation techniques, are discussed but are not generally suitable for use in eastern dendrochronology. Use of intra-annual features of rings, such as latewood width or maximum latewood density, may improve crossdating. Eastern tree-ring series often do not respond to climate strongly because eastern climatic regimes are generally mesic. Eastern trees often have high serial correlation in their ring width series, which makes crossdating more difficult. Sources of nonclimatic variance in eastern tree rings that may cause difficulty in dating are competition, logging, fire and air pollution. If possible, trees should be sampled at sites that are open, to reduce competition, and remote, to reduce human disturbance. There is also a good chance of finding old trees on such sites, which is important for some applications. Possible uses of absolutely dated tree rings lie in the areas of growth studies, tree growth-climate relationships, paleoclimate, archeology and ecology. A growing network of dated, well replicated chronologies in the East facilitates further dendrochronological progress.

Additional key words: Dendrochronology, dendroclimatology, crossdating.

INTRODUCTION

Dendrochronology is the science of dating tree rings and using them in various applications. Each annual ring in a dendrochronologically dated series has an assigned calendar year. Since tree rings are annual phenomena, isn't it accurate to just count rings when the date of the outer ring is known? While ring series in many trees are entirely annual in character, there are often exceptions. Because trees may have false and missing rings, counting growth layers in trees is not dating. Absolute chronological control is important in any study where environmental conditions are related to ring characteristics over a period of years. A good example is Larson's (1957) study of slash pine (*Pinus elliottii* Engelm.) latewood growth and specific gravity in dendrochronologically dated samples. Missing and false rings would have thrown off his climatic correlations, had they gone undetected.

Kilgore and Taylor's study (1979) of fire history based on fire scars is an example of questionable chronological inferences that have been made from undated tree rings. They used ring counts to derive dates for the fire scars, although it has long been known that ring counts are not adequate for accurate dating (Studhalter 1955; Fritts 1976 p. 12). Accuracy may suffer, not only from undetected false and missing rings, but from counting errors. Errors in simply counting tree rings occur frequently, particularly when rings are small and the series is long (W. R. Boggess and T. P. Harlan, Lab. of Tree-Ring Res., Tucson, Arizona, personal communication).

TREE-RING DEVELOPMENT AND GROWTH ANOMALIES

Irregularities in growth such as false and missing rings make attention to the details of cellular anatomy a matter of primary importance to dendrochronologists. A tree ring in a gymnosperm (also commonly called "coniferous" or "softwood") species typically consists of relatively large, thin-walled earlywood tracheids laid down first, followed by smaller latewood cells with thicker walls (Fig. 1). The transition from earlywood to latewood may be abrupt or gradual, depending on the species and environmental influences (Panshin and de Zeeuw 1964). The transition from one ring to the next, however, is virtually always sharp (Fig. 1).

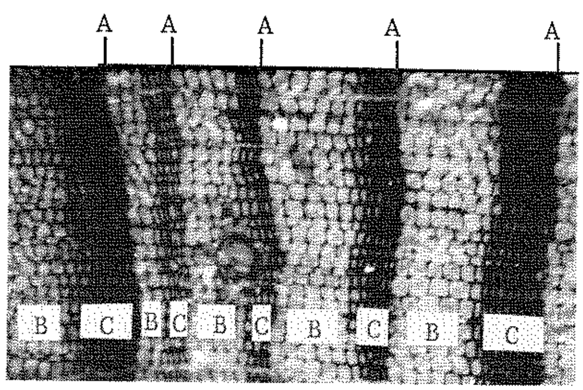

Figure 1. Photomicrograph of gymnosperm annual rings in cross-section, showing (A) interannual boundaries, (B) earlywood and (C) latewood. (Shortleaf pine (*Pinus echinata* Mill.), Clemson Forest, S.C., 38X mag.)

Rings of angiosperm (also commonly called "deciduous", "broadleaf" or "hardwood") species take several forms, but the ring porous type is of most interest to dendrochronologists. Ring porous growth increments have large earlywood vessels, followed by much smaller latewood pores (Fig. 2)(Panshin and de Zeeuw 1964).

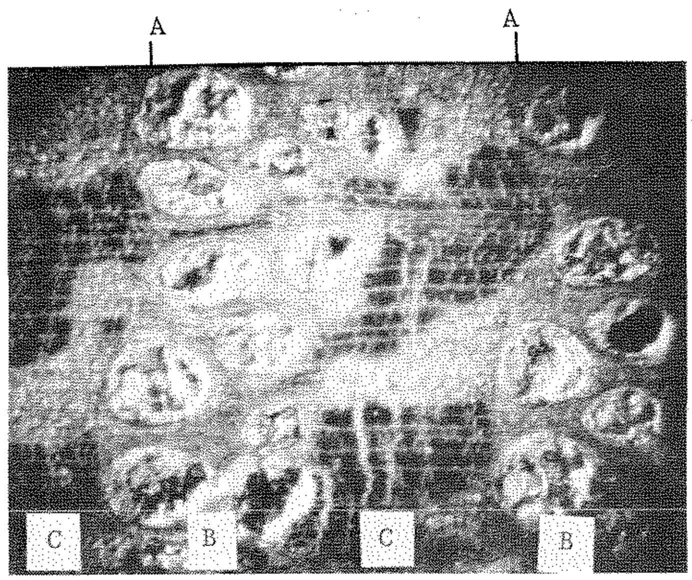

Figure 2. Photomicrograph of angiosperm annual ring cross-section, showing (A) interannual boundaries, (B) earlywood vessel zone and (C) latewood pore zone. (White oak (Quercus alba L.), Steiner's Woods, Tenn., 20X mag.)

FALSE RINGS

Moisture stress causes changes in cell size and wall thickness in gymnosperms (Zahner 1968 pp. 208-220; Fritts 1976 pp. 96-103). If growth fluctuates markedly during the growing season, perhaps due to drought followed by abundant precipitation, a false ring may be formed. Under these conditions, a temporary transition may be made to latewood cell formation. False rings usually have anatomical differences from true rings. For example, a false ring in earlywood will usually have a diffuse termination that differs from a true interannual boundary (Fig. 3).

False ring formation varies greatly in frequency from species to species. Gymnosperms are much more likely to have false rings than angiosperms. However, Huber and Giertz (1970) and Baillie (1973 pp. 26-29) reported false rings found in oak samples from Switzerland and Ireland, respectively. False rings have been found in some North

American white oaks (Fig. 4).

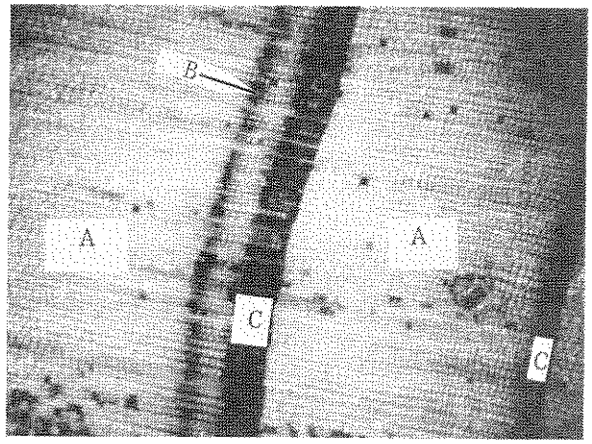

Figure 3. Photomicrograph of gymnosperm annual ring cross-section, showing (A) earlywood, (B) false ring and (C) latewood. (Ponderosa pine (Pinus ponderosa Laws.), Ditch Canyon, N.M., 18X mag.)

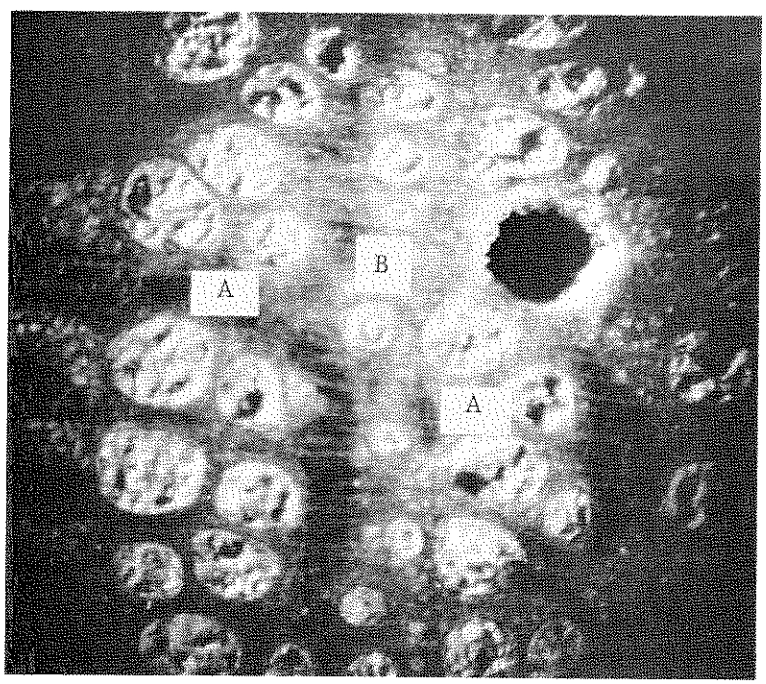

Figure 4. Photomicrograph of angiosperm annual ring cross-section, showing (A) earlywood vessel zone and (B) an extra row of vessels in the latewood pore zone. (White oak, Steiner's Woods, Tenn., 20X mag.)

MISSING RINGS

The cells that make up gymnosperm annual rings are produced by division of cambial mother cells between the xylem and phloem zones (Bannan 1962). If a tree is severely stressed by drought, competition or other limiting factors, large areas of the cambium may not produce xylem cells at all. If the tree is sampled at these places, there will be no ring for that year in the sample. The year is missing from that time series. Such rings may be missing from more than 99.9% of the cylinder of a tree's annual growth increment at all levels (Schulman and Baldwin 1939). Figure 5 is an example of a narrow ring "pinching out", or merging into an adjacent ring. If these two rings were merged everywhere on the sampled radius, a ring would be missing from the time series.

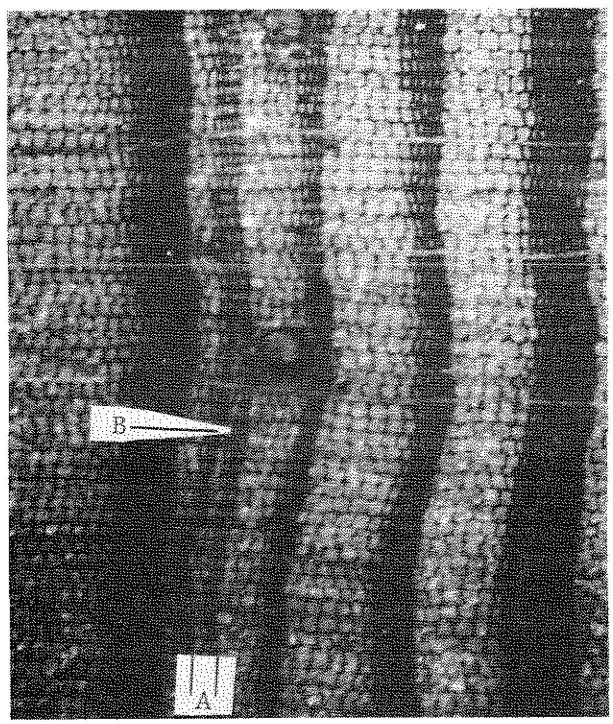

Figure 5. Photomicrograph of gymnosperm cross-section, showing (A) ring that merges into the ring from the previous year at (B). (Shortleaf pine, Clemson Forest, S.C., 38X mag.)

In oak that has grown extremely slowly annual rings may merge into each other, but missing rings seem to be quite rare under ordinary conditions. However, a missing ring has been reported (Morgan 1979) in an otherwise clearly defined oak ring series. Experience with other genera of angiosperms is lacking because Quercus has been used by dendrochronologists to the almost complete exclusion of other genera.

DATING TREE-RING SERIES

There is one fundamental method of deriving accurate relative or calendrical dates for tree rings. This method is called crossdating, and it relies on comparison of many samples from multiple collection sites to detect false and missing rings in individual samples (Stokes and Smiley 1968 pp. 11-18; Ferguson 1970; Dean 1978).

CROSSDATING BY SKELETON PLOTTING

The simplest method for comparing samples is skeleton plotting. The cross-section, or transverse surface (exposed by a horizontal cut through the upright bole of a tree), of a section or an increment core is prepared by cutting or sanding until anatomical detail is clear in microscopic examination. Then each ring is examined carefully and those rings that are narrow relative to their neighbors (perhaps four or five rings on each side) are plotted as lines on a piece of graph paper. The narrower the ring, the longer the line. While the narrow rings are of greatest importance, very large or anatomically unusual rings should be noted on skeleton plots (Stokes and Smiley 1968 pp. 47-55; Ferguson 1970).

Skeleton plots of radii from the same tree should be compared. If a ring is missing at one point on a tree's circumference, it may be present elsewhere. Similarly, false rings are often not uniform all the way around a tree. If two radii of a tree are in disagreement, the interval in which they stop matching should be determined (Fig. 6) and re-examined carefully. A ring might be very small instead of completely missing, and have been overlooked the first time. If the discrepancy in crossdating is caused by a false ring, it can often be detected by anatomical clues.

Skeleton plots of tree radii that crossdate should be combined into a composite plot with only those relatively narrow rings that agree between radii included. The composite plots are compared to resolve any problems and combined into a site composite, or chronology. The site chronology should be compared with other tree-ring chronologies from the area (Fig. 6)(Stokes and Smiley 1968).

A wide variety of sites should be sampled. Sites that provide freedom from severe competition and a good supply of what the trees growing on it need, mainly root and canopy space, nutrients and soil moisture, will have few, if any, missing rings. Unfortunately, there may be so little climatically caused variation in trees on such sites that they may be impossible to date. If such series are datable at all, they provide a good check for missing rings that may occur at sites that cause more stress in trees. Stressful sites yield chronologies that are valuable for applications such as reconstructing past climate.

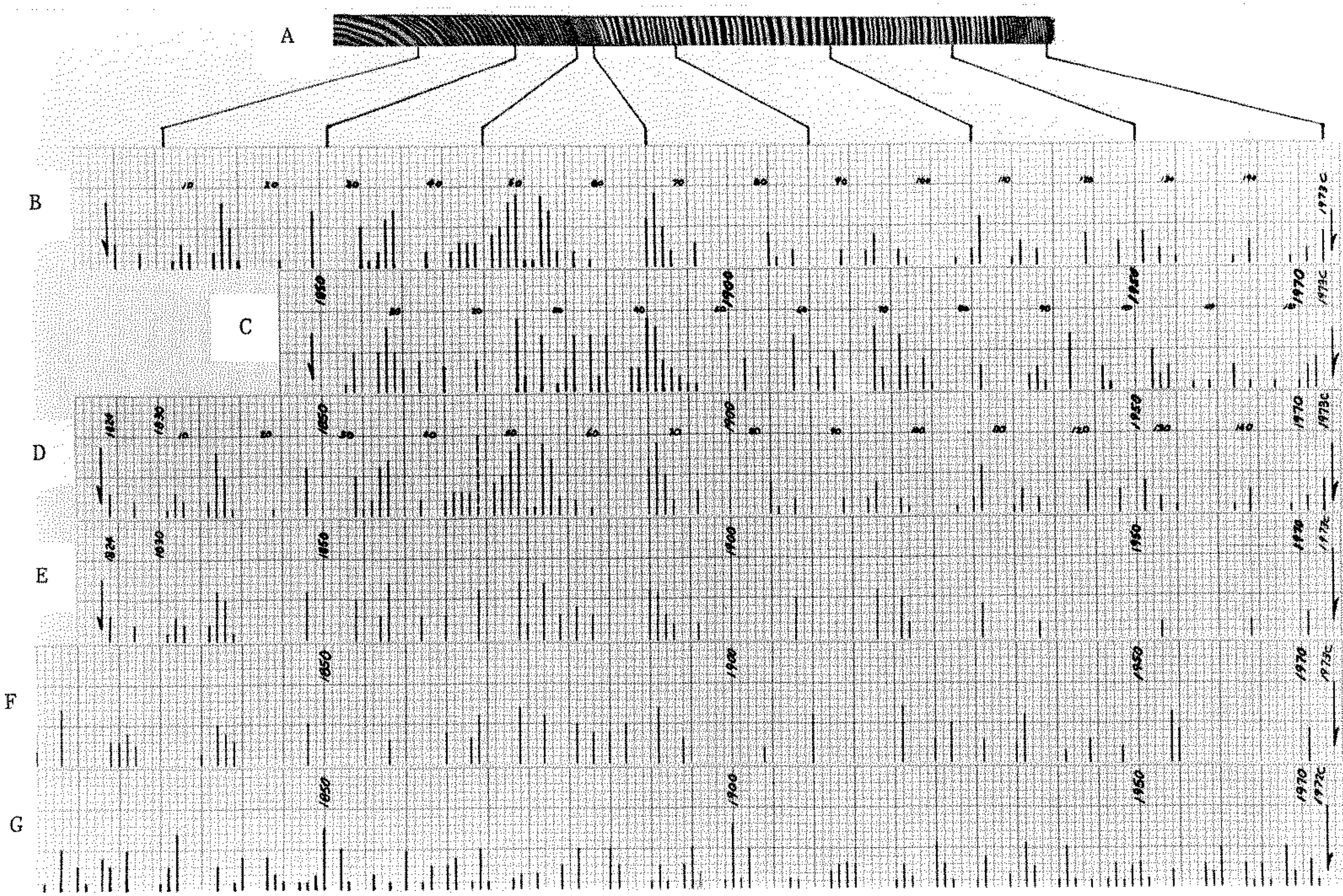

Figure 6. Crossdating by skeleton plot. (Items A through E from Tree 24, Clemson Forest, S.C. chronology.) (A) radius 1, (B) undated skeleton plot, radius 1, (C) skeleton plot, radius 2, (D) revised skeleton plot, radius 1, with missing ring inserted for 1869 based on crossdating and anatomical evidence, (E) composite of radii 1 and 2, (F) composite of all trees and (G) composite of other chronology.

OTHER TECHNIQUES OF CROSSDATING

In my opinion, skeleton plotting is the best technique for crossdating eastern tree ring series. However, there are other ways of approaching the problem. For example, undated ring series can be measured, plotted and compared visually. This method will work only with series that are quite strongly influenced by climate, which frequently is not the case with eastern trees.

In cases where two tree-ring series are known to be free of error, that is, false or missing rings, it may be possible to crossdate them by the statistical relationship between them as measured by the correlation coefficient (Steel and Torrie 1960 pp. 183-191). An example of statistical crossdating is the derivation of a calendrical framework for the Casas Grandes ruins tree-ring chronology in Mexico. Scott (1966) derived dates for this archeological tree-ring chronology by comparing it to eight chronologies in the southwestern United States and one in Mexico. All ten chronologies were carefully worked out and composed of averaged indices from many overlapping crossdated samples. However, the Casas Grandes chronology was compiled from archeological materials not tied to a calendar date. This is called a "floating" chronology (Ferguson 1970; Dean 1978). The distance between the sites was so great that the common influence of climate was too weak to allow crossdating with the Casas Grandes chronology by visual comparison. In each case correlation coefficients varied randomly about 0.0 except for one relative position. At that point, the Casas Grandes floating chronology became significantly correlated with the others, establishing its calendrical dating (Scott 1966).

European oak ring width series are often crossdated by statistical comparison with error-free, replicated chronologies. One laboratory uses a computer program to find the overlap that gives the highest correlation between two series (Baillie and Pilcher 1973). The oak trees for which this technique is used grow in a climatic regime so mild that the investigators have never found any rings missing in their samples. This technique is definitely not appropriate for North American gymnosperms.

The use of correlation as a measure of crossdating can be deceptive. LaMarche (1974) reported on two tree-ring index chronologies that crossdated well on the basis of coincidence of narrow rings in skeleton plots, but had a correlation coefficient of -0.10 over 150 years. The two chronologies were quite close geographically and of the same species, but one was from the treeline and the other was from the lower elevation forest border. The chronologies crossdated well, but were negatively correlated because the two groups of trees responded differently to climate. Both groups were affected in the same way by precipitation, but temperature variation evoked opposite responses.

RING CHARACTERISTICS OTHER THAN TOTAL WIDTH USED IN DATING

Crossdating is not limited to use of the relative width of annual rings. Schulman (1942) found the width of the latewood, or the ratio of latewood width in one year to the earlywood in the next, to be superior to annual ring width for crossdating shortleaf pine in Arkansas. Statistical analysis of the same species earlywood, latewood and total ring width chronologies in South Carolina shows considerably more climatically related variance in latewood than in earlywood (Cleaveland 1975 pp. 36, 81, 82).

Anatomical abnormalities can be used to establish dates. Frost rings are one example of this means of dating. When a severe frost occurs during the growing season, active cells next to the cambium are disrupted, giving those rings a distinctive appearance (LaMarche 1970). Morrow and LaMarche (1978) used frost rings to date trees that may not clearly show climatic influence in the size of their annual rings.

Fletcher (1975) and Tapper (1977) reported crossdatable anatomical anomalies in English and Continental Low Countries oaks from the 13th, 14th, 15th and 16th centuries. In a few years during this period the earlywood vessels of many samples were greatly reduced in size. In the Tennessee area latewood for 1774 is almost completely missing in many oaks (Fig. 7).

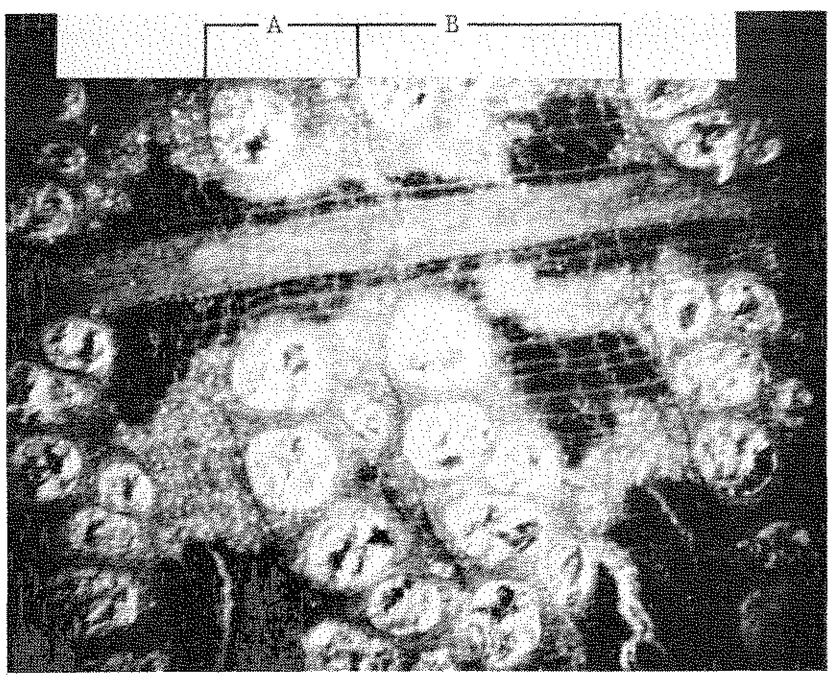

Figure 7. Photomicrograph of oak cross-section, showing (A) 1774 ring with greatly reduced latewood pore zone and (B) 1775 normal ring. (White oak, Steiner's Woods, Tenn., 20X mag.)

Perhaps the most promising among alternative crossdating characteristics is intra-annual density variation. Schweingruber et al. (1978) found maximum latewood density to be far superior to minimum earlywood density or to earlywood, latewood or total ring width for dating Norway spruce (Picea abies (L.) Karst.), silver fir (Abies alba Mill.), stone pine (Pinus cembra L.), Scotch pine (Pinus sylvestris L.) and European larch (Larix decidua Mill.). Maximum density was an especially good crossdating measure among chronologies compiled from different species (Schweingruber et al. 1978).

Parker and Henoch (1971) reported excellent crossdating of maximum latewood density data in Engelmann spruce (Picea engelmannii Parry) growing in Canada. Density maxima were reported by Conkey (1979) to crossdate well, much better than ring widths in red spruce (Picea rubens Sarg.) in Maine. Intra-annual density measurements will be an extremely useful crossdating tool in the East.

DIFFICULTIES IN DATING EASTERN TREE-RING SERIES

There are many reasons why patterns of narrow rings cannot be expected to match perfectly (Fig. 6). Trees are biological individuals and as such will display somewhat different growth responses to the same climatic stimuli. Growth response is even different from radius to radius in the same tree. Trees change their response to climate somewhat as they age (Fritts 1976 pp. 107-113). For example, ponderosa pine is more likely to form false rings when young and growing most vigorously.

Growth rings of eastern trees may not crossdate well in some cases because they are influenced by high serial correlation of biological origin (DeWitt and Ames 1978). This statistic is merely a measure of the likelihood of persistence of high or low growth from one year to the next. If serial correlation is high, response to climate will be delayed and modified. For example, if a year of high growth is followed by a year of moderate drought, food reserves in the tree and excess soil moisture from the first year may create another large ring. In general, the more sensitivity to climate trees exhibit in annual variation, the lower the serial correlation in the ring series (Fritts 1976 pp. 300-301).

It is difficult to find eastern trees that exhibit the superb crossdating found so commonly in southwestern trees. This is due in large part to climatic differences between the two regions. Satterlund (1972 p. 12) shows a water surplus (precipitation minus potential evaporation) of 10 to 40 inches over most of the eastern United States, but a net deficit in the Southwest. For this reason, soil moisture is far less likely to be limiting to growth in the East than in the Southwest.

In the East it is difficult to find trees suitable for dendrochronology that do not show the effects of natural and human influences that may interfere with dating. Some natural sources of growth disturbance are competition, insect attack and natural fires. When possible, dendrochronological sampling must be done in open, competition-free stands. Sites that support such stands will often have infertile, shallow soils with good drainage. Fortunately, these are just the site conditions that create moisture stress in trees, resulting in sensitivity to climatic variation and better crossdating.

Human sources of interference with tree growth include air pollution (Richards, Taylor and Edmunds 1968), grazing (Dunwiddie 1977), logging (Cleaveland 1975) and man caused fires. When possible, collecting sites should be remote from population centers. Sites located in rough terrain far from roads, where it is difficult for people to gain access or for loggers to remove felled timber, may be free of human disturbance.

It is often difficult to find very old trees in the eastern United States. This is a problem that is separate from the general problems of dating eastern tree rings, but important to many applications of dendrochronology. Fortunately, old trees are most frequently found on the stress sites described above that support trees with the most datable series.

PROGRESS IN EASTERN DENDROCHRONOLOGY

The key to dendrochronological progress in the East is the creation of a network of long, accurately dated chronologies of many species. Where possible, maximum density values as well as earlywood, latewood and total ring widths ought to be available from each site to make dating easier. When this network becomes a reality, it will be a simple matter to crossdate sensitive material and check the dating for errors. High quality dating control in the form of replicated ring width chronology indices (and in one case, replicated earlywood and latewood width indices as well) is now available for some areas (Fig. 8) (DeWitt and Ames 1978), but much work remains to be done. A growing number of investigators are now working in this field in the East, so progress should be rapid.

CONCLUDING REMARKS

As interest increases in climate and its impact on human affairs (The National Climatic Program Act Hearings 1976; Cooper et al. 1974; Lamb 1976), the search for means to investigate past climatic conditions in the absence of instrumental observations has intensified. Accurately dated tree rings are the best means of doing this over a period of several hundred years. Dendrochronology also gives us a way of investigating such diverse phenomena as archeological chronology (Dean 1978), wood quality-environmental relationships (Larson 1957; Parker et al. 1976), past levels of air pollution (Nash, Fritts and Stokes 1975) and other aspects of ecology and climate. The eastern

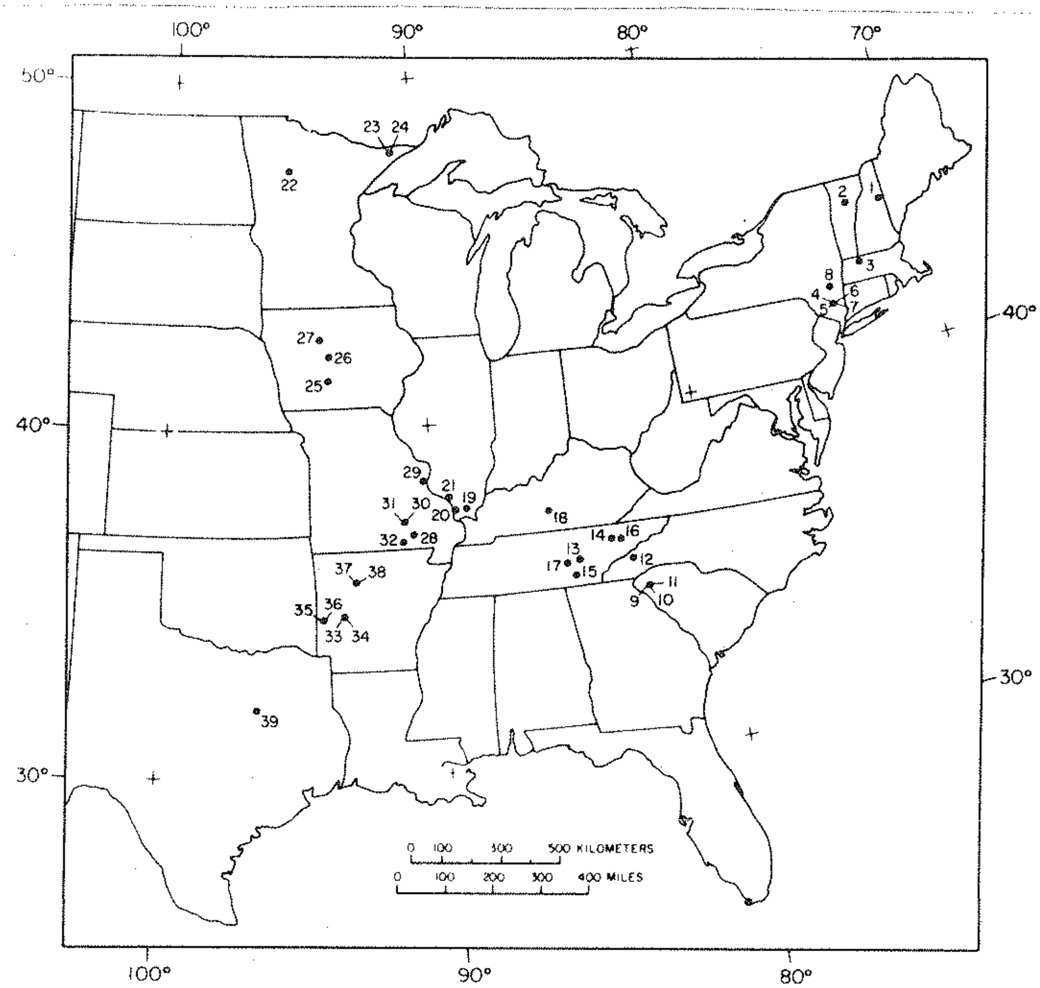

Figure 8. Locations of 39 tree-ring index chronologies published in DeWitt and Ames (1978). Map reproduced from DeWitt and Ames (1978) by permission.

United States has been a region of great unexploited potential for this type of study. To achieve this potential in the East, a network of chronologies will have to be created. Even with such dating control, crossdating will sometimes be more difficult in the East than in the Southwest. Eastern dendrochronologists do have the advantage of having a greater choice of species than their western counterparts, and the trees are less likely to have missing rings than western trees.

ACKNOWLEDGMENTS

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X-RAY DENSITOMETRY IN TREE-RING STUDIES

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X-ray densitometry as applied to tree-ring research is the determination of wood density and its variation in individual tree-rings by measuring the absorption of "soft" or long-wave x-rays as they pass through thin sections of wood. Wood density varies depending on the anatomy of different species and it also varies within a single species. The density varies throughout individual annual growth increments (rings) and varies from year to year in the growth increments depending on environmental factors influencing tree growth. Wood density is influenced by cell size, shape, lumen diameter, degree of lignification and other factors. Although the above is true for both angiosperms and gymnosperms the latter are of primary use in densitometric analyses. For the purpose of dendrochronology and dendroclimatology the variations in wood density can be analysed in conjunction with measured climatic parameters to determine cause and effect relationships between the climatic factors and the wood density. In dendroclimatic research these relationships can then be used to reconstruct past climates based on the density parameters determined from old trees that were growing prior to the recording of meteorological information. The calibration and reconstruction procedures are similar to those used in dendroclimatology based on ring-width analyses and those procedures are described in Fritts (1976).

For forestry studies in general, more knowledge of the causal relationships between environmental parameters and wood density could aid greater understanding of tree growth.

The use of x-ray densitometry in tree-ring research was pioneered by Polge and Lenz in Europe beginning in the 1960's. A review of the history of x-ray densitometry is contained in Parker and Kennedy, (1973). A review of the development of the technique and some potential new applications is in Polge, (1978). A recent comprehensive article on x-ray densitometry is in Schweingruber _et al_. (1978).

For dendroclimatology the use of x-ray densitometry provides the scientist with much more information about variations in tree growth than the single measurement of annual ring width that has been primarily used very successfully to date (Fritts, 1976). In addition to ring width, densitometric studies provide the researcher with quantitative measurement of earlywood width, earlywood density, minimum density, latewood width, latewood density, and maximum density. One can also study various combinations and permutations of these parameters, thus creating an extensive suite of measurements that greatly increase the amount of information about the individual annual growth increments.

In the x-ray analysis of wood specimens one could use direct measurement of x-ray absorption through wood. However, the best published results to date are from researchers using a film medium rather than direct reading of the x-ray absorption. This general procedure entails passing the x-rays through the wood specimen to make an x-ray film negative of the specimen. The x-rays must be parallel to the cell walls in order to produce clear definition of the wood structure. This parallelism can be achieved by either placing the x-ray source some distance away from the specimen, e.g., 2.5 m (Schweingruber et al., 1978) or by using an in-motion procedure wherein the x-ray source or the specimen moves to expose the film to a narrow beam of collimated x-rays perpendicular to the specimen and film (Parker and Jozsa, 1973). The x-ray negative is developed and then used in a densitometer to measure the amount of light passing through the film as influenced by the light and dark shadings. Thus the actual measured parameter is film density rather than wood density. With adjustments for non-linearity and other factors the film density can be used to accurately and quantitatively determine wood density variations (Schweingruber, et al., 1978). Most systems operational today determine a density value for each one hundredth of a millimeter (0.01 mm) along a radius of the tree.

The x-ray densitometric system at the Tree-Ring Laboratory of Lamont-Doherty Geological Observatory (L-DGO) uses an in-motion technique to make the x-ray negatives. The translation device is a carriage moved by a lead-screw rotated by a stepping motor (Figure 1). The pulses of the stepping motor are electronically controlled to precisely govern the speed of the in-motion photograph (Jacoby and Perry, 1979). The x-ray film is then developed using standard development techniques with a nitrogen-burst agitation to produce uniform film quality. A similar lead-screw and stepper-motor translation device is used to move the film between the light source and the photodiode in the densitometer (Figure 2). The output from the densitometer is directly read and recorded by a microcomputer. There is a monitor screen so that the operator of the densitometer can visually review the x-ray negative as it is passing through the densitometer to look for any abberations in wood anatomy that might produce spurious measurements. The computer also records and controls the stepping rate of the motor. Thus, the steps are recorded (which represent distance along the core) and the density value for each one hundreth of a millimeter. Because the volume of data is enormous a computerized system is essential in this type of analysis. A block diagram of the system at L-DGO is shown in Figure 3.

Figure 1. In-Motion X-Ray System

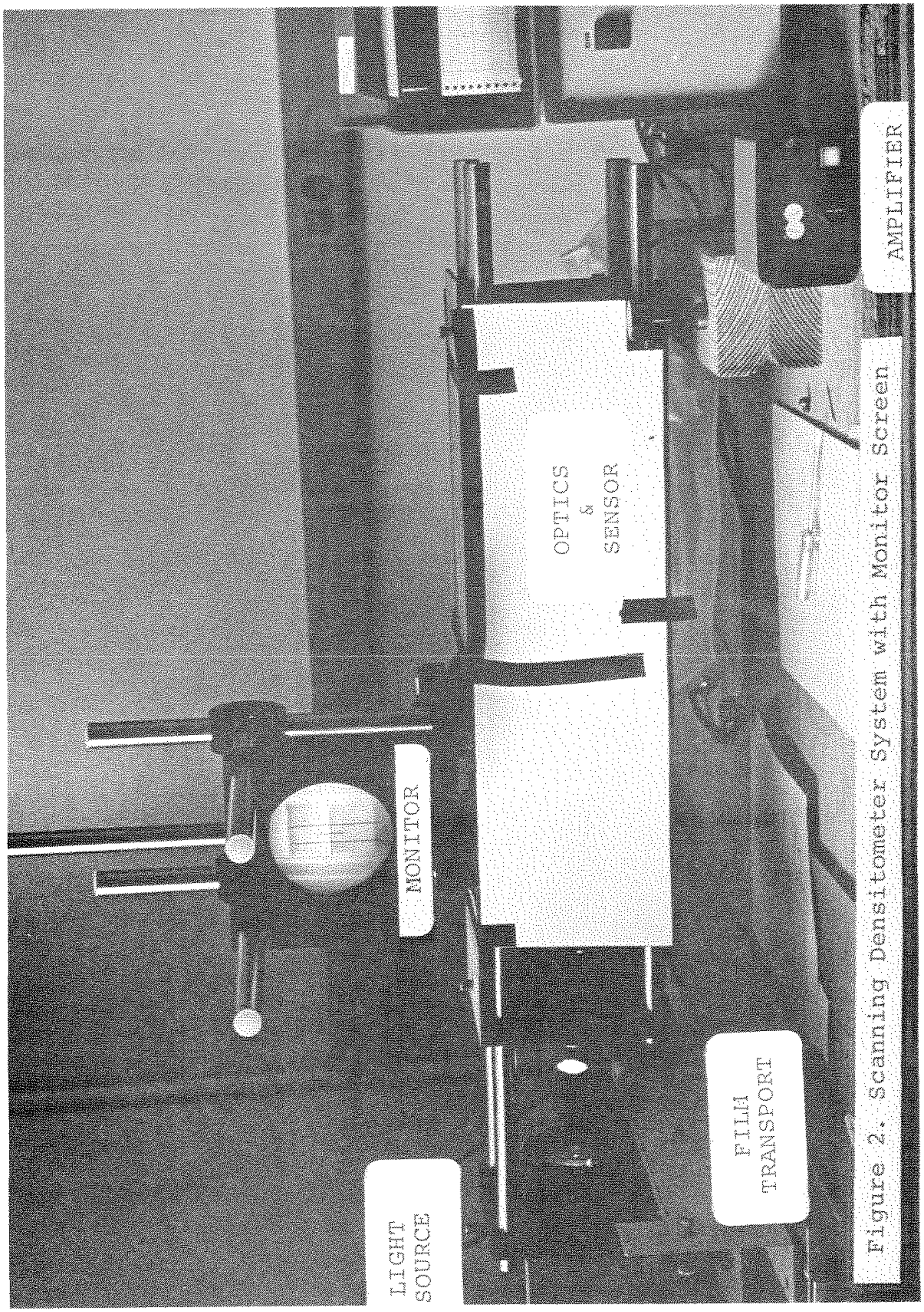

Figure 2. Scanning Densitometer System with Monitor Screen

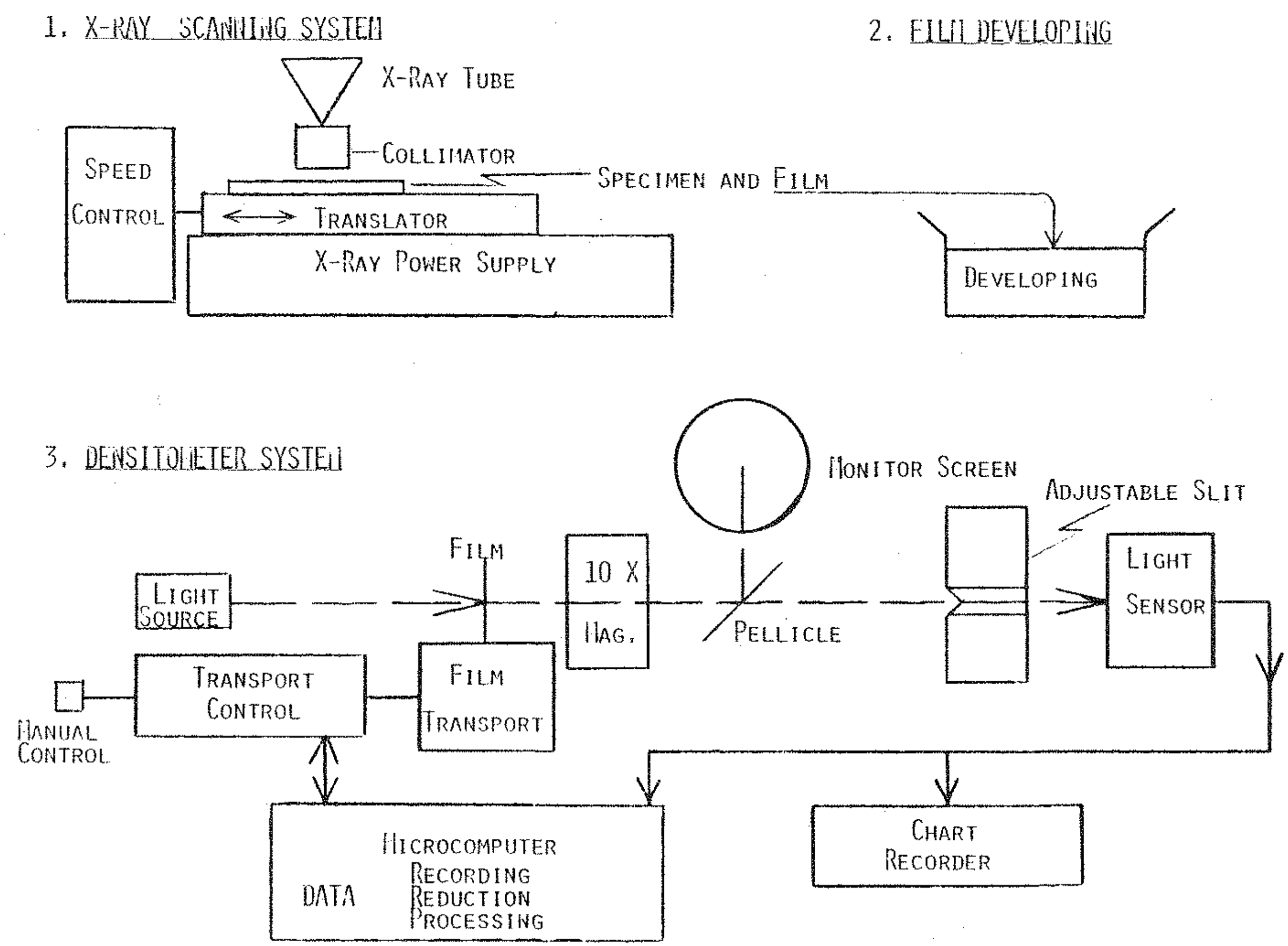

Figure 3. Block Diagram of X-Ray and Densitometer System.

Our computerized densitometer system has only recently come on line and our first study involves only a few cores from Mount Washington, New Hampshire. Polge, (1970); Parker and Henoch, (1971) and Schweingruber _et al._(1978) have all shown that density variations are more sensitive to climatic variations than ring width. We concur. For red spruce (_Picea rubens_ Sarg.) from the Mount Washington site, earlywood density appears to be greater with higher June temperatures and greater precipitation in winter and spring. Latewood density appears to be greater with higher summer temperatures. These results are tentative; however, they agree in general with the results of other densitometric studies.

Densitometric data has another attribute that enhances their value. The time series developed from ring-width data have to be standardized to remove growth trends that are not climatically influenced (Fritts, 1976). The standardization methods remove some of the climatic signal, expecially in the lower frequencies. Density data produces a climatically sensitive time series that does not require the types of standardization used in ring-width analyses.

A chart recorder plot of a densitometer run is shown in Figure 4. This plot clearly indicates the density variations within each year and from year to year in this red spruce sample. The computer system records density parameters in real time as the x-ray negative is scanned. As in standard dendroclimatic studies, many core specimens must be processed and the final chronology or time series is a mean value function based on an adequate number of samples to produce a reliable data set.

Densitometry may also prove to be especially useful in dendroclimatology in the eastern United States where the signal to noise ratio of climatic effect on ring width is less than in the western U.S.

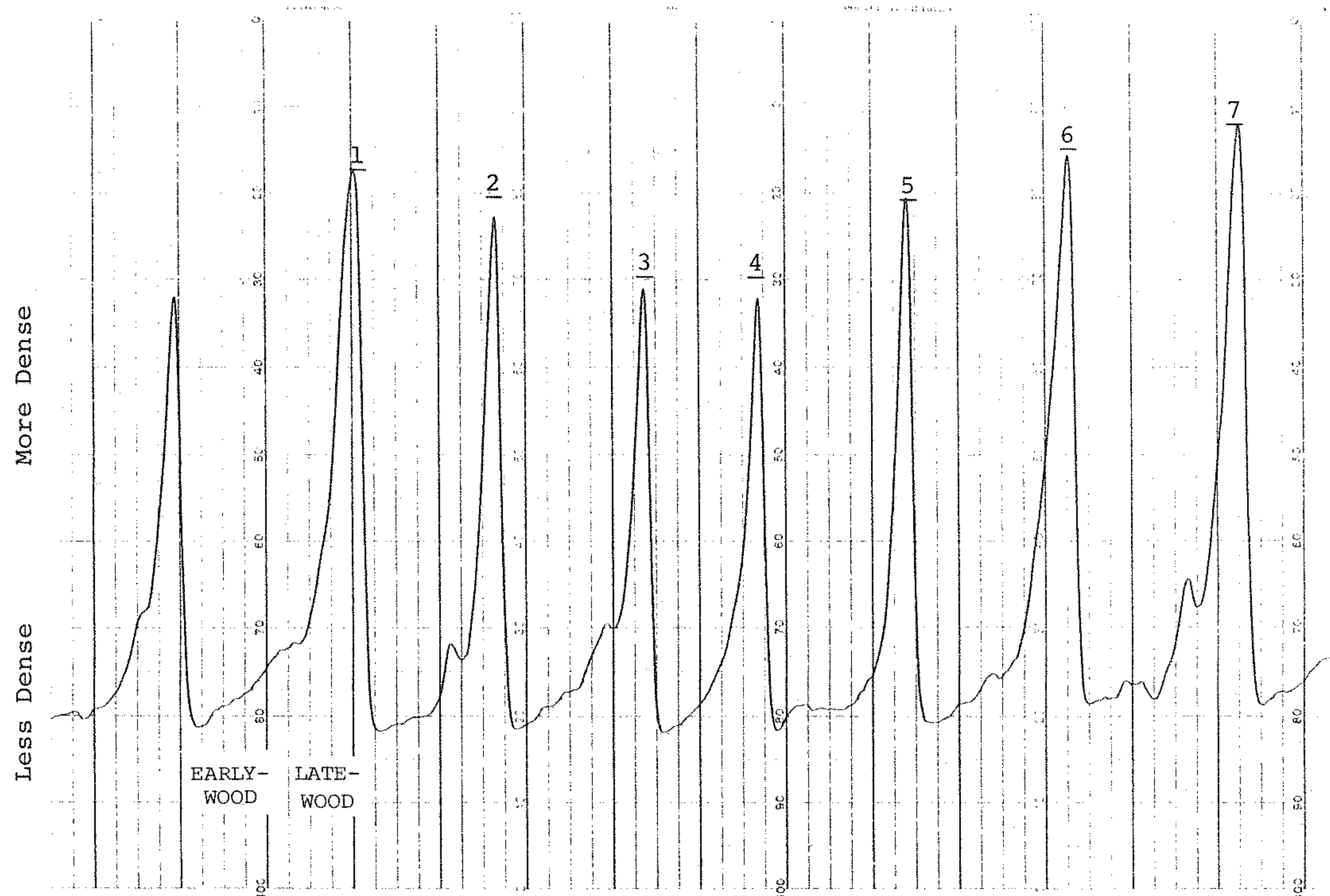

Figure 4. Chart Recorder Output from Scanning Densitometer; 7 complete rings.

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A DENDROCHRONOLOGICAL STUDY OF DROUGHT IN THE HUDSON VALLEY, NEW YORK

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SUMMARY

The annual ring-width variations in trees can be used to reconstruct past climate. On certain sites in the Eastern Deciduous Forest Biome, older trees are often limited in growth by the availability of soil moisture. The "drought sensitive" character of these trees can be exploited to derive a long drought reconstruction for a particular region. This has been done for the Hudson Valley, New York, back to 1694. The reconstruction indicates that spring-summer climatic variability has been below average in the 20th century along with the occurrence of moderate-to-extreme drought. There is also evidence for a quasi-periodic recurrence of wetness and dryness in the reconstruction, but the climatological implications of this phenomenon are extremely uncertain.

INTRODUCTION

During the 1960's, the northeastern United States experienced a drought of extreme severity that seriously depleted municipal water supplies in major population centers such as New York City and Washington. For much of that time, the center of drought severity was located in the Hudson Valley region of New York. By the end of July 1965, the extensive New York City water reservoir system had been depleted to only 45% of capacity compared to a normal 80% for that time of year (Andrews, 1965). Heavy rains in September 1966 broke the drought, and generally adequate precipitation since then has caused this episode to be virtually forgotten, leaving important questions about drought variability unanswered. For example, what is the probability that a drought of similar magnitude will occur in the future? Can we make reasonable statements about expectations of drought variablility in the Hudson Valley based upon the last 80 to 100 years of meteorological data? And, what are the long-term characteristics of drought and how should they be related to expectations of wetness and dryness in the Hudson Valley region?

Long-term characteristics of climatic variability are often poorly understood because of the shortness of the available meteorological and hydrological data series. This problem has become even more apparent with the growing realization that the climate of the 20th century has been highly anomalous compared to the previous several centuries and that we may now be returning to climatic fluctuations seen more commonly prior to 1900 (Lamb, 1966; Wahl, 1968; Wahl and Lawson, 1970; Lamb, 1978; Fritts et al. 1979). Thus, any estimates of parameters of regional and global climatic variability, such as means, variances, and recurrence probabilities, are likely to be biased when the data base is primarily of 20th century origin. The annual radial growth increments of trees offer a means of quantitatively extending the climatic data base back several hundred to several thousand years (Fritts, 1976; LaMarche, 1978).

Although most of the eastern deciduous forest biome has been cleared at one time or another, scattered remnant stands of centuries-old timber still exist. The climatic information that can be derived from the ring-width variations of these old trees is a unique and extremely valuable resource that is useful in studying and understanding past climate and the causes of climatic change.

A DROUGHT RECONSTRUCTION FROM TREE - RINGS

Recently, Cook and Jacoby (1977) investigated the feasibility of quantitatively reconstructing July drought in the Hudson Valley (fig. 1), using the annual tree-ring series of moisture sensitive trees growing in that region. The measure of drought was the Palmer Drought Severity Index (PDSI) (Palmer, 1965a). Although it is called a drought index, a series of PDSI's reflect both soil moisture deficits and surpluses. Thus, PDSI's are time series of relative wetness and dryness. Cook and Jacoby (1977) found that July PDSI's could be reliably reconstructed from tree-rings, and they produced a July PDSI reconstruction back to 1730. Since that time, additional tree-ring chronologies have been developed from the Hudson Valley, and they have been used to produce a new PDSI series that spans the years 1694-1972 (Cook and Jacoby, in press). This 279-year sequence is shown in fig. 2. The top figure shows the actual tree-ring estimates and the bottom one shows the same series after low-pass filtering to emphasize frequencies of once-in-ten-years or less.

A scrutiny of the unsmoothed series in fig. 2 reveals that in terms of both intensity and duration, the 1960's drought has never been exceeded since 1694. This finding

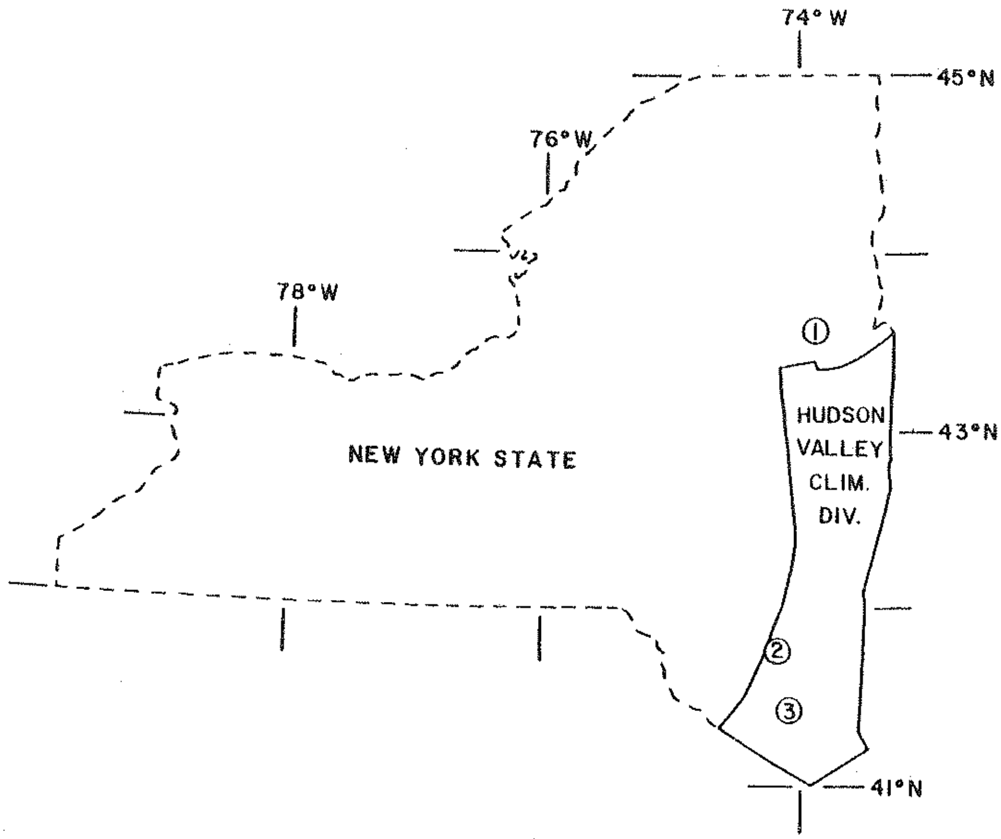

Figure 1. The Hudson Valley Climatic Division of New York State. The circled numbers refer to the locations of the tree-ring sites used in reconstructing past drought for the division.

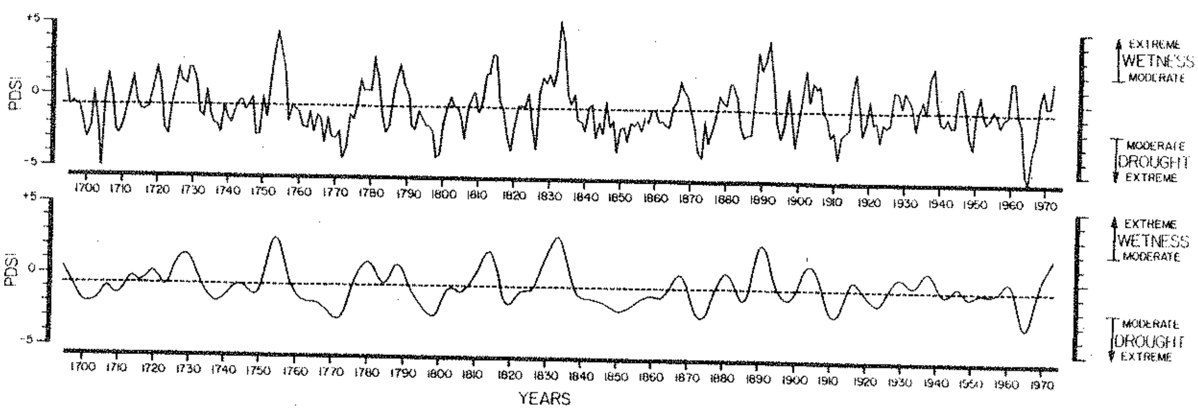

Figure 2. Reconstruction of July PDSI in the Hudson Valley Climatic Division based on tree-ring analysis. The lower curve has been processed through a low-pass filter to empasize frequencies of once-in-ten years or less.

supports Palmer's (1965b) more intuitive comment that the drought was of such rare intensity that "we should ordinarily expect it to occur in this region only about once in a couple of centuries". Although this is good news for water sources planners, the reconstruction also indicates that anomalies of wet and dry intervals tended to be more persistent in the past although the dry anomalies were less severe than the 1960's drought. This tendency is especially evident prior to 1900. Such an increase in the persistence of wet and dry anomalies could have a significant impact on reservoir design and the ability of current reservoir systems to meet demands during longer periods of below-average precipitation.

Another way of analyzing the PDSI reconstruction is to investigate the frequency of occurrence of different classes of PDSI variability. Two classes will be investigated here: moderate-to-extreme drought (PDSI< -2.0) and moderate-to-extreme wetness (PDSI> +2.0). These classes are the most significant ones to consider since large departures from the norm have the most impact on people and systems.

Fig. 3 shows the frequency histograms of the PDSI series for its entire length (3A), the 18th century (3B), the 19th century (3C), and the 20th century (3D). The histogram of the Mohonk Lake, New York PDSI data (3E) for the 20th century is included to illustrate a bias in the reconstruction. By comparing the histograms of the actual and reconstructed series (D and E), we see that the tree-ring estimates underestimate the frequency of moderate-to-extreme wetness by about 10%. This bias was not surprising since above-average radial growth rates are not so strongly influenced by increases in soil moisture as below-average radial growth is limited by decreases in soil moisture. The frequency of moderate-to-extreme drought in the tree-ring estimates is very similar to the actual data, 16% and 18% respectively. Thus the reconstruction is a more reliable indicator of dryness than wetness.

The histograms indicate that the frequency of moderate-to-extreme drought was 27% in the 18th century, 20% in the 19th century, and only 16% thus far in the 20th century. The long-term average from 1694 to 1972 is 22%. These percentages suggest that the frequency of moderate-to-extreme drought has been below average in the 20th century in spite of the serious 1960's event.

The histograms also indicate that the frequency of moderate-to-extreme wetness was somewhat higher in the past. The previously noted bias indicates that the corrected frequencies should be as follows: 15% for the 18th century, 18% for the 19th century, and 13% for the 20th century. The

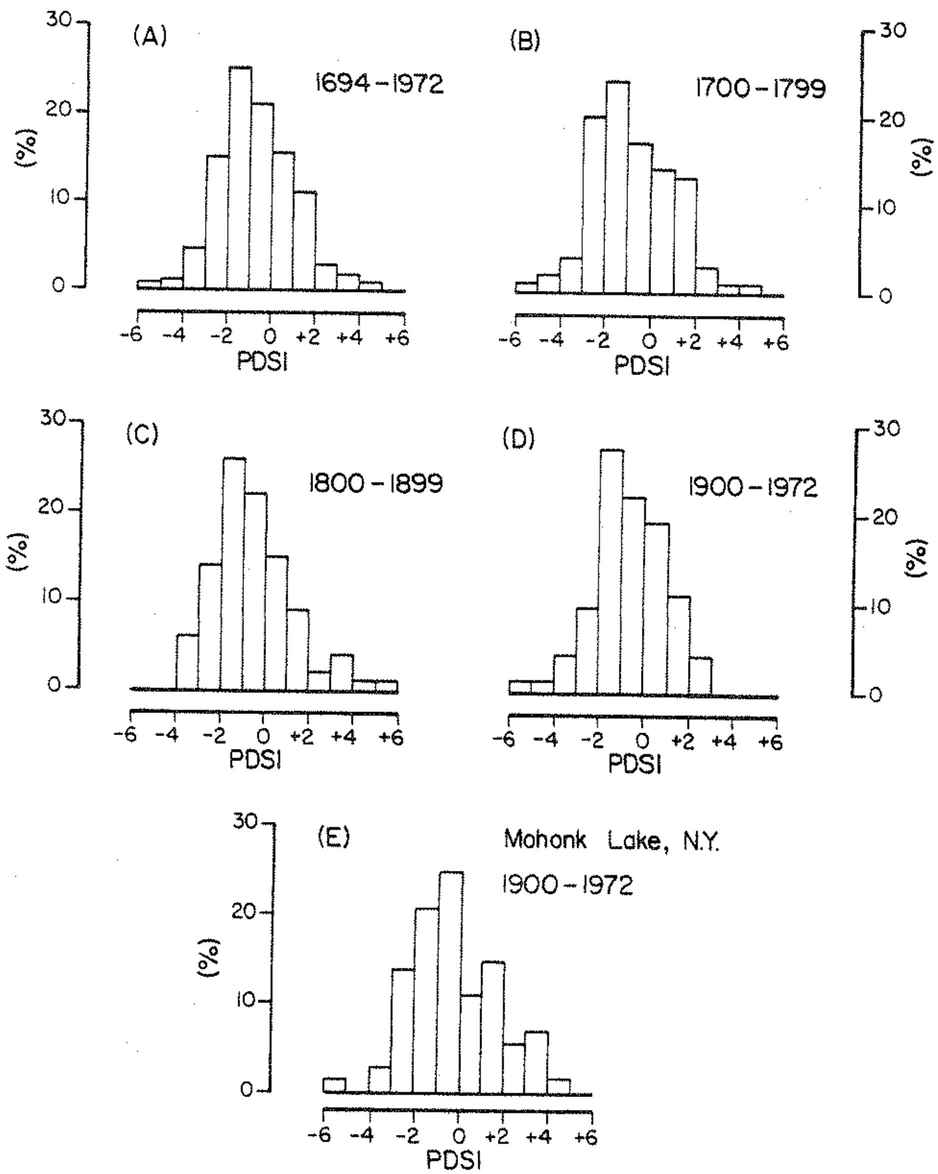

Figure 3. Frequency histograms of July PDSI for the entire reconstruction (A), the 18th century (B), the 19th century (C), the 20th century (D), and for the Mohonk Lake meteorological station in the Hudson Valley (E).

1694-1972 frequency is 16%. Again, the 20th century has a below average frequency of wet anomalies.

The below average frequency of both dryer-and wetter-than-average years in the 20th century implies that spring-summer climatic variability in the Hudson Valley has been anomalously low. If we compare the variance of the 1694-1972 period to that of the 1900-1972 period, July drought in the latter period has been 16% less variable. This lower variability is particularly evident during the one-time 1931-1960 "climatic normal" where the variance is 48% below that of the total period! That "climatic normal" was one of the most abnormal periods in the past 279 years.

Another way to examine the drought reconstruction is through spectral analysis. This statistical technique measures the way in which the variance in the time series is distributed as a function of frequency in cycles per sampling interval (one year in our case). Statistically significant peaks of variance in the spectrum near these events in the series tend to recurr at fairly constant time intervals, i.e. the series has a wave-like character to it.

Fig. 4 shows the variance spectrum of the PDSI series shown in fig. 2. We can see that the spectrum exhibits two statistically significant peaks at the frequencies of 1/26 and 1/11.4 years. The physical (or climatological) meaning of these peaks is extremely uncertain at this time. They should only be interpreted as reflecting a quasi-periodic behavior of drought and wetness in the past and can not be used for assigning probabilities of future climatic behavior without a knowledge of the causal mechanisms.

CONCLUDING REMARKS

What do these findings suggest in terms of our expectations of drought (and wetness) in the Hudson Valley? If we accept the premise that we have indeed begun to experience climatic conditions more similar to the 18th and 19th centuries than those of most of the 20th century as Lamb (1966, 1978) has convincingly argued, then we should expect more frequent and, perhaps, more persistent extremes of wetness and dryness in the future. The fact that the severe 1960's drought has been followed by a more or less continuous series of wet summers in the 1970's suggests that the amplitude and persistence of climatic variability may, indeed, be increasing. The behavior of the past 15-20 years may be a harbinger of increased spring-summer climatic variability in the Hudson Valley and

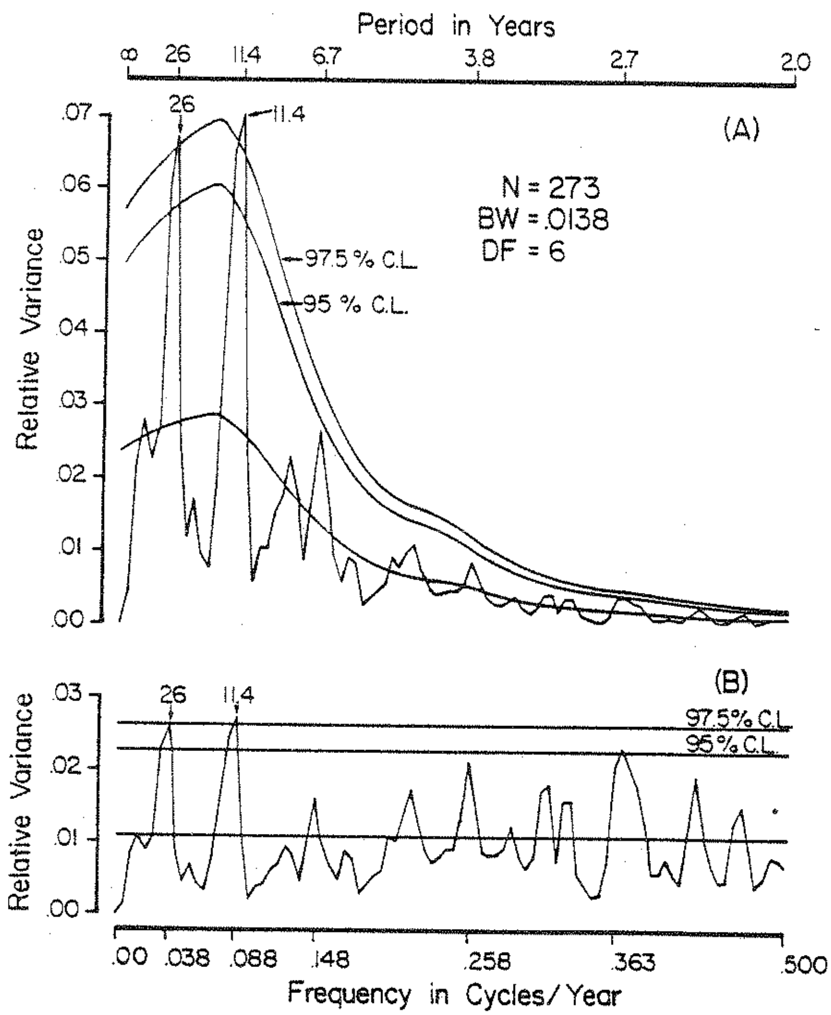

Figure 4. Variance spectra of the July PDSI reconstruction shown in figure 2 (top). The two spectra differ in the ways that the confidence intervals were derived, but they each show the same peaks of variance to be significant at the 97.5% level.

surrounding areas in the northeastern United States.

The insight gained about the long-term characteristics of drought in the Hudson Valley from tree-rings demonstrates the usefulness of dendrochronology and dendroclimatology in the Eastern Deciduous Forest Biome.

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PAST AND PRESENT TRENDS IN DENDROLOGY INSTRUCTION

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INTRODUCTION

As only one of many technical courses that forestry students take, dendrology has been the subject of an inordinate amount of published discussion in the past 10-15 years. Dendrology teachers have variously presented their views on the amount of instruction in the subject that should be required of students (Harlow 1965, Fechner 1965), course content (Fechner 1965, Wiant 1968, Lanner 1969, Coufal and Martin 1970), and innovative methods of presenting the material (Fechner 1972, Bever 1974). More recently, Stettler (1976) and Brown (1977) advocated approaches to the subject that were, in their views, departures from the traditional concept of dendrology.

The clearest perception that one gets in reading these articles is that the scope of dendrology is debatable -- and that dendrology is considered important enough to warrant the debate. I am also concerned about dendrology. But before adding my views to the discussion, I decided to determine the scope and status of the course as it is being taught. I wanted to see whether dendrology is really taught as variably as appeared to be indicated by the authors cited above. This was done through a lengthy questionnaire intended to reach everyone who teaches a course in the subject in the United States. Results of this questionnaire were summarized in a recent article by Steiner and Kunsman (1979).

In this paper I go into more detail on some of the subjects covered in the questionnaire. The discussion will be confined to dendrology courses at professional forestry schools. Of 52 such schools canvassed, partial or complete responses were received from 42 (81 percent), 37 of which were accredited by the Society of American Foresters. These represented 88 percent of the schools accredited as of December 1975.

SOME BACKGROUND

In addition to discussing the present status of dendrology instruction, I was asked to describe how it was taught in the past in order to give some perspective to the current situation. This required a deeper venture into the literature than I had thus far attempted; and I approached this task with the belief that at some earlier time dendrology was more sharply defined than it is now. I reasoned that the circumscription of the subject was once clear in everyone's mind, and that dendrology has only recently been adulterated (as some would say) by such departures from "traditional" approaches as suggested by Lanner (1969) and Stettler (1976).

This proved to be a naive expectation. In fact, it appears that at no time in the past was there universal agreement on the definition of dendrology and the proper content of a course in the subject. As early as 1912, Graves stated that "there is still considerable difference as to the conception of the scope of dendrology, and in the methods of teaching it..." (The first forestry schools in the country were organized in 1898.) De Forest (1914a) felt compelled to offer a working definition for forestry educators, which was promptly criticized by two of them, including the editor of the journal in which it was published. A quarter-century later, Dayton (1938) still noted "wide divergence of opinion among authorities as to what dendrology really is."

Dayton (1945) took stock of the opinions offered up to that time and proposed his own definition. This one, also, did not pass unchallenged (Sinnott 1945, Forbes 1946). However, it is instructive to review Dayton's history of the use of the term. The following is a sampling of references from this article, plus one that I have added:

U. Aldrovandi (1668) used "dendrology" (spelled in Greek letters) in the title of a work that covers names, history, law, marvels, proverbs, miracles, superstitions, prodigies, monstrosities, symbols, numismatics, and uses pertaining to trees. This is the first reference to the word that Dayton (1945) could find.

J. Kersey (1708) defined dendrology as simply "a treatise or discourse of trees" (from Dayton 1945).

P. W. Watson (1825) wrote "Dendrologia Brittanica" in which were covered the morphology, growth, nomenclature, terminology, bibliography, planting sites and instructions, plant associations, phenology, and geographic ranges of trees and shrubs (from Dayton 1945).

K. Koch (1869) described botanical characteristics, distributions, phenology, adaptability to local conditions, variations, and nomenclature of trees and shrubs in a work entitled "Dendrologie" (from Dayton 1945).

G. B. Sudworth (1908) defined dendrology as "the botany of trees," including the study of distinguishing characteristics, taxonomy, morphology, anatomy, physiology, natural distributions, habitats, silvicultural characteristics, and ecological associations.

B. E. Fernow (1914) defined dendrology as including descriptive characteristics (including wood anatomy), taxonomy, physiology, phenology, and ecological characteristics.

H. de Forest (1914a,b) conceived of dendrology as encompassing a broad field of knowledge about trees, but limited to the knowledge or facts per se and not the science (e.g., systematics, ecology, physiology) involved in their discovery. For example, "systematic dendrology" should be concerned with species "ear marks" for identification, but not the study of the systematics of tree species.

H. S. Graves and C. H. Guise (1932) defined dendrology as the "natural history" of trees, and apparently included in their definition of this nebulous term the peculiarities of form and structure by which trees are identified and classified, and various characteristics of internal structure, physiological behavior, and ecological distribution.

Finally, Dayton (1945), after considering the past use of the term, proposed that the subject of dendrology should cover:

"Those phases of botany and forestry which deal with the taxonomy, nomenclature, morphology, anatomy, phenology, geographic distribution, and economic significance of forest tree species, subspecies, varieties, and forms [and other taxonomic categories].

It is noteworthy that Forbes (1946), a botanist, objected to this definition to the extent that dendrology is now generally regarded as strictly a branch of forestry, and that the reference to botany should be deleted.

Dayton's definition was offered to correct the omission of dendrology from the Society of American Foresters' glossary of forest terminology. It appears that it never was accepted, despite the careful deliberation that Dayton obviously put into it. The definition that is now given official status by the S.A.F. is "the identification and systematic classification of trees" (Ford-Robertson 1971). In view of the past use of the term, this definition is clearly an over-simplification and was probably arrived at only because it recurs as a common denominator in previous definitions. In fact, there appears to be ample historical precedent for all of the subjects, including physiology, ecology, genetics (in a limited sense), and morphology, that recent authors have proposed to include in dendrology. And there is no justification for Coufal and Martin's (1970) statement that dendrology never meant anything other than nomenclature, classification, and identification of tree species.

However, I have not yet given an entirely accurate perspective on early dendrology education, because there developed at some time a schism between the definition of dendrology as a discipline and the scope of dendrology as a course. For example, Graves and Guise (1932) defined dendrology rather broadly, as shown above, but noted that the term as ordinarily used in forest education was "arbitrarily" more restrictive. Forestry schools in the United States have always required training in a subject called dendrology (Graves 1925). The early forestry curricula were influenced strongly by the nature of the civil service examination for entrance into the Forest Service (Graves and Guise 1932). For many years, this examination was weighted 10 percent on "dendrology," defined as the botanical classification and characteristics of forest trees (Hendrickson 1941).

Thus, there was probably an early tendency in forestry education to use dendrology primarily as a vehicle for teaching tree identification. As early as 1912, Graves noted that in some schools dendrology was devoted almost exclusively to the identification and classification of woody plants, while in others dendrology included geographic distributions and silvicultural characteristics as well. This latter circumscription is exactly that given by Harlow and Harrar (1937) in their introduction to Textbook of Dendrology, the first published text on the subject to appear in this country. Prior to that time, Sargent's (1905) Manual of the Trees of North America was probably the most frequently used text for the course. This book is primarily a taxonomic manual with some notes on silvicultural characteristics and thorough descriptions of geographic distributions. Finally, Dayton (1945) described a fairly general tendency in even the earliest dendrology courses to cover taxonomy, nomenclature, morphology, phenology, and geographic distributions, with some courses also covering wood anatomy, properties, and uses.

This evidence suggests that dendrology courses have had certain characteristics in common from the very beginning of forestry education in this country, despite widely differing opinions about the definition of the term. But always, as now, the scope of the course has varied considerably according to the interests of the instructor and the needs of the curriculum. I think the following generalizations are reasonably accurate:

(1) The primary emphasis in courses by this name has been on identification and classification of woody plants since the first forestry schools were organized. This emphasis may be partly attributed to the skills needed by a national forest service in a country rich in tree species. Elsewhere, dendrology was not necessarily limited in this way [MacCaughey (1916) described a dendrology course in Hawaii that included lectures on physiology, ecology, conservation, and the timber industry]. Dendrology still often carries broad connotations in Europe.

(2) Morphological characteristics, geographic distributions, and silvicultural characteristics were often taught either as aids in identification or as background for subsequent forestry courses.

(3) Wood anatomy and identification, commercial properties and uses, phenology (and probably other aspects of physiology), and perhaps some other topics were always present in some courses because they are also characteristics of tree species and fit well with the factual nature of dendrology.

DENDROLOGY TODAY

With this brief historical perspective in mind, let's look at the character of dendrology courses today. I will focus on the results from those parts of the questionnaire concerning subject and species coverage.

Subject Coverage

To determine the present scope of dendrology courses, a section of the questionnaire was devoted to various topics that instructors might conceivably cover. Respondents were asked to rate the emphasis these topics receive in their courses on a four-point scale (1=none, 2=light, 3=moderate, and 4=great). Tables 1-6 show the results averaged for the 41 professional schools from which responses to this question were received. The topics are grouped into the categories of taxonomy, silvicultural characteristics, plant geography, economic importance, genetics, and physiology.

As expected, average scores varied considerably among topics. Those rated highest were identification, species habitats, and scientific names. Others that received at least moderate emphasis were geographic distributions of species, common names, morphological traits, shade tolerances, and definitions of botanical terms. Topics rated lowest were physiology of growth and development, phenology, phyllotaxy, and floristic relationships among regions.

Averages do not convey the full results, because there was some variation in response among instructors. However, no one placed less than moderate emphasis on identification, and only one instructor each placed less than moderate emphasis on scientific names and species habitats. As expected, scientific names were generally stressed more than common names. But three instructors did the opposite, and one appeared not to teach scientific names at all.

Virtually everyone placed <u>some</u> importance on identification, scientific and common names, morphological traits, definitions of terms, habitats, tolerances, associated species, successional stages, mature size and form, geographic distributions of species, and commercial and other uses. On the other hand, virtually no one gave great emphasis to English meanings of scientific names, maximum sizes and ages, floristic relationships, folklore, genetic variation patterns, physiology of growth and development, phenology, and phyllotaxy.

Although responses varied for all topics, this was especially true for distribution and composition of forest types and several topics pertaining to silvicultural characteristics. For each of these, a number of instructors felt great emphasis was appropriate and others felt none was appropriate. This indicates more than the usual divergence of opinion regarding the pertinence of some aspects of ecology to courses in dendrology. Another topic that seems to fit in this category is skill in the use of keys. Just over half of the instructors placed no or light

Table 1. Average emphasis given to topics pertaining to taxonomy in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Identification of species and genera	3.9
Memorization of scientific names	3.5
Memorization of common names	3.2
Memorization of morphological traits	3.2
Definitions of terms used in description	3.0
Principles of nomenclature and classification	2.6
Skill in use of keys	2.6
English meanings of scientific names	2.1

[a]1=none, ...,4=great

Table 2. Average emphasis given to topics pertaining to silvicultural characteristics in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Habitats	3.6
Shade tolerances	3.1
Associated species	2.9
Successional stages	2.9
Mature size and form	2.7
Serious insect or disease problems	2.7
Unusual aspects of regeneration	2.6
Maximum sizes, ages, and growth rates	2.2
Seed production and germination	2.1

[a]1=none,...,4=great

Table 3. Average emphasis given to topics pertaining to plant geography in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Geographic distributions of species	3.3
Distribution and composition of forest types	2.7
Geographic distributions of families and genera	2.4
Floristic relationships among regions	1.7

[a] 1=none,...,4=great

Table 4. Average emphasis given to topics pertaining to economic importance of taxa in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Industrial and medicinal uses	2.9
Importance for wildlife	2.7
Aesthetic or ornamental uses	2.4
Folklore and cultural importance	2.1

[a] 1=none,...,4=great

Table 5. Average emphasis given to topics pertaining to genetics in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Principles of geographic variation and speciation	2.4
Occurrence of hybridization among important species	2.4
Genetic variation patterns of important species	2.3

[a] 1=none,...,4=great

Table 6. Average emphasis given to topics pertaining to physiology in dendrology courses at 41 professional forestry schools.

Topic	Emphasis[a]
Description of life cycles	2.2
Physiology of growth and development	1.9
Phenology	1.9
Phyllotaxy	1.9

[a] 1=none,...,4=great

importance on this in their courses, but 24 percent apparently stressed it heavily.

Species Coverage

The extent of species coverage was quite variable among courses, with some instructors teaching a rather meager number of important species and others an almost excessive number of major and minor trees and shrubs. The median number of species of which some knowledge (identification, distribution, habitats, etc.) was required of students was 160, but it ranged from 80 to 500 (Table 7). The median number of species for which skill in identification was required was 131. However, 9 respondents required identification of fewer than 100 species, and 6 required identification of more than 180. One asked that students be able to identify a mind-boggling 300 species -- this taught in one semester plus 40 hours of summer camp. About 30 percent of all respondents taught nothing of species not native to the United States or Canada. When non-native species were taught, they comprised an average of 7 percent of total species coverage.

Table 7. Number of species taught in dendrology courses at 41 professional forestry schools.

	Median	Range
Number of species of which some knowledge is required	160	80-500
Number of species of which identification is required	131	55-300
Number of species in silvics manual[a] of which some knowledge is required	96	45-127
Number of species in silvics manual[a] of which identification is required	77	32-127
Number of genera in silvics manual[a] of which identification is required	37	28- 40

[a]Fowells (1965). Total number of species in silvics manual =127.

Most instructors covered a fairly large proportion of the commercially important species in the United States, here loosely defined as those in Fowells (1965) silvics manual. The situation should be even more encouraging to "traditional" dendrologists when only the 40 genera in this book are considered. Although some instructors taught the identification of as few as 28 of these, 60 percent of the instructors taught the identification of at least 37 and some taught all 40 (Table 7).

I listed the genera covered in Fowells (1965) and asked respondents to circle those for which identification is taught. These results are presented in Tables 8-10, separated according to whether the genera occur naturally in the eastern or western parts of the country. Almost half of the genera were taught at all schools. In general, western instructors did a better job of covering eastern genera than eastern instructors did of covering western genera. This may have been caused in part by the relative unimportance of some of the genera endemic to the West. But responses to another question indicated that instructors in the West tend to spend much more time in the lab and less in the field than their eastern counterparts. Greater reliance on herbarium specimens may have afforded greater latitude in species coverage.

All but three of the instructors taught the identification of some shrubby species, and an average of 28 were covered. However, in only five courses were some herbaceous species covered. In those, the average number of herbaceous species was 11.

Table 8. Proportion of dendrology courses at 41 professional forestry schools in which identification of genera endemic to the East is taught.

Genus	Location of school	
	East[a]	West
	--percent--	
Fagus, Tilia, Ulmus	100	100
Carya	100	90
Liriodendron, Magnolia	97	100
Gleditsia	97	80
Nyssa	94	90
Liquidambar, Taxodium	90	100
Sassafras	90	70
Diospyros	78	40
	n=31	n=10

[a]Includes all responding schools from east of the Rocky Mountain states; all other schools considered western.

Table 9. Proportion of dendrology courses at 41 professional forestry schools in which identification of genera endemic to the West is taught.

Genus	Location of school East[a]	Location of school West
	--percent--	
Pseudotsuga	97	100
Sequoia	79	100
Libocedrus	65	90
Umbellularia	16	60
Arbutus	7	60
Lithocarpus	10	50
	n=31	n=10

[a]Includes all responding schools from east of the Rocky Mountain states; all other schools considered western.

Table 10. Proportion of dendrology courses at 41 professional forestry schools in which identification of genera native to both the East and West is taught.

Genus	All schools
	--percent--
Acer, Betula, Fraxinus, Juglans, Juniperus, Larix, Picea, Pinus, Platanus, Populus, Prunus, Quercus, Robinia, Thuja, Tsuga	100
Abies, Cornus, Salix	98
Celtis	95
Aesculus	93
Chamaecyparis	90
Alnus	88
	n=41

DISCUSSION AND CONCLUSIONS

Harlow (1965) complained that some schools no longer taught an adequate course in dendrology, and Wiant (1968) felt that the course doesn't get the support it deserves in undergraduate education. Yet Graves (1925) said much the same thing 40 years previously -- that forestry graduates then were less well equipped in dendrology than those at the turn of the century. We will probably hear a similar complaint 40 years from now. However, one wonders if the concern isn't well founded. Probably for the first time since the beginning of forestry education in this country, some accredited schools no longer have a dendrology requirement (Gemmer 1979). Indeed, this was true of at least one school that responded to my 1975 survey, despite the S.A.F. accreditation requirement for curricula to provide a working knowledge of the classification, distribution, characteristics, and identification of forest species.

Is dendrology evolving, as suggested by Fechner (1972)? More specifically, has the scope of dendrology courses changed and are fewer species being covered? My analysis suggests that the answer is "no" to the first part of the question and "yes, probably" to the second.

Over 65 years ago, Graves (1912) noted that the primary emphasis in dendrology courses was the identification and classification of woody plants. This is unchanged -- there appeared to be almost unanimous support among 1975 respondents for Coufal and Martin's contention that the first task of a course in dendrology must be training in identification. Furthermore, other than nomenclature and morphological characteristics (which are part of identification), those topics that are presently next-most emphasized by instructors are precisely those that were so emphasized in Graves' (1912) time: geographic distributions and some silvicultural characteristics. Of course, most instructors cover other topics, also, and some even place heavy emphasis on them. But this has probably always been true. Phenology, and probably wood anatomy, appear to be covered in fewer courses than formerly, but they have been replaced as secondary components of dendrology courses by such topics as genetics and the distribution and composition of forest types.

It is more difficult to determine if a change in species coverage has occurred. Without data for previous years, the question must be approached indirectly by looking at the length of required dendrology courses. Unfortunately, of the several surveys of forestry curricula that have been made over the years, I have found only one that listed the dendrology requirement separately. Chapman (1936) reported that 18 forestry schools surveyed required an average of 4.5 semester credits of the subject, which is more than the mean of 3.2 credits required now (Steiner and Kunsman 1979). This indicates a formerly greater emphasis on the importance of dendrology, because average total graduation requirements have changed very little (Chapman 1936, Gemmer 1979).

However, average dendrology requirements might very well fluctuate from time to time, so the above comparison does not necessarily suggest a long-term trend. Better support for Harlow's (1965) belief that dendrology requirements are being reduced comes from a comparison of his own data with mine. Table 11 shows approximate class time requirements in 1965, derived from his figures, compared with those in 1975.

Table 11. Amount of instruction given in required dendrology courses in professional forestry curricula, 1965 and 1975.

	Mean		Range	
	1965[a]	1975	1965[a]	1975
Number of lecture hours	32	27	10- 60	0- 48
Number of laboratory hours	82	59	30-130	30-104
Number of total hours	114	86	70-160	56-130
			n=26	n=38

[a]Adapted from Harlow (1965).

The average number of lecture hours devoted to dendrology decreased only slightly from 1965 to 1975, but the number of hours spent in lab decreased substantially. This is probably attributable to the elimination of dendrology from summer camp. Substantially fewer schools taught this subject in summer camp in 1975 (Theoe 1975) than in 1965 (Harlow 1965), and those that did so formerly tended to have larger amounts of lab time devoted to the course. Two conclusions are possible: either fewer species are being covered than a decade ago, or less time is spent in teaching their identification.

However, to end on a positive note, half of all courses in this survey covered the identification of at least 131 species, and most educators would probably agree that this is rather full coverage. Nine instructors required the identification of fewer than 100 species; but these courses probably easily met Dana and Johnson's (1963) minimum criteria for dendrology if the species were well chosen. Finally, 60 percent of the courses covered the identification of at least 37 of the genera in Fowells (1965). This is very close to Graves' (1912) recommendation that at least one species should be mastered in each of the more important genera, which he numbered about 40.

Concerns and questions about dendrology by today's instructors were apparently shared by their predecessors of decades past. However, Coufal and Martin (1970) appear to be justified in their contention that dendrology is not ailing or dead, as suggested by others. It is perhaps evolving (Fechner 1972), because it is not quite the same course that was taught 70 years ago. But dendrology is certainly not mutating wildly. It will undoubtedly continue to change by degrees to meet the needs and challenges of changing forestry curricula.

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AUDIO-VISUAL DENDROLOGY---WHY IT WORKS

by

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Being dendrology teachers in the heartland of the eastern deciduous forest biome, we are not sure whether it is brave or foolish of us to suggest that an audio-visual system for teaching dendrology has value and should be used. This is, however, the cause we champion. Some background information may help us justify this argument.

BACKGROUND

Fifteen years ago when a 4-year forestry program was being developed at the University of Tennessee, one of the strongest arguments favoring its location at Knoxville, in the Great Valley of East Tennessee, was our proximity to the most diverse woody flora to be found in the north temperate zone. Located within an hour's drive of the Knoxville Campus are native stands of loblolly pine (*Pinus taeda* L.), pine-oak, oak-hickory, the complex mixed mesophytic forests, and, with increasing elevations along the Unaka Mountains, Appalachian hardwoods, northern hardwoods, and finally spruce-fir forests above 5,000 feet. A checklist of "Woody Plants of the Great Smoky Mountains" includes 255 species and a number of varieties (Stupka, 1964). Expand this by the 30-40 trees native to middle and west Tennessee but not found in the Smokies, and it becomes apparent that our dendrology instructors are not handicapped by an inadequate field opportunity. It has long been recognized that the southern Appalachian uplands provided the refuge from which much of the present vegetation of eastern North America migrated following Pleistocene glaciation. It is the very length of the local species list plus the fact that it contains only 14 gymnosperms that presents the problem with a single, field-oriented dendrology course.

A GOAL

A basic philosophy in our training of foresters is that they are competent to accept employment anywhere in the U.S. or Canada, a view generally held in accredited forestry programs. While the basic principles of silviculture and forest management can be applied broadly and translated from one region to another, identifying the trees of the various regions and understanding their silvical characteristics and site requirements is best accomplished by studying them in their native habitats. The rich opportunities for field study in our region, far

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in excess of that allowed by traditional contact hours in dendrology courses, can lead to serious omissions. Although trained in Tennessee, we expect our graduates to be able to identify and know the silvical and site characteristics for the gymnosperms that dominate the woody flora of the western U.S. How can this best be accomplished?

Proposed solutions have been to utilize arboreta, ornamentals or establish demonstration plantings. We have an excellent arboretum within 30 minutes drive of the Knoxville campus in which a continuous effort is made to establish and keep alive representatives of our western forests; and ornamental Douglas-firs are doing well on our campus. These efforts simply are not, and will never be, satisfactory for realistically translating to students the diagnostic, silvical, and site characteristics of western trees such that they can treat them with understanding.

OUR APPROACH

To assure adequate treatment of both local and non-local trees, we require two dendrology courses of our forestry majors, one on woody angiosperms, for which our local flora is more than adequate, and the other on gymnosperms with major representation in the west.

In attempting to name these courses we encountered another problem. According to the FAO/IUFRO committee on forest terminology (Ford-Robertson, 1971), what we wanted to teach (and had been teaching) was more than just dendrology. Feeling that perpetuation of loose semantics is a serious injustice to both our students and our profession, we accepted their very narrow definition that dendrology is "the identification and systematic classification of trees" and named our two courses: 1) Dendrology and Silvics of the Woody Angiosperms (Forestry 3040), and 2) Dendrology and Silvics of the Gymnosperms (Forestry 3050). Their definition of silvics appears to incorporate both silvical and site characteristics.

As should be expected, the angiosperm course is field-oriented, having two lectures and one 3-hour laboratory each week plus one required weekend field trip. With one exception, field trips are traditional with the instructor covering diagnostic, silvical, and site characteristics for an assigned group of species.

The exception allows some self-pacing on the part of the students. Within walking distance of the campus is a nature trail on which 71 trees, shrubs, and vines (stations), representing 51 species, have been numbered. Students check out a cassette tape player and taped program from our departmental office or the library. A field guide keyed to the tape and the numbered specimens is also available. The guide contains maps and support materials for identifying each numbered specimen. In the first laboratory session students are directed through the first 8-10 stations to assure understanding of the system; approximately 3 weeks later they are quizzed specifically on the content of this program.

AUDIO-VISUAL

The audio-visual system is fully implemented, according to our standards, in the gymnosperm course taught during the winter quarter. It was inspired by the "deadly dull" evaluations received from students taking our gymnosperm course, an expected result where lecturing on, and showing dried specimens of, trees from "another land" is the teaching method. Reaction to the few color slides we had been using of trees in their native habitats suggested an audio-visual approach.

In the system implemented three quarter hours of credit are earned for the following weekly schedule: one lecture, one hour when each student has reserved use of a study carrel, and a two-hour recitation period for reviewing and quizzing. A conventional laboratory is converted into a "learning center" by assembling six study carrels, each containing a cassette tape player, a Kodak Ektographic slide projector (with 3" lens), and a 2' x 2' screen. A student teaching assistant is in charge of the center to assist with questions and to check out study units. In addition to the reserved hour assigned to each student, there is ample free time when carrels are available for additional study and review.

Study material is presented in eight audio-visual "units" that are structured according to the generic groupings from Textbook of Dendrology (Harlow, Harrar, and White, 1979); one unit is covered each week with quizzing in recitation periods on Thursday and Friday. A workbook developed specifically for the audio-visual system and keyed to the cassette program is sold to students through the bookstore.

Audio-visual study is supplemented with specimens (fruit, foliage, etc.) to the extent satisfactory material is available. These materials are displayed in "Exhibits" at the back of the room. To reduce the time that carrels are "tied up", students are referred to the exhibits at the end of each program, after they have turned in tapes and slides.

Providing teaching assistants to supervise the center approximately 40 hours each week is accomplished by giving special credit to seniors who earned an "A" or "B" when they took the course. Teaching assistants are required to review each unit prior to the week in which it is given and submit suggested quiz questions for the recitation periods. They are assigned one unit on which they will assist the instructor in developing an appropriate exhibit. We have even involved them in developing audio-visual programs on the trees of specific regions.

DEVELOPING THE SYSTEM

Developing and implementing an audio-visual system is time-consuming and expensive. The full-time involvement of a graduate student (junior author of this paper), who used the development and evaluation of our system as his thesis study, enabled us to implement the program.

Good color slides showing species characteristics and species-site relationships are essential. We begged, borrowed and otherwise obtained sufficient slides to implement the program. Having access to good photographic equipment enabled us to copy other photographs and, when specimens were available, take pictures showing diagnostic features for species. Slides showing species-site relationships were harder to find; many were obtained by the senior author during a summer appointment with the U.S. Forest Service in Oregon which enabled travel over much of the western United States. Providing students who have summer jobs in the West with film and specific instructions has been rewarding. However, incorporating additional materials in a completed unit is time-consuming as it generally requires re-doing the entire program. This does, however, assure periodic revision.

Carrel design evolved from considerable experimentation. The rear-projection screen described by Fechner (1972) was tested but poor definition (especially critical in seeing details such as armed umbo's, etc.) made it undesirable. A unit was constructed wide enough to allow the use of a carousel slide projector equipped with a 3" lens and a high reflectance screen (Figure 1). These units are easily dismantled and stored, an important feature as the room is used as a learning center only one quarter each year.

EVALUATION

Valid evaluation of the audio-visual system was difficult. Some insight was gained by: 1) a test evaluating student performance and 2) questionnaires to determine student satisfaction with the system.

A Test: Student performance was evaluated by comparing learning effectiveness on one of the eight weekly units with the same material taught in the more conventional group-paced manner. The test population consisted of 94 students enrolled in Forestry 3050: Dendrology and Silvics of the Gymnosperms during the winter quarter of 1976, the first year the audio-visual system was fully implemented.

The class was divided into two groups: 1) experimental (self-paced) and 2) control (group-paced). To assure approximately equal performance levels in the two groups, students were assigned on the basis of their cumulative grades at mid-term. Eight quizzes (four written and four practical) were averaged to rank students from highest to lowest. Students were paired in this sequence and randomly assigned from each pair, one to each group. They were assured that the study would not adversely affect their grade as an adjustment would be made according to group averages.

Unit Six: "The Spruce and Fir Trees" was used for the test as: 1) it contained the largest number of species (19), enabling evaluation of an argued advantage of the audio-visual system; i.e., more material can be covered in an allotted time period,

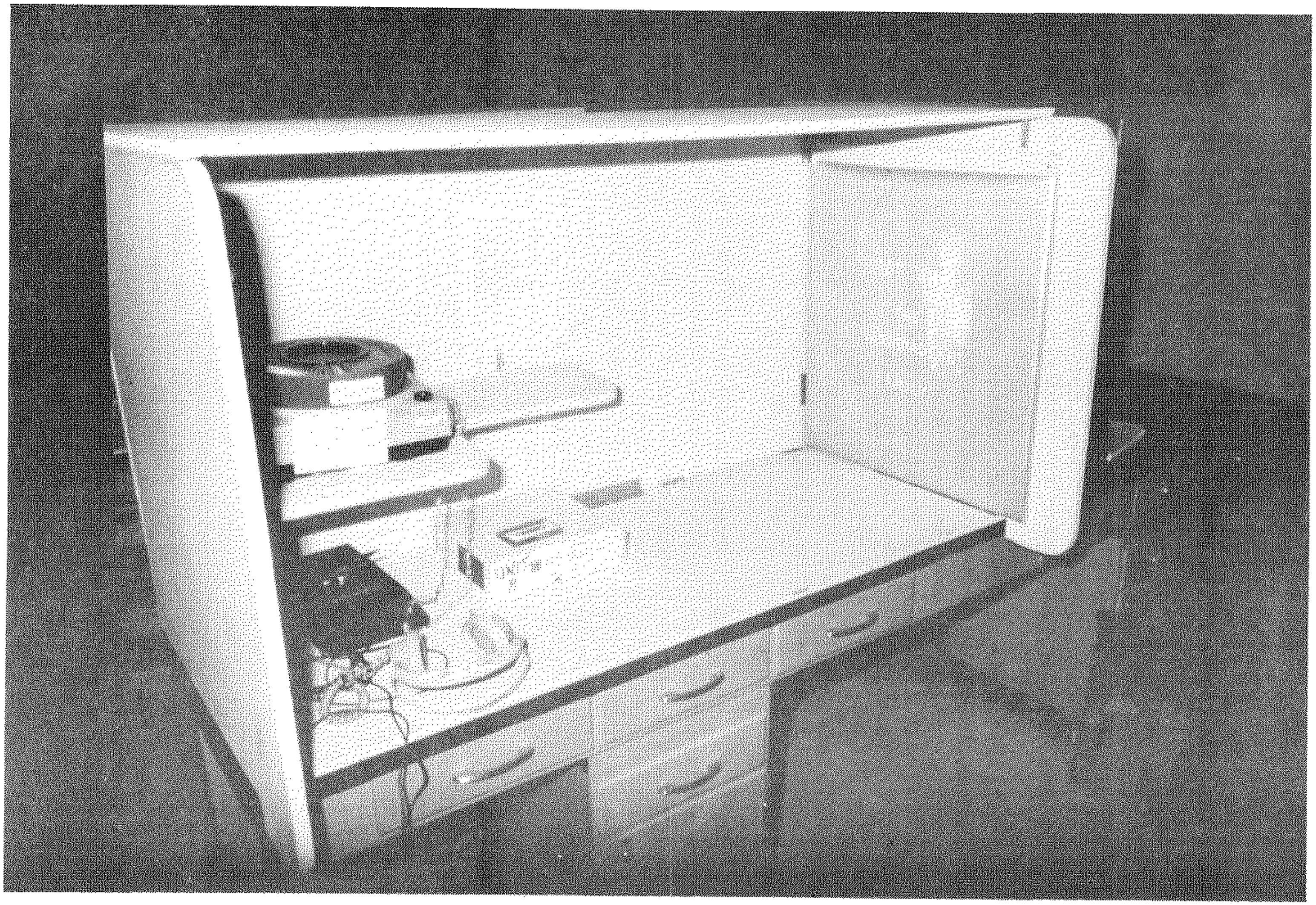

Figure 1. Carrel showing location of slide projector, cassette player and screen.

2) aside from length, it was "typical" of the other seven units, and 3) it was taught after the mid-term enabling a better statistical design for the test.

The same instructional materials were used with both groups, which included: 1) a 27-page guide to direct study and facilitate note taking, 2) approximately 80 color slides showing diagnostic characteristics and native ranges and sites, and 3) an "exhibit" of cones and leaf mounts to be used following the lecture or audio-visual presentation. The thorough literature review made in developing the audio-visual system resulted in more material being covered than under the conventional system used previously.

Evaluation was by means of written and practical tests given simultaneously to both groups on the Tuesday following the week during which the two systems were administered. The written test employed a variety of question types which were approved as "fair" by two members of the forestry faculty. The practical test had five cones for identification. Retention was tested by grading separately a section of the final exam devoted to material covered in this unit and comparing the performance of students in the two groups.

The instructional format for the control group was that used prior to implementing the audio-visual system, i.e., instructor lecturing with the aid of transparencies and slides. Logistically this was accomplished by using the four, two-hour recitation periods scheduled in the audio-visual format for review and quizzing. The full two-hour period was required to cover the material contained on 45 minutes of tape. Students in the self-paced group were not allowed to attend these lectures.

The experimental (self-paced) group used the study carrels previously described; lecture material and instructions contained on a cassette tape coordinated the use of slides and guidebook materials. The same "exhibits" displaying foliage and cones were used for both groups. Teaching assistants made sure that those in the group-paced section did not use the cassette tapes and slides.

Results: The average grade on the written exam for the control group (74.6) was higher (1.6) than for the experimental group (73.0). However, the median score of the experimental group (76.5) was higher (1.0) than that of the control (75.5). In comparing grade distributions the most obvious difference was an increase of seven percent in the number of students in the 90-100 grade category.

More students making higher grades in the experimental group yet a lower group average indicates a wider grade-spread between good and poor students. Self-pacing probably results in lower grades for poorly motivated students. The practical test on identification supports this with test averages of 87.4 for those required to attend the lecture-laboratory compared to 85.5 for the self-paced group.

Retention as tested several weeks later showed both higher average and median scores for the experimental group compared to the control (Table 1).

Table 1. Average and median scores on a retention test on material studied under self-paced versus group-paced teaching methods.

	self-paced (experimental)	group-paced (control)
Average grade	83	80
Median grade	92	83

Once again, when grade distributions were compared the most prominent difference was an increase of 11 percent in the number of students in the "A" category (92-100) for the self-paced group as compared to the control.

Using the t-test for paired comparisons, none of the grade differences reported were statistically significant.

An attempt to compare grade distributions in previous, conventionally-taught courses with those since the audio-visual system was implemented revealed a dramatic improvement in grades. The validity of this comparison is questionable, however, due to lack of continuity in instructors and changing standards for grading.

Since significant differences in student performance could not be demonstrated, student satisfaction was the next criterion of concern. Four evaluations of student satisfaction with the audio-visual method were made. A problem in evaluating this characteristic was that, except for the small "control" group described previously, students had no opportunity to compare the audio-visual with the conventional method for teaching this course. Most students questioned had previously taken the field-oriented angiosperm course, resulting in frequent comments reflecting a preference for that format, which was not possible for most gymnosperms studied.

Despite this handicap, there was strong preference for the audio-visual method. Although questions differed somewhat from year to year, the percentages of students ranking the system as "good-to-excellent" were: 88 percent in 1975, 75 percent in 1976, and 85 percent in 1977. When tested at Haywood Technical College in 1979, 97 percent ranked the course as good to excellent.

In summarizing student comments on various evaluations attempted, the primary advantages of the audio-visual system are:

1) it is highly self-paced, enabling students to study as best fits their schedule,

2) it permits repeating material as needed for comprehension,

3) more material is covered in the allotted time, and

4) pictures of trees in their native habitats maintains a higher interest level and enables better understanding of species-site relationships for non-local trees.

IN CONCLUSION

The audio-visual system provides an effective method for studying non-local trees that is better received by students than the conventional lecture-laboratory method. It is not recommended where field study of trees in their native habitat is possible, although it can be used to expand on field observations.

Initiating the system is time-consuming and costly; however, results more than justify the time and investment where a large number of students are involved.

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WINTER IDENTIFICATION

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Over a forty-five year period, the author has, intermittently, taught courses in dendrology. During this period forestry has evolved from a comparatively simple, preservation-oriented profession to a highly technical, sophisticated, scientific one; one which is concerned not only with maximizing timber production but also with complicated and often competing environmental and recreational demands. Over this period, dendrology as a course taught in our forestry schools has changed but little, much less than other portions of the forestry curriculum, although less time and credit is now given to it.

Over a period of 300 years, dendrology has been defined in many ways to include many different things, but in this author's opinion the first goal of this course has been and must continue to be teaching students to identify forest trees. A forester who is unable to distinguish between the important trees in his working area is a poor forester indeed and is apt to lose the respect not only of his associates but also of the public he is attempting to serve. Unfortunately many practicing foresters have less than adequate ability to identify trees, a reflection either on the qualification of their teachers or on the decreased emphasis given to dendrology. As other papers at this conference point out, dendrology includes much more than tree identification, but this basic goal must not be lost sight of.

The increasing importance which broadleaf species are now receiving requires that more emphasis be placed on the use of identifying characters available after leaf fall. Inventory, marking and other forest practices in hardwood forests are being carried out in greater measure during those periods when the trees are bare, as greater accuracy of observation is possible. Obviously the observer must be able to identify his material. Most courses in dendrology minimize or completely omit identification by winter characters. Based on the author's personal experience this neglect was based on the lack of training he received in this area as well as on the unavailability of suitable teaching material. The major thrust of this paper is to urge greater emphasis on the identification of forest trees in winter.

Broadleaf trees in winter are far from being the characterless objects they appear to be to an uninformed observer. Freed from their canopy of leaves, trees often exhibit characteristic forms, barks and branching habits which permit easy identification. Generally, however, winter identification relies heavily on distinctive features of the twigs and buds and on fruits which may be persistent. Once the techniques have been mastered, winter characters are fully as reliable for identification purposes as are summer characters. An 8 or 10 power hand lens is essential for determining many features of twigs and buds.

In developing a segment of his dendrology course to cover winter identification, the author at first relied heavily on the excellent key and photographs in Dr. Harlow's Twig Key to the Deciduous Woody Plants of Eastern North America (1959). This was supplemented by mimeographed local keys of the Raleigh area by Dr. James Hardin and Dr. Michael Baranski, which were later modified by the author on the basis of several years use by students. A need for a more complete manual became apparent, which would permit verification of identification made through use of the key. The manual Identification of Southeastern Trees in Winter (1976) by Valerie G. Wright and the author was prepared to fill this need. This manual is usable throughout the eastern United States as most northern species are present in the southern Appalachian mountains.

This manual is in three sections: the first describes the characters used in winter identification and explains how to use the following key; the second section is the key to the genera, with excellent line drawings by Valerie Wright, which emphasize the distinguishing features of each genus; the third section describes each genus in some detail, listing in order their distinguishing features. This section thus serves as a check on the identification determined by using the key. This third section also keys out the species where a genus contains more than one species. A glossary, bibliography and index complete the manual.

The author found that students could attain reasonable mastery of winter identification in four 2-hour laboratory periods. These periods were scheduled for the last of the semester, although they could be moved earlier to take advantage of inclement weather.

Finally, in every dendrology course, the author urges that consideration be given to the following suggestions:

1. Emphasis should be placed on recognizing the native genera. If the forester knows the genera, local species can easily be learned on the job.

2. Too often dendrology courses are assigned to teachers who are not qualified or interested. As dendrology is often a student's first introduction to forestry, the course should be thorough, demanding and taught by a qualified individual.

3. Laboratories, to the greatest extent possible, should be in the field and deal with living material. Many of us here have suffered from long hours of work with dried up herbarium specimens or from needless drawing of cones and leaves already pictured in texts.

4. Construction and use of keys is most important. Unless students actually construct keys, they never fully understand them. The best way to insure that students do understand is to inform them that they will be asked to construct a key on each major test.

5. Today students generally come into dendrology with no background in taxonomy. It is essential, therefore, that basic taxonomic principles be included in the lectures, covering such subjects as the concept of species and genera, the basis and need for scientific names, and the classification of higher plants.

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TEACHING DENDROLOGY IN THE FIELD

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To many foresters it might seem that there is no other way to teach dendrology than in the field. Nevertheless, there is a tendency in forestry schools to reduce the total amount of time allocated to dendrology courses, thus reducing time spent in the field, and at the same time to replace traditional methods with innovations that in themselves often reduce the amount of time devoted to field study still further. Even so, the results of a questionnaire recently circulated to 100 institutions offering forestry degrees indicated that virtually all schools in the United States included field instruction in their dendrology courses (Steiner and Kunsman, 1979).

THE PURPOSE OF DENDROLOGY

Strictly speaking, of course, dendrology is the study of trees, and yet, in a sense, all of forestry is the study of trees, so it is obvious that through the inclusion of dendrology in the curriculum of forestry schools it is intended that the course should be concerned with a restricted phase of the study of trees.

A widely held belief among forestry educators is that "the first task of a course in dendrology must remain training the student to identify trees" (Coufal and Martin, 1970). One teacher expresses disagreement with this view, stating the opinion that it is "much more crucial that we provide the student with a conceptual framework within which he can accommodate the organismal diversity he encounters" (Stettler, 1976). Nevertheless, these views are apparently identical, since no two trees are exactly alike, presenting "organismal diversity", which for the sake of convenience, we include within a "conceptual framework", i.e., the name of the particular species in question.

We might conclude, then, that foresters are at least <u>almost</u> unanimous in stating that the identification of trees is the prime purpose of dendrology. Merely to make the identification, however, requires a knowledge of many different facts concerning trees: morphology, silvics, genetics; even phytogeography is helpful.

No one could say, in view of all this, that anyone might regard identification as merely the memorization of names, whether Latin or vernacular. In the identification of pines, for example, students observe "fascicles" of leaves ("needles"). The number of needles in a fascicle is critical, since in this manner soft pines, in general, may be distinguished from hard pines. Within the soft pine group, the length of the needles, the size and shape of the cones, even the characteristics of the habitat and the geographical distribution are important. It is obvious that a knowledge of terminology is essential, since, for example, a student is unable to say if the umbo is armed or unarmed, if he (or she) does not know what the umbo is.

It might be stated, therefore, that identification is impossible without some consideration of morphology, terminology, taxonomy, habitats, and the like, and that it may involve to some extent a knowledge of natural ranges, genetics, some aspects of silvics, the composition and distribution of forest types, even such subjects as paleobotany and dendrochronology. It is basic, too, that economic importance be considered, since, otherwise, it might be asked, why are we studying this species in the first place?

WHERE TO STUDY

Just as the purpose of teaching dendrology seems to have general agreement, as indicated by the questionnaire of Steiner and Kunsman (1979), so do the traditional teaching techniques seem to be still most popular, despite a wide variety of innovative procedures, including autotutorial systems. Virtually all schools use field instruction: it could even be inquired, how could dendrology be taught without it? This is not to say that indoor instruction is not also necessary. There is no campus where all trees of economic importance can be observed nearby. The use of preserved specimens or slide presentations is necessary to provide an introduction to trees which do not grow in the area.

Most of the 100, or so institutions in the United States offering forestry curricula are within reasonable traveling distances of natural forests including those maintained by federal or state agencies, or those privately owned. Here the trees may be observed in their natural habitats, and attention given to associated species, successional stages, shade tolerances, the composition of forest types, and the like, along with the morphological characteristics of the individual trees.

In addition, many trees not indigenous to the area may be planted around buildings along city streets or in public parks. Dendrology instructors normally have a knowledge of the location of such trees and are able to show them to their students. The subject matter in such instances is,however, much limited. Here little or no attention, for example, can be given to associated species. There may be no trees nearby, or, if there are, they may not be those that are normally seen about them under natural conditions. Even some of the morphological features may be different and attention needs to be called to these differences. For example, baldcypress (Taxodium distichum) grows very well along the streets of Morgantown but lacks there the remarkable "knees", which are regarded as distinctive for the species under natural conditions.

Many, perhaps most, forestry schools are likewise within easy reach of an arboretum. Although arboreta and botanical gardens are sometimes more or less ridiculed as "tree zoos", it is seldom that they do not provide opportunity to observe some species not normally found in the neighborhood. Ornamental cultivars of a species are, of course, usually atypical, and a good arboretum will include more normal specimens from natural populations. Collections such as these, it should be pointed out, are not designed merely as instructional facilities for dendrology students but for the use of the general population.

WHEN TO STUDY

Teaching dendrology in the field has, of course, limitations associated with changes in the weather and in the seasons. It is not practicable to work outside in the rain, nor in extreme cold weather. Nevertheless, there are advantages in arranging the curricula so that opportunities are provided for the examination of trees in all seasons of the year. In the institution with which I have been most familiar, the students largely began their work in the late summer or early autumn, then continued it through the winter into spring. This was followed by work in camp during the summer. In a region dominated by deciduous species of trees, this is especially rewarding. There are features that can only be observed at certain seasons of the year. Foliage, gradually transformed into the flaming colors of autumn, were observed at the beginning. Autumn was also the best time to study fruiting in most species. The cold season was the time to study winter characters: bark, twigs, buds, leaf scars. Students sometimes remarked in the spring that they were sorry to see the leaves coming out on the trees, because they had learned so well how to identify them without leaves. Spring and summer are the best seasons to observe flowers on most trees.

It is regrettable that the tendency now is to reduce the length of time devoted to dendrology in forestry curricula. Steiner and Kunsman's questionnaire indicated that the average number of credits (semester equivalents) was 3.2 in professional schools and 3.0 in technician schools. The average number of credits was 3.3 when dendrology was taught in forestry departments against 2.8 when taught in biology departments, which might indicate that foresters had a somewhat higher regard for the value of dendrology courses. Even so, most schools required only one term. Only five schools, out of 68 reporting, required students to take dendrology in such a manner that trees would be studied in all seasons.

All this, of course, has a very direct bearing on field studies. When courses are limited to one term, regardless of which term it is, opportunities for seasonal observations are curtailed. In our institution there were originally five credits, three in the fall, two in the spring, but the tendency here, as elsewhere, has been towards the reduction in the number. My recommendation would be that, if the number of hours devoted to field work is not actually to be increased, they might at least be stretched over most of the year. This recommendation is especially pertinent in the East, where deciduous forests predominate, and seasonal changes are the greatest.

AUTO-TUTORIAL PROCEDURES

Among innovative methods in the teaching of dendrology auto-tutorial techniques are prominant. In some schools (see Bever, 1973) these are used virtually to the exclusion of regular lecture and laboratory periods. Students are told "that the lectures are not mandatory; that they can pass the course without attending them, and many don't attend. Laboratories are unscheduled; students decide for themselves when and how much time to spend in studying Dendrology."

There is no doubt that self-teaching methods are important. After all, the professor cannot learn for the student; the student can only do that on his own. Nevertheless, there is a danger in encouraging lack of contacts between professors and students. Tapes and slides have their place (they, of course, were made by people, regardless of their impersonal nature), but in learning nothing can replace the give-and-take, question-and-answer, relationship between students and their teachers. Guided field tapes are useful; they do not, however, replace in value field trips conducted by the instructor. Tapes should not be used as substitutes for traditional field trips, but only to supplement them.

MORPHOLOGY

The study of the morphology of trees in the field is casual and informal but nevertheless of tremendous significance. In his mind, when a student examines a tree to determine its identification, he makes comparisons similar to those used in following printed keys. Are the leaves apparently evergreen or deciduous? What is their arrangement on the stem, alternate, opposite or whorled? What type of leaves are they, narrow and needle-like, or broad? If they are needle-like, are they in fascicles? If they are in fascicles, how many are there in each fascicle? If the leaves are relatively broad, what is their average length and breadth? What is their shape? What is their texture, thin and papery, thick and leathery, or in between? What sort of a margin do they have, smooth or toothed? What shape is the base and the apex? What sort of venation do they have? Are they sessile or petiolate? Are the buds fairly large or relatively small? How many scales do they have? What color are the young twigs? Are they slender or relatively thick? How might you describe the bark on the main trunk of the tree? Are there any flowers present? What about fruits?

These are certainly among the most important questions a student might be asking himself as he undertakes the identification of a tree, more or less unconsciously following down a dichotomous key, but other similar questions might occur to him, especially with respect to particular species.

SILVICS

The study of dendrology in the field cannot overlook matters pertaining to forest ecology, formerly at least, referred to as silvics. Forest ecology was earlier more concerned with autecology, that is, the ecology of a single tree, but today the emphasis is on the concept of the entire ecosystem (Smith, 1974).

In studying a given tree in the field, a student almost unconsciously deals with such matters as elevation above sea level, habitat (marshy or well-drained), associated species, successional stages, shade tolerances and the like. These become naturally a part of his knowledge of the species. In merely reading about the tree, they would be matters that would have to be memorized. As a matter of fact, this is basically the difference between field study and "book learning".

NOMENCLATURE AND TAXONOMY

The Bible records (Genesis 2: 19) that the Lord brought all the animals "unto Adam to see what he would call them; and whatsoever Adam called every living creature, that was the name thereof." We might assume that Adam named the plants also.

The point of all this is, of course, that plants and animals do not, of themselves, have names; but whatsoever human beings call them, these are the names thereof.

Names are necessary for all things with which we have contact; this is the reason for language. Nevertheless, the memorizing of names, particularly scientific names, is often most boring and too much emphasis on this may result in a dendrology course becoming a nuisance (Wiant, 1968). This is not necessary, however; names are indispensable, even scientific names, and need not be regarded as tiresome. Technicians cannot talk about trees without having names for them and professional foresters need to know not only the vernacular names but the scientific names as well.

The arrangement of names of things is called taxonomy. Related things are grouped close together; the degree of relationship may be shown in the taxonomic system. As with nomenclature, taxonomy too may become tedious. But, again, this may depend upon the method of instruction. Merely memorizing names of species, genera, and families can indeed be meaningless and mere drudgery.

In the field, however, students do not need to be told that certain trees are closely related, others more distantly related. Pines are obviously closely related: They all have cones, and needles in fascicles. Pines, hemlocks, and spruces are related but not so closely; they all have cones and needle-like leaves but not all of them have needles in fascicles. Again, it is easy to see oaks are all related; they all have acorns as their fruit type.

Thus, without realizing they are doing it, students acquire much of the needed knowledge of nomenclature and taxonomy through contacts in the field and need to consult books only to round out their knowledge.

ECONOMIC IMPORTANCE

Students only indirectly acquire a knowledge of the economic importance of trees through field work. The size of tree trunks may suggest that the species has commercial value or the students may observe logs of certain species being transported to processing plants, such as sawmills. Dendrology does not normally profess to teach which trees are commercially of great value, or of lesser value. Almost all of the remainder of forestry courses deal with this aspect of the subject.

GENETICS

Genetics is a youthful science and in forestry even more youthful than in many other fields, since the results of hybridization are not so immediately seen, as, for example, in hybrid corn. Nevertheless, it is of growing concern to professional and commercial foresters.

In field work of dendrology courses, the instructor can play a significant role in pointing out genetic principles (Stettler, 1976). As a matter of fact, these principles are self-evident to wide-awake students in the field, just as are so many other principles which we have pointed out. For example, "it is hard to conceive of a modern dendrology course that does not adequately elucidate the continuum of variation in trees and the emergence of species within a genetic/evolutionary framework." "Similarly, it is hard to discuss the diversity of tree species without considering adaptation, or adaptive strategies... A student should learn to think of the most probable selection pressures operative in different environments..." "A further case for a genetic approach to dendrology can be made in connection with interspecific hybrids. They abound in trees, yet seem to be singularly unpleasant to classical dendrologists and are only cursorily treated even in the latest editions of traditional textbooks." There is no shortage of well documented studies of hybridization in forest trees and research is continuing at an ever-accelerating pace. For one of the most recent of these, concluded at West Virginia University during the past month, see Johannes, 1979.

SUMMARY

As a summary of the value of dendrological field work, as it concerns the topics discussed above, the student is likely to emerge from the course with a lesser amount of encyclopedic knowledge but with a vastly greater knowledge of useful facts than if he took a course lacking in field work.

PLANT GEOGRAPHY

Field studies in dendrology must necessarily vary from one section of the country to another and the remaining sections of this study will deal briefly with some of these variations. Forestry students normally begin their education by becoming familiar in considerable detail with the forests of a particular geographical area; almost always, however, in their later career, they add to this initial experience a knowledge of one or more additional areas.

The vegetation of continental United States and Canada may be roughly divided into ten floristic provinces, not all of which include forests of commercial value. As classified by Gleason and Cronquist (1964), these are the tundra, the northern coniferous forest, the eastern deciduous forest, the coastal plain forest, the tropical or West Indian forest, the grasslands, the Cordilleran forests, the Great Basin, the chaparral, and the Sonoran desert.

The tundra, the grasslands, and the desert areas, in general, of course, lack forests, and will be omitted in the following discussions.

THE NORTHERN CONIFEROUS FOREST

This forest type, in a broad belt 500 miles wide, lies south of the tundra in Alaska and Canada but dips into the "Lower 48" of the states around the northern Great Lakes and in the mountains of New England. As the name implies, the forest is dominated by coniferous trees, the most characteristic of which are white spruce (*Picea glauca*), black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), and larch (*Larix laricina*). In drier places the forest may be composed of jack pine (*Pinus banksiana*), which may also be a successional tree. Three species of broad-leaved trees are also abundant in this general area, paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*).

The climate is cool and moist and most of the trees are fairly small. A field trip through such a forest may be very difficult because of low branches, fallen trees, frequent muskegs or bogs, and the difficulty of locating landmarks for guidance.

THE EASTERN DECIDUOUS FOREST

Originally this forest covered the major portion of the eastern half of the United States, with tall stately trees whose canopies formed almost unbroken crown covers. It was immensely variable, depending upon geographical areas and local ecological conditions, with dozens of species of commercial trees. Most of the virgin forest has now been removed in lumbering operations and much of the area is covered with second-growth forests in various stages of development.

Around the Great Lakes an intermediate type, which may be referred to as the Lake Forest, includes species of trees common farther north, or farther south, as well as some species most characteristic of this area alone, such as red pine (Pinus resinosa) or white pine (Pinus strobus).

In the higher, moister, Appalachians is a forest type known generally as the northern hardwood forest. Typical trees, among dozens of others, are sugar maple (Acer saccharum), red maple (Acer rubrum), yellow birch (Betula alleghenìensis), black birch (Betula lenta), beech (Fagus grandifolia), and cucumber-tree (Magnolia acuminata).

At lower elevations in the mountains and in the hilly sections is an infinitely varied mixed deciduous forest which may be roughly divided into xeric, mesic, and hydric communities, keeping in mind that the extremes on either end are not very extreme.

Among the xeric species chestnut (Castanea dentata) was formerly prominent, now removed by blight. Many kinds of oaks are found: among them may be named black oak (Quercus velutina), post oak (Q. stellata), scarlet oak (Q. coccinea), and shingle oak (Q. imbricaria). Hickories, including pignut (Carya glabra) and mockernut (C. tomentosa), are common, mingled with such pines as pitch (Pinus rigida) and Virginia (P. virginiana).

A still greater number of species may be classed as mesic. These include tulip-tree (Liriodendron tulipifera), white oak (Quercus alba), red oak (Q. rubra), black walnut (Juglans nigra), shagbark hickory (Carya ovata), bitternut (C. cordiformis), basswood (Tilia americana), black cherry (Prunus serotina), black gum (Nyssa sylvatica), and a host of others.

Among characteristic hydric trees are black willow (Salix nigra), sycamore (Platanus occidentalis), sweet gum (Liquidambar styraciflua), cottonwood (Populus deltoides), shellbark hickory (Carya laciniosa), pecan (C. illinoensis), American elm (Ulmus americana), silver maple (Acer saccharinum), and box-elder (Acer negundo).

Walking through a mature forest is easy and pleasant. There is a well-developed understory of shrubs but these are normally not troublesome. In spring, before the leaves are out on the trees, a multitude of low herbs expand their beautiful flowers.

It may be emphasized that the eastern deciduous forest includes a greater number of species of commercial trees than any other forest type in the country.

THE COASTAL PLAIN FOREST

This type is characterized by the presence of extensive pine forests, especially on the drier sites. Northwards pitch pine (Pinus rigida) is dominant. Farther south loblolly pine (P. taeda), slash pine (P. elliottii), and longleaf pine (P. palustris) are abundant.

In fairly moist areas hardwoods replace the pines; these include evergreen Magnolia (Magnolia grandiflora), live oak (Quercus virginiana), and southern red oak (Q. falcata). Beech, sweet gum, many other oaks and some species of hickory are also common. Marshes where water stands part of the year support forests of bald-cypress (Taxodium distichum); southern white-cedar (Chamaecyparis thyoides) is common in some boggy areas, known as pocosins.

Parts of the coastal plain are easily traversed on field trips; other areas may be too wet for walking, or infested with troublesome prickly vines.

THE WEST INDIAN FOREST

On the southern tip of Florida there was originally an extension of tropical forests. These include a very large number of woody species, but few of them have value as timber trees. One of the most characteristic trees, forming considerable stands, was the custard apple (Annona glabra); land formerly covered by these stands is now largely under cultivation. Low muddy seacoasts are covered with stands of tangled trees known as mangroves (Rhizophora mangle).

While providing a fascinating area for the study of many species of remarkable trees, this vegetational province does not lend itself to traditional dendrological field work.

THE CORDILLERAN FORESTS

The so-called Cordilleran Province occupies much of the area from the eastern base of the Rocky Mountains to the Pacific Ocean. At the north, in western Canada, it merges with the northern coniferous forest. To the south it is divided into two long prongs separated by the Great Basin.

This area is dominated by coniferous forests, although a few broadleaved trees occur; quaking aspen is the most widespread and abundant. Water is mostly a critical factor, although the section west of the Cascade Mountains is more moist than the Rocky Mountain area in general. The Pacific Northwest is the home of some of the tallest, most magnificent forests found anywhere in the world.

In the lower portion of the Rocky Mountain forest the most characteristic tree is ponderosa pine (Pinus ponderosa). Farther up, the most dominant tree is Douglas fir (Pseudotsuga menziesii), while the highest forest zone is characterized by alpine fir (Abies lasiocarpa) and such spruces as Engelmann spruce (Picea engelmanni), northwards, and Colorado blue spruce (P. pungens), to the south. Lodgepole pine (Pinus contorta) is a frequent tree at middle elevations. The bristle-cone pine (Pinus aristata) may attain the greatest age of any living things.

In the Pacific Northwest the most common trees are Douglas fir, one of the most valuable timber trees in the world, western hemlock (Tsuga heterophylla), and western red cedar (Thuja plicata). At higher elevations these give way to mountain hemlock (Tsuga mertensiana) and western white pine (Pinus monticola). Along the coast, scarcely ever 30 miles from tidewater, from southern Alaska to northern California, Sitka spruce (Picea sitchensis) is a dominant tree; Alaska cedar (Chamaecyperis nootkatensis) is often associated with it, as are various firs, including Pacific silver fir (Abies amabilis). In northern California are the famous forests of redwood (Sequoia sempervirens), the tallest trees in the world.

The Sierra Nevadas have a forest type the aspect of which somewhat resembles that of the Rocky Mountains. Some of the same species of trees occur, notably ponderosa pine. But there are also species whose range is more restricted, as Jeffrey pine (Pinus jeffreyi), sugar pine (P. lambertiana), and red fir (Abies magnifica). Among the best known are the bigtrees (Sequiodendron giganteum), the most massive of all living beings.

Dendrology field trips in the Cordilleran forests may be the most rewarding of all. The scenery is magnificent, ranging from sea level to over 14,000 feet above sea level, the trees are also often magnificent, the associated vegetation extremely varied. The climate ranges from very dry to the rainiest in North America.

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PUTTING THE Dendrology BACK INTO DENDROLOGY

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SUMMARY

The primary orientation in Dendrology instruction should be on the audience we teach, not on any arbitrary definition of the science. Field phases of DENDROLOGY, the course, should stress identification of whole trees, for which arboreta should be developed, and lecture should include slide show presentations of the ecology and natural history of each species across its range. The current decline of Dendrology in college curricula might be reversed if professors interpreted the subject liberally as "the study of trees," not exclusively as "the taxonomy of woody plants."

INTRODUCTION

With your indulgence, I would like to state my views on the nature and the role of Dendrology, the subject, in a college curriculum, and then explore one way DENDROLOGY, the course, may be presented as a synthesis of topics, not exclusively the taxonomy of woody plants. Naturally, I must refer specifically to our two courses at Syracuse to explain one way that philosophy may be put into practice, but I believe the central theory and philosophy of our approach is adaptable to most curricula in other forestry programs and institutions.

THE PHILOSOPHY

The key question we face, I believe, is what is the purpose of the Dendro course in the student's curriculum? Where do our students go, what careers do they follow, and how does the DENDROLOGY course influence their professional achievement?

In effect, I am suggesting our primary orientation in Dendrology instruction should be on the audience we teach, not on the subject we present. Although Dendrology, a science, is our specific purpose in being in the classroon, DENDROLOGY is only one of many courses the students must study in an all-too-crowded curriculum while pursuing their college education. In practically all cases, their "Dendro" is one of many ancillary subjects supporting a curriculum concentration elsewhere in forestry or natural resources; few go on deeply into the topic, either now while in college, or later in their professional lives. This fact should make us cautious, perhaps humble, in going too deeply into the fine details and particulars of our discipline, as we the specialists may perceive them. Realistically we should be aware many of our students (and colleagues!) understand this point in advance and accordingly most members of our audience are subconsciously but continuously selecting out only the most relevant points from our lectures, however detailed and intense our presentation may be.

Further, we must accept the fact none of us can afford to retain for long the secondary and tertiary levels of information, the mass of supporting detail and data that amplify the important key points we stress. Such banks of information are always available when and if needed at some future time; in Dendrology we are lucky--blessed with hundreds of excellent books and bulletins, for example, at all levels of complexity and breadth. The professor, accordingly, should assist his audience of students by deliberately and carefully selecting a limited assortment of highlights that will serve as keystones, so to speak, upon which varying secondary points may be constructed, some selected by the professor as the course goes along, others picked up by the students from the lectures, field trips, readings, and the like. At the end of the course, then, each student will hopefully share mastery of certain common highlights but they individually will also have selected out those lesser points personally relevant and of interest to them individually. This framework of individualized Dendrology information, I hold, should be the ultimate goal of any DENDROLOGY course, regardless of curriculum concentration.

To provide the "keystones," therefore, the professor must interpret and present Dendrology in its broadest dimension, liberally as "the study of trees," remembering that to a large portion of his audience the DENDROLOGY course will become part of their general education, a subject which hopefully will interest them the rest of their lives even though it may only peripherally involve their professional competence or responsibilities later in life.

My own experiences at Syracuse tell me that the "generalist" in the classroom audience far outnumbers the "dendrologist" per se, and, more importantly, that Dendrology broadly presented can have a life-lasting impact upon this majority group if we are skillful in developing the future interests of our students in the subject while presenting the current importance.

I hasten to add that I do not believe DENDROLOGY courses need be so polarized, one way or the other, as outlined here with Dendrology either presented sensu latu, liberally as "the study of trees," or sensu stricto, exclusively as "the taxonomy of woody plants." Both objectives, once recognized and appreciated, can be incorporated into a single course if the laboratory phase concentrates on the need to recognize species and the lectures on the need to understand species.

THE SYNTHESIS

Given this educational philosophy, the basic problem then becomes a matter of distilling out those elements of Dendrology, however defined, appropriate for our many students in their several curriculum concentrations. Viewed as a particular synthesis of information drawn from various sources, Dendrology instruction at Syracuse is organized into two courses, a core course and an advanced one.

Dendrology I, as we call it, is a sophomore-junior level course of 3 credits which serves primarily students in resource management and in environmental sciences, an audience of about 300. Over the 25 years I have presented this course--since my friend and mentor Dr. William H. "Bill" Harlow retired--we have settled on a selected core of 80 tree species to be known in detail. The weeding out process, spread over several years of trial and error, was based on three criteria: (1) ecological importance of the species in natural ecosystems; (2) economic importance of the species in the country today; (3) taxonomic diversity and biological interest. These 80 tree species we have agreed upon constitute only 10% of the tree flora of North America but represent nearly 90% of the harvest, so to speak. Admittedly, there is a certain personal-professional bias in any such grouping, but in any case the 80 species represent a reasonable intellectual effort for a 2-lecture, 1 3-hour lab per week course.

The Dendrology II course is designed primarily for those students wishing greater field competence with regional woody plants plus acquaintance with secondary tree species native elsewhere in other states. The 120 species covered are studied primarily for field identification and characteristics; there are no separate lecture periods as such in the course dealing with silvical characters or natural history, though those topics automatically come out in response to student inquiries as the species are encountered. Most importantly, after completing this second Dendro course, students can complete field studies in their respective concentrations knowing essentially all the native woody plants in Central New York except for several locally escaping exotic ornamentals.

We make minimal use now of any standard Dendrology textbook, at least for routine work. Instead I have written a course manual for each of the two courses; the respective manuals provide the minimum botanical diagnosis necessary for field identification of these species, plus other textual materials coordinated with the field, laboratory, and lecture instruction. The manuals (Ketchledge, 1979a,b) are an essential tool for summarizing the keystone highlights of each species.

THE COVERAGE: FIELD AND LABORATORY - 50%

Because field competence in identifying tree species is the central purpose of our section meetings, we believe three skills must be programmed into Dendrology field and lab work:

1. Recognition of all 80 species as living organisms in the field. To that end, we have all 80 Dendro I and most of the 120 Dendro II species planted (1) as ornamentals on our main campus, or in our several tall glasshouses if they are temperature sensitive; (2) individually or in small groups at our 40-acre arboretum-experiment station four miles from campus; and (3) in the eight city, one county, and one state parks we visit the first seven weeks of the semester. We believe it is absolutely essential the students see and study the living plants, whole trees, at various ages and growing under various conditions. Developing such arboreta should be the second major professional responsibility of the professor in charge, second in importance only to the meeting of classes.

2. Because the professional forester or biologist often receives specimens to identify, we believe graduates should be competent in making identification with partial evidence, with only twigs or cones or fruit provided. Accordingly, we spend our last six weeks in the laboratory studying these materials, using fresh or dried materials collected from most of the core 80.

3. In order to identify unknowns, or to verify tentative identifications, skill in the use of keys to foliage, to cones and fruit and to twigs is essential. All of our indoor lab work is based upon the use of keys.

In short, in the laboratory and field phases of DENDROLOGY we do teach Dendrology *sensu stricto*!

THE COVERAGE: LECTURES - 50%

Here in the lectures we are as wide-ranging as the interest of our clientele, the inquisitive student. Here is where we interpret Dendrology liberally, *sensu latu*, as "the study of trees!"

First of all, in our beginning course, we discuss species grouped by forest regions, as follows:

BOREAL FOREST

1. Populus tremuloides
2. Populus balsamifera
3. Betula papyrifera
4. Pinus banksiana
5. Larix laricina
6. Picea mariana
7. Picea glauca
8. Abies balsamea

NORTHEASTERN FORESTS

9. Betula alleghaniensis
10. Betula populifolia
11. Fagus grandifolia
12. Acer saccharum
13. Pinus strobus
14. Pinus resinosa
15. Pinus sylvestris
16. Picea rubens
17. Picea abies
18. Tsuga canadensis
19. Thuja occidentalis

CENTRAL HARDWOOD FORESTS

20. Salix nigra
21. Populus deltoides
22. Juglans nigra
23. Juglans cinerea
24. Carya ovata
25. Carya cordiformis
26. Ostrya virginiana
27. Quercus alba
28. Quercus macrocarpa
29. Quercus rubra
30. Quercus velutina
31. Quercus palustris
32. Ulmus americana
33. Celtis occidentalis
34. Magnolia acuminata
35. Liriodendron tulipifera
36. Sassafras albidum
37. Platanus occidentalis
38. Prunus serotina
39. Gleditsia triacanthos
40. Robinia pseudoacacia
41. Acer rubrum
42. Acer saccharinum
43. Acer negundo
44. Tilia americana
45. Nyssa sylvatica
46. Cornus florida
47. Diospyros virginiana
48. Fraxinus americana
49. Pinus rigida
50. Juniperus virginiana

SOUTHERN OAK-PINE FORESTS

51. Quercus phellos
52. Quercus nigra
53. Liquidambar styraciflua
54. Ilex opaca
55. Pinus echinata
56. Pinus taeda
57. Pinus elliottii
58. Pinus palustris
59. Taxodium distichum
60. Chamaecyparis thyoides

ROCKY MOUNTAIN FORESTS

61. Pinus flexilis
62. Pinus ponderosa
63. Pinus contorta
64. Picea engelmannii
65. Picea pungens
66. Abies concolor
67. Pseudotsuga menziesii
68. Cupressus arizonica

CALIFORNIAN FORESTS

69. Umbellularis californica
70. Pinus lambertiana
71. Sequoia sempervirens
72. Sequoiadendron giganteum
73. Calocedrus decurrens
74. Chamaecyparis lawsoniana

PACIFIC NORTHWEST FORESTS

75. Alnus rubra
76. Pinus monticola
77. Picea sitchensis
78. Tsuga heterophylla
79. Abies grandis
80. Thuja plicata

Each species is discussed, about 15 minutes at a time, in the same casual, natural history "recounting" fashion as students think of the trees, starting with some distinctive "keystone" features and building up several separate sub-themes about each. The story-telling approach may not seem very sophisticated, but it is effective because at least one of the sub-themes will "touch" every student, regardless of curriculum concentration, and subconsciously becomes a bridge or framework on which to store the supporting details. The best literary example I can think of that parallels our oral presentation is that of Arno and Hammerly (1977) in their "Northwest Trees," a simply fascinating account of trees that quickly charms every student who picks it up.

After we have reviewed the species in a particular forest region, we have one or two slide shows reviewing each species; as it is seen across its range; how it is recognized subjectively from a short distance or up close; what its habitat or association relationships may be; how it is used as an ornamental or planted for production or harvested; what disease or pest problems may plague it; how it regenerates after logging; all those things that become part of the personal history of people who work with the trees year in and year out.

Obviously, the preparation of a thorough set of color slides, transparencies, of each species is the other major professional responsibility of a Dendrology professor, much as is the creation of arboreta of living specimens. To that end, the lecturing DENDROLOGY professor must devote a significant share of his annual personal and professional time traveling to other forest regions, taking photographs of forest trees in all their dimensions, so that his students can see and perceive those species through his eyes. With living specimens and with good photographs, a professor's effectiveness is multiplied many-fold. Both should be made department requirements for whoever is given the DENDROLOGY assignment (privilege!).

I have talked too long, for which I beg your indulgence. Let me conclude with one central thought. I personally believe the declining importance of DENDROLOGY courses we witness today can be reversed if we give up the strict interpretation of our discipline (taxonomic) and tell the student more about the exciting uniqueness of each species, not only botanically but in those biological, ecological, economic, cultural dimensions that highlight each species across its range. Thus broadly interpreted, Dendrology can be a liberalizing influence long after the student has left our classroom and long after he is settled into his professional career, wherever that may be.

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A QUARTER-CENTURY OF TEACHING DENDROLOGY

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One of my most rewarding experiences in 26 years as a forestry educator has been teaching dendrology. I have taught this subject in various capacities for 34 semesters of approximately 100 contact hours each, with a total enrollment of over 1500 students. If preparation time is included, about 8,000 hours would probably be a fair estimate of the time I have officially devoted to dendrology during the past quarter-century. Nevertheless, I am still enthusiastic about helping students "know their trees" (and shrubs) and look forward eagerly to meeting each new dendro class for I continue to enjoy sharing my knowledge with others and to adding to it each year.

Much of my early experience in teaching dendrology was at the technician-level in our 2-year Stockbridge School of Agriculture, where I taught for 8 years. When this program was discontinued in 1962, I assumed responsibility for the dendrology course in our professional forestry curriculum. Traditionally, this 3-credit course had been offered only during the spring semester and concentrated almost entirely on the winter characteristics of trees with little or no attention given to other woody vegetation. Several course changes have occurred since then. The laboratory check list has been expanded to about 160 species which include all the native trees, shrubs and vines in the Amherst area as well as certain exotics which are commonly planted in the Northeast. The course was offered both semesters for the first time in 1972-73. This was done not only to meet the increased enrollment of forestry students but also to accommodate non-majors wishing to study dendrology. Opening the course to any student, including those at other colleges in the area, resulted in an enrollment of over 200, the maximum number served in any one academic year (Table 1). Since then we have limited our enrollment to 80 per semester and about 150 students complete the course each year. Changes in the forestry curriculum and certain administrative factors caused a marked reduction in the enrollment this past spring. We will be experimenting with "block teaching" this fall and dendrology is one of the courses to be included. Over 50 percent of the students who have completed our dendro course over the past six years have been non-majors and 15 percent were students outside our department (Table 2).

LABORATORY INSTRUCTION

Laboratory class time consists of two, 2-hour sessions each week and 50 percent of the course credit and grade is granted for this work. Students learn the scientific and common names of all species in the check list and are assisted in doing so by the administering of two name-quizzes per week for 5 weeks plus a final exam of 150 species. During the spring semester, major emphasis is placed on the use of winter keying, using twig specimens brought into the laboratory. Colored slides and other visual aids, especially the overhead projector, are utilized in presenting the major identifying characteristics of each species. Classes are held in the field after our spring recess (mid-March), weather permitting. This arrangement has the advantage that students acquire, in advance of field work, the knowledge necessary to identify and name all the species to be encountered. They are disadvantaged by the fact that the semester ends early in May and thus they do not see many species in full foliage.

In the fall semester course, the students are also assigned the scientific names on a semi-weekly basis, as in the spring, but must learn them concurrently with their field identification work. This handicap is offset by the presence of all identifying characteristics, more favorable weather conditions and a longer season of outdoor labs. Inside work, using winter keys, starts when we change to Standard Time which usually coincides with leaf-fall and onset of cold weather.

The number of species involved imposes quite a challenge to the average student to become proficient in identification. Little time is available for introducing other dendrological subject matter. However, our spring course does include an assignment of phenological observations and the fall semester has contained exercises in vegetation sampling.

We have used Graves' (1956) book for identification for many years because we have not found any other publication to match it for economy of price, conciseness of descriptions and completeness of coverage of both native and naturalized trees and shrubs. Our high regard for this book comes as a result of trying numerous other publications which all fall short of meeting our needs largely because of our emphasis on the shrubs. I have also written my own manual for identifying the species on our check list. Several other books are used by the instructors and teaching assistants that are not ordered for student purchase. These include Symonds' (1958, 1963) two books on tree and shrub identification; Viertel's (1961) pictorial guide to ornamental woody plants in the Northeast: Rehder's (1937) manual of cultivated trees and shrubs; and Little's (1953) check list of native and naturalized trees. H.P. Brown's (1938) old book, in my opinion, is still one of the best ever published. Native trees of Canada (Hosie 1969) and North American Trees (Preston 1976) are also used.

Until a few years ago, our laboratory sections were all taught exclusively by those faculty members best qualified to do so, regardless of academic rank. I am sure that no one ever felt that they were debased by this responsibility which has been shared through the years by the youngest instructor to the most senior professor and even the department head.

With changes in the faculty and more emphasis on research and graduate study, we have been able to employ students to teach some of the labs. Generally, these have been graduate students under teaching assistantships. However, we have used undergraduates, when qualified graduate students were not available, and they have generally performed extremely well. Another form of assistance has come about by a policy of offering academic credit for assisting in dendro labs and we have had excellent participation by both undergraduate and graduate students. They usually serve as an aid to the regular instructor at the beginning of the semester and after a few weeks are placed in charge of a sub-section of the lab. Credit is granted by a special course designated for such a purpose - Independent Study-Teaching Aid. Students benefit in several ways from this training. They receive experience in teaching, which appears on their academic transcript, and they also become more knowledgeable and proficient in dendrology skills. A student who takes the fall course and helps teach it in the spring (and vice versa) has an excellent opportunity to round out his capabilities in woody plant identification.

Although there is a good representation of species on or near the University campus, we lack a good arboretum of native and naturalized trees and shrubs. Therefore, it is very desirable to schedule several field trips to selected off-campus sites to view certain species which would not otherwise be seen by the students and to visit different types of plant communities. These trips are, by necessity, limited to a radius of 5-10 miles because our lab periods are so short. Ideally, we should lengthen them to 3 hours so that we could see more and learn at a more leisure pace. I always seem to have a greater sense of urgency than do my students for there is always more to see than we have time to look at and more to look at than we have time to learn.

I cannot conceive of a more pleasant duty than to conduct a dendro lab on a beautiful autumn afternoon in New England when the leaf-colors of the angiosperms are at the height of their splendor. It is rivalled only by a similar task on a warm April day when the promise of spring has been kept, trees and shrubs are in flower and the phenology of their foliage fascinates even the more apathetic students as they view the vernal transition of the forest landscape. No wonder that in comparison dendrology lectures seem dull, even if novel or innovative.

DENDROLOGY LECTURES

Lectures in dendrology at the University of Massachusetts deal more with forests than with trees even though the two courses are taught by professors of quite different academic backgrounds and professional interests. We feel that our laboratory class time (60 percent of the course), which concentrates upon the development of identification skills, is sufficient to meet this major objective of the course without further discussion in the lecture room except for a few introductory lectures on taxonomy.

Student acquisition and appreciation of ecological, sociological and economic knowledge of forest vegetation constitutes the other objective of the course. Thus, we encourage students to learn the names, distribution and important silvical characteristics of the major tree and shrub species throughout the United States and Canada and provide special lists for this purpose. Students are expected to acquire much of this type of information on their own through readings in the textbook (Harlow et al. 1979) and other sources such as Silvics of Forest Trees of the U.S. (U.S. Forest Service 1965).

A majority of the lectures deal with the composition and distribution of forest types, by regions, emphasizing vegetation dynamics and the genetic, ecological and historical factors responsible for species distribution. Forest land-area statistics and the economic importance of major species and forest types are stressed. Colored slides are shown extensively and transparencies of range maps of major species are used on the overhead projector. A few movies have become valuable aids and we wished that there were more available such as: The Boreal Forest; Life in the Deciduous Forest; and The Wisconsin Forest. I believe that students should gain much more knowledge of the silvical characteristics of trees and shrubs than for what they are held responsible in dendrology. However, our silvics course picks up where dendro stops, and the instructor emphasizes this type of information in about 15 percent of his course.

Ideally, we hope that our students are broadly educated in the fundamentals of dendrology. The foundation for this accomplishment is achieved by becoming familiar with the local vegetation, learning the techniques for identifying unknown species and developing a capability for anticipating species to be encountered anywhere in the country. More detailed and specific knowledge of the distribution, ecology and value of individual species is the product of the instructors lecturing efforts and the self-study and motivation of the individual student.

We do not expect all students in our dendrology classes to be equally enthusiastic about all its content. Our course offering might be considered to be somewhat of a "smorgasbord" with something especially appealing, and useful for all. We do not expect non-majors to accept all items with the same appetite as forestry students and in many instances, personal gratification may be equally significant as professional competence in the dendrological diet of the students we strive so hard to nourish.

PHILOSOPHY OF DENDROLOGY

I suspect that everyone who has ever taught a course in dendrology has a personal philosophy regarding the content and methodology which best serves the interests and goals of the students who take it. That such teachers should be biased by their own training and professional specialization is understandable. However, any dendro course with sound objectives, a knowledgeable and enthusiastic instructor, good laboratory facilities and an adequate number of class hours should provide an optimum learning opportunity for students. Who teaches the course, in most instances is not important - whether a full professor or young instructor, botanist or forester. When I studied dendro at the University of Maine, it was under the tutelage of a botany professor. However, he had a forestry background, a perspective of the profession and a teaching ability and personality which caused his students to esteem him highly. I considered dendrology to be the best forestry course in the curriculum. Field trips were fun and the highly compatible student-teacher relationship is as important to me as a teacher as when I was a student and for this reason I have always made a special effort to become acquainted with our students as early as possible in their four years with us.

Teaching dendrology, because it has always been a freshman or sophomore course, has provided me with an excellent chance to do so.

The large increase in the number of students in forestry schools has necessitated assigning much of the laboratory instruction to non-faculty personnel or left the student to educate himself by the self-study method. This is unfortunate for by so doing a unique opportunity is lost to develop better student-faculty communications and students are deprived of the personal contacts with their teachers which can be very meaningful, especially during their pre-forestry tenure as undergraduates. The dendrology lab is a great place to reveal to others, both forestry students and non-majors, the beauty, diversity and dynamics of the forests which dominate so much of our American landscape. There is no better testing-ground for a teacher, whether young or old, to meet the ever-present challenge of helping those who are enthusiastic to learn as well as changing the attitudes of those too apathetic to do so.

Even in the lecture room, the dendro teacher is in an advantageous position to interest his students in forestry. This can be very important in the case of non-majors, for he can help them acquire an understanding of our profession and the societal roles of foresters. Dendrology for many students is the first, last and only formal education which may influence their attitudes toward forestry and the difference between preservation and conservation of our forest resources.

Numerous papers have been published in recent years regarding dendrology education. Some myths have been created and some destroyed. The course is said to be controversial because no one knows what it is and that those who teach it reach into other disciplines for material (Steiner and Kunsman 1979). I think it is a healthy attribute to be controversial and I am glad that dendro teachers are not in academic straight-jackets or so professionally static that their subject matter is restricted to definitions of earlier eras. I don't know of any forestry course that does not reach into other disciplines if well taught and I suspect that there is as much diversity in the methodology and subject matter in some other courses as there is in dendrology. The three contemporary textbooks in silvics imply that considerable latitude is exercised in the teaching and interpretation of this subject. Even a stereotypic course such as silviculture varies tremendously from school to school, depending upon the geographical location and the professional idiosyncrasies of those who teach it.

I am sure that there are several ways of teaching dendrology, each having its own merits, sufficient to produce a good course. However, innovation does not necessarily result in improvement and substituting gadgets for guidance can be an abandonment of instructional responsibility. Good dendrologists are made not born and good teaching is essential for the making thereof.

I suspect that many who have devoted much of their professional lives to teaching dendrology suffer from the same syndrome as I do - frustration over the unimportance of the subject in the minds of so many in forestry and wildlife management. Dendrological ignorance prevails among these professions and too often graduate degrees are granted to those with little if any plant identification skills or knowledge of dendrology subject matter.

Pathetically humorous stories abound of the dendro-deficiencies of those responsible for the management of our forests for wood, wildlife, water and recreation, yet conservation educators and other professionals stoically accept this lack of knowledge.

The conscientious teacher, if a forester, regrets the dendro shortcomings of his students who display such meager interest in trees, even after graduating and becoming employed in the profession. He also feels sorry for those who should have taken his course but did not because they were not required to do so or their faculty advisors, though professional conservationists, did not consider it important that they should.

I have never seen a "born again" dendrologist. Good dendrologists are people who had a good course in college and who thereafter maintained a proficiency in identification skills, taking pride in knowing their trees, shrubs and vines. Those foresters, wildlifers and other conservationists who are content to depend on others to tell them what the trees are have a poor vision of our forests and do their professions a disservice.

Let's face it, "dendrological dumbbells" are nice people and you don't have to know your vegetation to be a specialist or expert in telling others how to manage it. I am grateful that the medical profession isn't that tolerant toward their training in anatomy!

Table 1. History of Enrollment in Dendrology September 1964-May 1979*

	Fall Semester				Spring Semester				
		#Students	Instructional Hours			#Students	Instructional Hours		Annual
Year	#Students Enrolled	Rejected (Est.)	Weekly Lect. Hours	Weekly Lab Hours	#Students Enrolled	Rejected (Est.)	Weekly Lect. Hours	Weekly Lab Hours	Enroll. (#Students)
1978-79	78	10	3	16	35	0	3	12 (3 sections)	113
1977-78	76	15	3	16	57	0	3	16 (4 sections)	133
1976-77	82	20	3	16	85	10	3	16 (4 sections)	167
1975-76	86	20	3	16	83	20	3	16 (4 sections)	169
1974-75	103	20	3	16	79	0	3	16 (4 sections)	182
1973-74	97	25	3**	16	79	0	3	16 (4 sections)	176
1972-73	103	25	2	12	101	25	2	16 (4 sections)	204
1971-72	Not Offered				Not Offered - Shifted to Fall Semester (Instructor on Sabbatical)				
1970-71	" "				69	0	2	16 (4 sections)	69
1969-70	" "				50	0	2	12 (3 sections)	50
1968-69	" "				28	0	2	12 (3 sections)	28
1967-68	" "				50	0	2	12 (3 sections)	50
1966-67	" "				58	0	2	12 (3 sections)	58
1965-66	" "				45	0	2	8 (2 sections)	45
1964-65	" "				27	0	2	8 (2 sections)	27

* Figures are of number students completing course. Initial enrollment 10% greater (approx.).

** Credits increased from 3 to 4.

Table 2. Dendrology Enrollment by Major September 1973-May 1979.

Year	Forestry	Natural Resources	Wildlife	Wood Technology	Other	Total
1978-79	57	10	5	31	10	113
1977-78	63	28	16	10	16	133
1976-77	72	52	3	10	30	169
1975-76	51	51	9	15	43	173
1974-75	92	46	10	10	24	182
1973-74	98	35	13	12	18	176
Totals	433	222	56	88	141	940
Percent	46	24	6	9	15	100

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WOODY PLANTS AHEAD

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Dendrology is evolving in many ways, and the purpose of this paper is to examine its evolution in action on several fronts and to give examples of some of these directions based on our sequence of woody plants courses at the University of Michigan. "Woody Plants Ahead" embodies one of the most important recent changes, the evolution of Dendrology as study of trees only to the study of all woody plants--trees, shrubs and vines including their identification, biology, ecology, and uses. The broad woody plants approach leads directly to two other important and evolving areas. A holistic ecosystematic approach is becoming the cornerstone of education in natural resources and forestry, and the Dendrology of Woody Plants course now has the opportunity to push ahead in introducing this concept to beginning students. The broadened emphasis on woody plants as a group and their place in the ecosystem leads to the amplification of the student body from that of foresters only to the university community, as well as the public at large through continuing education courses. In addition, there are a variety of new teaching approaches and techniques now available to get across our message of the role of woody plants in terrestrial ecosystems to an increasingly wider audience. In the following sections I describe these major features of the evolving dendrology scene, and conclude with some aspects of our Woody Plants sequence at The University of Michigan and the status of woody plants teaching in the year 2000.

EVOLUTION FROM DENDROLOGY TO WOODY PLANTS

In the past Dendrology was devoted to the practical study of trees, primarily their identification, wood properties, and uses. This followed naturally upon the rise of commercial forestry and concentration of interest and research on the important coniferous species plus a few hardwoods. In time, more and more tree species were added, together with some of the important shrubs. A parallel is evident in the publication sequence of the five volume Atlas of United States Trees which presents the natural distributions of tree species. The first volume (Little, 1971) contains the conifers and some important hardwoods, 200 species in all. Later, volumes 3 and 4 were devoted to "minor" western hardwoods (Little, 1976; 210 species) and "minor" eastern hardwoods (Little, 1977); 166 species). Volumes 2 and 5 deal with trees (and some shrubs) of Alaska (Viereck and Little, 1975) and Florida (Little, 1978). Only a few shrubs are considered (primarily in Alaska), but it is only a matter of time before the North American ranges of shrubs will also be defined and published. It is also significant to note the change of emphasis in a major text from the Physiology of Trees (Kramer and Kozlowski, 1960) to the Physiology of Woody Plants (Kramer and Kozlowski, 1979).

The treatment of shrubs and vines in Dendrology courses is currently much less than that of trees, but it is undoubtedly greater than 50 or 30 years ago. Steiner and Kunsman (1979) reported that an average of 28 shrub species "were covered" by professional and technical schools. In contrast, some knowledge at professional schools was required of 178 trees and identification required of 134 species (values for technical schools were 115 and 77). At the University of Michigan we currently require identification of 86 shrubs, 41 percent of the total. Ultimately, it is not the number or percent of shrubs taught that is important but the focus and significance of the instruction. The perceived idea today is that Dendrology deals only with trees. However, it is a more inclusive and significant experience to offer the fascinating diversity of woody plants as an interacting group.

Why Teach and Learn Shrubs and Woody Vines?

Trees are obviously important because they dominate the forest community, and many are of important commercial value. Despite moans and shrieks of students having to learn shrubs and vines, as well as "all those trees," shrubs are vital components of the forest ecosystem, and well worth knowing on their own merits as the points below bring out.

* Shrubs may have been the original flowering plant ancestors from which not only trees but also herbaceous plants arose (Stebbins, 1974). "Shrubs exemplify more than any other kinds of plants the great plasticity that has been largely responsible for the outstanding success achieved by flowering plants" (Stebbins, 1972).

* Many shrubs have relatively narrow tolerance ranges to site conditions and can be used effectively to determine site quality by their presence, absence, cover, and abundance. Following logging or fire, shrubs may provide important clues to site quality to the knowledgeable observer, whereas trees may be absent or of lesser indicator value.

* Shrubs and vines are important functionally in the forest ecosystem. They recycle substantial quantities of nutrients, particularly when the stand is open as in the juvenile stage of development. Following fire or logging, shrubs and vines resprout or are released and grow vigorously thus reducing erosion. They also absorb and store nutrients that might otherwise be carried away by overland flow or be leached into the subsurface water table.

* Many of the shrub species have become highly prized landscaping and decorative plants. Examples of genetic variation in the form of varieties or cultivars can be graphically presented in shrub genera, for example in Rhododendron, Rosa, Euonymus, and Ilex.

* Shrubs often provide specific conditions that are conducive to the establishment of trees. They are often present in an earlier successional stage and provide shade or create microsites that enable certain tree species to become established. In grazed forests and old fields armed shrubs, such as species of Rubus, Ribes, Smilax, and Rosa, provide havens for the establishment and growth of trees that would otherwise be killed by browsing.

* On the contrary, shrubs may sometimes be managed, with or without resort to herbicides, along rights-of-way (highways, railroads, electric transmission lines, long-distance telephone lines, open irrigation ditches, and pipelines) so that the succession to trees is retarded and a relatively stable low vegetation is maintained (Niering and Goodwin, 1974; Niering, 1978, 1979).

* Shrubs and vines compete with tree species. They may prevent seedling establishment, kill trees by strangling and overgrowing, and utilize water and nutrients that otherwise would be available to trees. The invasion and take-over of forest sites by shrubs and vines is a primary consideration in the silvicultural management of forests, particularly in the West. The problems created by strageler figs in the Tropics, Japanese honeysuckle and kudzu in the South and Southeastern United States are well known. Even grape vines may cause serious problems to young stands on better sites in the Appalachian Mountains (Trimble, 1977).

* Shrubs and vines have enormous wildlife value for food, shelter, and hiding. In turn wildlife species influence greatly the life of forest trees (Spurr and Barnes, 1980, chapter 13). Insects were instrumental in the evolution of angiospermous trees, and pollinate many tree species. Birds and mammals feed on shrub fruits, seeds, and foliage, disperse tree seeds, and help prepare sites for seedling establishment. Rodents provide aeration, channels for water movement, and mixing of organic matter with mineral soil by their burrowing activities. Animals may cause significant damage to trees and sometimes regulate species composition and density. Obviously not all animal activities can be related directly to shrubs and vines, but the significance of shrubs in the population dynamics of animals should not be underestimated. Shrubs can serve as a valuable teaching device to introduce the animal component of the ecosystem, and their specific interrelationships with plants can be described.

Although I have chosen to emphasize Woody Plants in this brief look at the progress of Dendrology, it is but an intermediate point in the evolution of its subject matter content. One sees that further evolution would bring us to the biotic community (and not just trees or woody plants) as the focus of the first field identification course in the forestry or natural resources curriculum. Such a course might be titled "Forest Communities" and would stress the identification and biology of selected species of all groups of plants and the major animals of selected local and regional ecosystems. It is a course that might be innovatively team-taught by a botanist, forest biologist, and a wildlife biologist.

The diagram below illustrates certain features of this kind of model.

Evolutionary Stage	PAST	PRESENT	FUTURE
Course Title	Dendrology	Woody Plants	Forest Communities
Organisms	Trees	Trees, Shrubs, and Vines	Selected woody plants, herbaceous plants, mosses, lichens, fungi, animals, etc.
Subject Matter Content	Identification Uses Wood properties Ranges (Biology and ecology)	Identification Biology and Ecology Plant geography and ranges Uses	Identification Biology and ecology Ecosystem dynamics Plant and animal geography Uses
Next Related Courses in Curriculum	Tree Physiology Forest Ecology or Silvics Wildlife Biology and Ecology	Tree Physiology Forest Ecology or Silvics Wildlife Biology and Ecology	Plant Physiology Forest Ecology or Silvics Wildlife Biology and Ecology

In the study of shrubs and vines we deal inescapably with the interrelations between them and trees, other plants, animals, and their physical environment of soil and air. Although the organisms we teach may increase in diversity, as we expand from trees to woody plants, they need to be taught within an ecosystematic approach--the subject of the next section.

EVOLUTION FROM SINGLE FACTOR APPROACH TO THE HOLISTIC OR ECOSYSTEMATIC APPROACH

The forest ecosystem comprises the forest community of trees, shrubs, associated other plants, animals, and the physical environment (habitat or site) surrounding and available to the biota. The living community of plants and animals is affected by the physical environment of atmospheric and soil factors and the community in turn affects and modifies the physical factors. This reciprocal interaction of biotic and physical components forms a dynamic system that constantly changes in time and space.

Although the idea of an ecological system or ecosystem of interacting parts is of great antiquity, the decade of the 1970's marked the beginning of an era in which we can deal with ecosystems as a whole on a scientific basis. Foresters and wildland managers can no longer respond to each new crisis by simplistic studies of isolated factors. The totality of the forest system must be recognized so that the effects of disturbances or treatments to one component, clear cutting the forest overstory for example, can be interpreted on the other system components.

Dendrology or Woody Plants, being typically the first major course in which students have the opportunity to consider the forest community and the physical site factors is the ideal time to introduce the ecosystem concept and illustrate it graphically in field laboratories. Instructors must not only stress individual plant characteristics but discuss the whole plant in relation to its environment. For many plant species the habitat is an extremely important supplementary diagnostic identification characteristic. In more advanced courses the details of ecosystem structure and function can be presented. However, the exciting challenge is here for the dendrology professor to lay the foundations.

EVOLUTION FROM FORESTRY STUDENTS TO ACADEMIC COMMUNITY AND PUBLIC AT LARGE

The Woody Plants course taught in an ecosystematic framework offers great potential for a markedly broadened and expanded audience. At the University of Michigan and some other schools the adoption of a woody plants approach has meant a change from a narrowly packaged course in the Forestry Department to a widely elected university-wide course. It is not only stimulating for the instructors to teach a diverse group of interested students, but the increased visibility and insight into forestry programs and environmental concerns is substantial. It is ironical that Dendrology, which was often in the past considered a deadly and boring identification course, is potentially one of the few areas in Forestry that can generate university-wide appeal.

Public interest is also very high in woody plants because of both naturalistic and ornamental aspects, and a course that offers more exciting fare than pure identification of trees can be very successful. For example, during the past 12 years at the University of Michigan, Professor Warren H. Wagner, Jr. has taught a non-credit Woody Plants course in the fall with enrollments of 25-40 people ranging in age from 16-75. The public arena for the teaching of a Woody Plants course is just opening up and we can expect major advances in this area by the year 2000, especially in view of the trend toward lifetime learning.

EVOLUTION OF TEACHING TECHNIQUES

Judging by the number of published papers on the nature of Dendrology, course content, and teaching techniques, this appears to be the most controversial and most rapid area of evolution in dendrological teaching (see papers cited by Steiner and Kunsman, 1979). However, I see no single, best prescription for a good course assuming an expanded woody plants approach. Instruction in a given situation is determined by a number of factors, including the nature of the school, its geographical region, content of the curriculum, the semester the course is taught, the number of hours of credit, and the background and interests of the teacher. The best yardstick for the course is that it be stimulating and productive--intellectually stimulating to the student and instructors, and practically productive in that students are able to identify whole plants (not just specific parts such as leaves) and relate them to their habitats. Clearly, students must know their plants and the traditional strengths of field instruction and winter identification should be maintained and improved. Beyond this, various different approaches that mesh with a particular region, school, curriculum, and instructor may be viable and successful.

I would recommend the trend I see in reserving the laboratory period for teaching identification, habitat relationships, and natural history features. These are the topics best taught in the field. The lectures may then be devoted to the biology, ecology, utilization, and other aspects of woody plants. The content may vary considerably in such areas but should not overlap greatly with more advanced and specialized courses.

The plant geographical or regional approach described by Brown (1977) has much to recommend it and may be combined with basic woody plant biology and ecology. Good organismic botany is often needed more than plant geography because in some schools the freshman botany course has been replaced by a biology course which is devoted primarily to molecular biology. Compared to the students of 25 or 30 years ago the modern student may be particularly weak on the fundamentals of structure and function of roots, stems, leaves, and seeds, and on growth relationships.

I particularly recommend advancing toward as much field teaching as possible in natural communities of the local area. The quality of teaching is improved in direct proportion to the amount of field instruction. The quality of teaching of specific woody plants is, I believe, more important than quantity of credit or contact hours alone. Although Harlow (1965) was "horrified" on spring trips to discover how much the students had forgotten since the previous fall field trips, in spite of continuing laboratory work with winter twigs, fruits, and other materials, I am not surprised. Forgetfulness is a common student syndrome and not limited by any means to students of Dendrology! This suggests that effectiveness of instruction, especially in the field, is more important than mere amount of contact hours. Thus I do not feel we should be overly concerned by the 20 percent decline in total instruction time per school as reported in a survey by Steiner and Kunsman (1979).

Several techniques may be used to increase teaching effectiveness and even do more in less time:

1. Block up laboratory time. Change from two 2-hour laboratory periods to one 4-hour period.

2. Concentrate laboratory teaching in the field, but provide continuously open, attractive indoor study labs for study during free-time during the day and evening.

3. Provide carefully selected study materials in the indoor labs to promote free-time study (e.g., herbarium sheets, fruits, cones, twigs, fresh materials, drawings, photographs, posters, jokes, etc.).

4. Use well informed and enthusiastic teaching assistants to effectively direct the study of small groups of students.

5. Provide audio-visual materials in study labs that supplement lecture and laboratory instruction (Fechner, 1972).

6. Develop bike hikes and walking tours of the campus, residential areas, or in the nearby countryside. Maps showing the location of different species enable students to use free afternoons or week-ends to combine recreation and education.

7. Assign plants and have study specimens of them available before the student sees them for the first time in the wild.

8. Reduce the numbers of species outside the local region required for identification, while intensifying the coverage (a) on one or two very important local ecosystems using these as models on how to approach any ecosystem, or (b) on only the few most important regions outside the local region.

The use of audio-visual instruction is one of the most important advances in teaching techniques (Fechner, 1972; Bever, 1974; Buckner and Palmer, 1980). These techniques will evolve rapidly in the future, but should never take the place of at least some personalized field instruction. The use of graduate teaching assistants is more important than use of machines. They provide the human touch, generate enthusiasm, stimulate the desire to learn, instruct the instructor, gain themselves in teaching experience, and are the key to teaching large classes and yet maintaining high student interest and performance.

WOODY PLANTS AT THE UNIVERSITY OF MICHIGAN

A sequence of four Woody Plants courses has been developed stressing hands-on field and laboratory (greenhouse) teaching. The basic pair of courses are:

Woody Plants I: Identification and Biology

Woody Plants II: Structure and Function

Woody Plants I is a 4-credit course which is team taught in the fall term (15 weeks) by Professor Warren H. Wagner, Jr. and myself. It was designed and first taught in 1965. Enrollments have ranged from 50 forestry students the first year to numbers ranging between 150 and 220.

Woody Plants II was designed and taught for many years by Dr. Robert Zahner, and it is currently taught by Dr. Paul E. Marshall. It stresses the structure and function of woody plants from birth to death. Strong emphasis is placed on laboratories at the University of Michigan Matthaei Botanical Gardens where students use plant materials of all kinds in various experiments, some of their own concept and design.

In addition to this basic pair of courses, the Forest Ecology course and the Advanced Forest Ecology course (which I teach) are subtitled Woody Plants III and IV. The named sequence provides visibility for a related series of courses whose title identifies a teaching philosophy of hands-on, field-oriented instruction taking place in real world situations.

The over-all objective of Woody Plants I is to provide a stimulating field oriented course for all university students interested in learning woody plants. The major features of the approach are:

1. To focus the teaching on all woody plants, trees, shrubs, and vines rather than almost exclusively on trees.

2. To present important aspects of biology and ecology of woody plants in lecture periods and concentrate identification, together with natural history and habitat relations, in field laboratories.

3. To conduct the field instruction primarily in natural communities where natural habitat conditions exist and interrelationships among plants can be vividly demonstrated.

4. To encourage students to learn plants by their own careful observations, drawings, and descriptions rather than copying down the descriptions given by the instructor or textbooks.

5. To establish indoor laboratories as centers of study during daytime free hours and evenings.

6. To involve instructors from two different campus units.

7. To involve students of diverse interests from different schools and colleges.

The lectures, two per week, consist of a botanical component and an ecological component. Topics stressed in the former are vegetative and reproductive morphology, reproductive processes, winter condition, cultivars, and systematics. Topics stressed in the ecological component are variation (genetic and environmental), autecology (mainly physical site factors) and synecology (succession, understory tolerance, competition), and forest communities of the major forest regions outside Michigan. Biological and ecological features of the trees and shrubs in the different regions are stressed rather than their morphological characters. The regional communities include Boreal and Northern Forests, the Southern River Floodplain Forest, Coastal Plain Forest, Southern Appalachian Mountain Forest, Rocky Mountain Forests (including aspects of the Sierra Nevada Mountains and Pacific Northwest region), Northern and Central European Forests, and Tropical Forests. Sets of color slides illustrating the species and their habitats in the North American regions are made available in one of the indoor study laboratories.

Field laboratory instruction, from 1-6 PM one day per week for 12 weeks, consists of field trips to a series of natural communities followed by walking tours of the Nichols Arboretum and the main campus. The communities include two Beech-Maple Forests, three Oak-Hickory Forests, a second-growth Lake Plain Forest, two River Floodplain Communities, an open Bog and Bog Forest, a Marsh and Swamp, and various highly disturbed areas such as roadsides and old fields.

Two large indoor study labs are open day and night. They are separately located in buildings housing the natural sciences and natural resources respectively. Each is supplied with a set of herbarium sheets and fresh specimens of all assigned species, fresh and mounted twigs, fruits and cones, and a variety of displays, habitat drawings, and photographs. Materials for newly assigned plants are set out <u>before</u> the students see them in the field. Fresh specimens are placed in trays half filled with water. They keep relatively fresh for the two weeks they remain in the lab. One or two students are hired as collectors to service the study labs and assist with examinations.

An average of about 20 plants are typically assigned for each field laboratory except on days of major field examinations. We require students to know the names and major characters of these species prior to their seeing them in the field. To accomplish this a list with the assigned species and herbarium sheets, fresh specimens, fruits or cones, and twigs are available for study 1 to 6 days beforehand. Thus the students learn their plants ahead of time and can make the maximum use of field time studying variation, habitat, and making their own observations and drawings rather than copying down oral descriptions by the instructor. This procedure was one followed and suggested by our best students; it has greatly improved the teaching-learning process.

Field laboratories are taught by six graduate student teaching assistants. Each teaching assistant teaches two sections of from 12 to 17 students per week. Quizzes or field exams are given in every field lab except the first one. Indoor midterm and final practical identification examinations are also held. Two exams based on a combination of lecture and field material count 35 to 40 percent of the final grade. A standard course evaluation is required in the School of Natural Resources; and the professors and teaching assistants are evaluated, as well as the course as a whole. The results of the course evaluation are published and available to all prospective students in the counseling office.

In recent years the student body has been about 85 percent undergraduate and 15 percent graduate students. A large part of the graduate enrollment is made up of landscape architecture Master's students, who are required to take the course unless they have had an equivalent course elsewhere. About 70 to 80 percent of our students are from the School of Natural Resources and most of the remainder from the College of Literature, Science, and the Arts, but with a sprinkling of students from other schools and colleages, such as Engineering, Music, and Public Health.

Our experience has been that students thrive on our field exercises even though they are long, conducted in all weather, and that the quizzes and exams are given regularly. Teaching assistants are invaluable, and they enable a large student body to receive individualized instruction and attention. We use student feedback a great deal in making improvements in the organization, content, and presentations by the professors and the teaching assistants. Although no one textbook fits our needs we recommend several texts and require Harlow's (1959) Fruit Key & Twig Key to Trees and Shrubs or Core and Ammons (1973) Woody Plants in Winter. We rely strongly on students to observe and characterize the plants by their own drawings and descriptions. Reading assignments are made in the Textbook of Dendrology (Harlow et al., 1979).

WOODY PLANTS AHEAD -- THE YEAR 2000

In conclusion, what future evolution is likely to occur in the next 20 years in dendrology teaching? Here are some of the advancements that may take place:

1. The woody plants approach, now more or less a part of many courses, will at least be more widely adopted--if not so much in major additions of required shrubs and vines--as in accepting the more appealing focus of the study of woody plants at large rather than the study of trees alone.

2. The holistic or ecosystematic concept will provide the dominant theme in natural resources and forestry programs throughout most of the country. Many Woody Plants and Dendrology courses will exploit, and profit from, this movement.

3. Greatly increased enthusiasm for the environment will generate a thirst for knowledge of woody and herbaceous plants as well as in natural resources programs in general. Site classification of forested lands will spur this interest. The marked rise of quantitative and computer-dominated aspects of resource management may generate a backlash favoring more grounding in plant-site relationships.

4. A rapid increase in the abundance and sophistication of audio-visual techniques will have occurred. Sight and sound methods of information

transfer will have proliferated. Cassette types of audio-visual tapes illustrating communities, habitats, and individual species will be marketed. These will be available to students as well as to instructors for classroom use. However, these methods will tend to replace textbooks rather than personal instruction. Few totally self-taught courses will be viable, because we need more human contact in our teaching.

5. Field instruction, one of the main values of the Woody Plants course, will be in jeopardy because of high transportation costs and urban encroachment on forest areas. Fewer schools will be able to maintain budgets for field trips, and students themselves will increasingly bear much of this cost. A major difference in the quality of education and the product will begin to appear between those schools that retain strong field instruction, and those that elect mostly indoor techniques.

6. The diversity of students in Woody Plants and Dendrology courses will increase greatly as more and more courses expand from a forestry base to university-wide stance. Extension and continuing education courses will be more and more widely available in cities and university communities.

7. Woody Plants courses will proliferate in community colleges and other schools that do not now have Forestry programs. Hybrid courses of various kinds involving woody plants, forest ecology, and landscape design will also be attracting attention.

8. More and more woody plants teaching will be done by graduate students and instructor-level professors. As economy measures, many schools will support fewer major professional chairs with an increase in numbers of instructors.

9. No one major approach to instruction in woody plants will be dominant. A variety of stimulating alternatives and techniques will be available and in use, depending on the school and the teacher.

Finally, the future of Woody Plants instruction looks bright except for the prospect of prohibitive costs we may incur for field instruction. Despite some hybridization and introgression with other fields, Dendrology by any name will retain much of its distinctness and gain in enthusiastic supporters. But there is still very much to be realized--therefore, our battlecry: Woody Plants, AHEAD!

SUMMARY

The purposes of the paper are to examine the evolution of dendrological teaching and to give examples of some of these directions based on the Woody Plants course sequence at the University of Michigan. The most important evolutionary trend is the change in focus of Dendrology from the study of trees only to the study of woody plants. Although Dendrology has been perceived to deal only with trees, it is a more inclusive and significant experience to offer the fascinating diversity of woody plants as an interacting group. Second, the holistic or ecosystematic approach is becoming the basic cornerstone of forestry education, and the Dendrology or Woody Plants course is the ideal time to introduce the ecosystem concept. Third, we are evolving from a student body of forestry majors to the academic community and the public at large. The woody plants focus and the ecosystematic approach tend to increase the diversity of our audience, and the increased visibility and insight into forestry programs is substantial. Fourth, the most rapid area of evolution is in the variety of teaching methods and the major advances in audio-visual techniques. However, audio-visual methods should never completely replace personalized instruction. Although decreases in the amount of time allotted to Dendrology are reported, the quality of field teaching may make up for this decrease; ways to improve the quality of teaching are described. At the University of Michigan a series of four Woody Plants courses have been developed. The major features of the initial Woody Plants identification course are (1) focusing on woody plants as a group; (2) stressing personalized field instruction by using teaching assistants; (3) studying the plants in their native habitats; (4) teaching the biology and ecology of woody plants in the lecture periods; and (5) reaching a university-wide audience.

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