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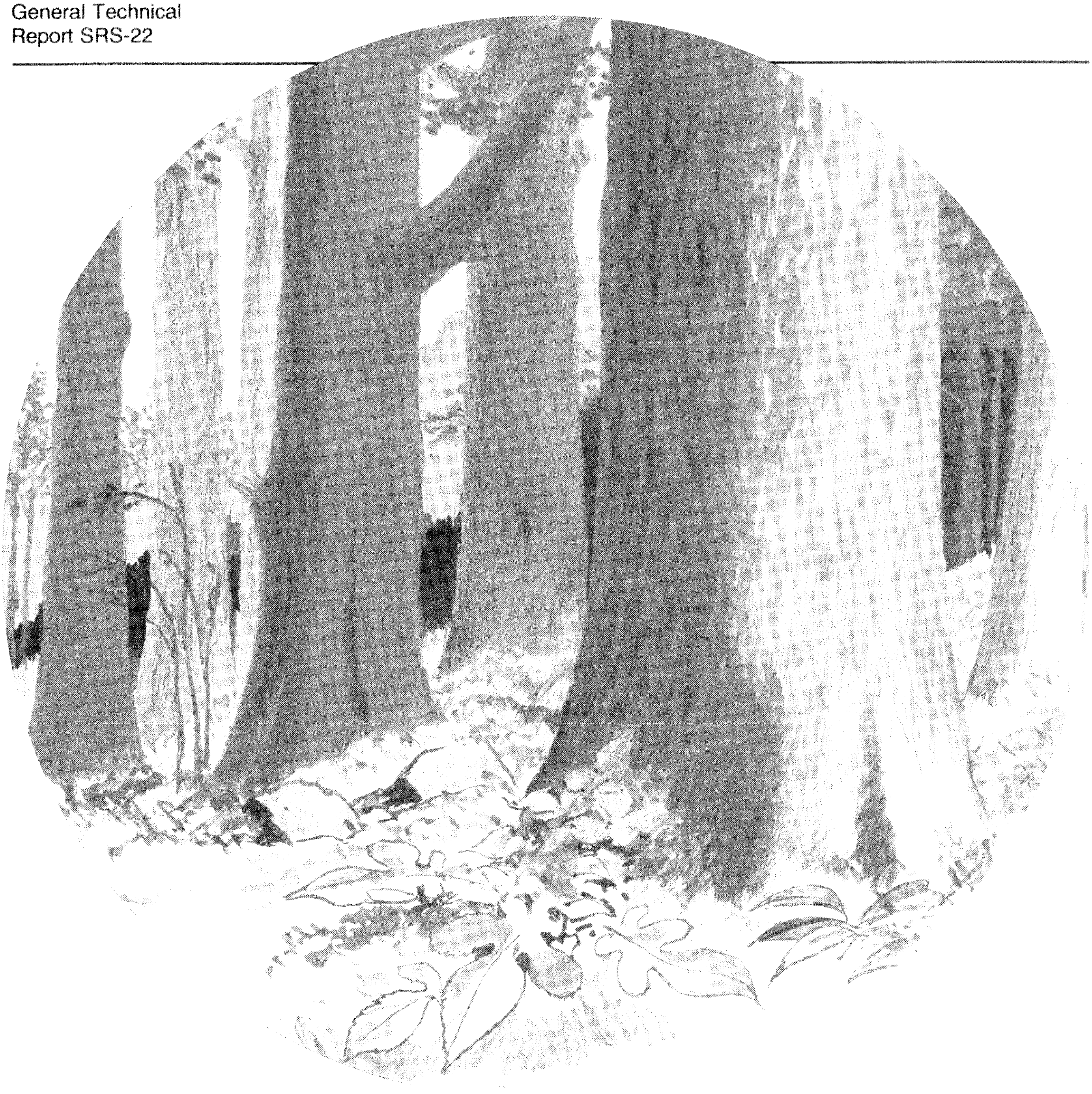
An Old-Growth Definition for Western Hardwood Gallery Forests

Kelly Kindscher and Jenny Holah



A Section of the Old-Growth Definition Series

The Authors:

Kelly Kindscher, Assistant Scientist, and Jenny Holah, Research Assistant, Kansas Biological Survey, University of Kansas, Lawrence, KS 66047-2906.

Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

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Southern Research Station
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Introduction

Old-growth western hardwood gallery forests are found across the Great Plains and are an important plant community associated with stream corridors. This plant community is dominated by the plains cottonwood (*Populus deltoides* var. *occidentalis* Rydb.) and associated stands of willow (*Salix* spp.) trees. Its description is important for both future research and regional planning purposes. Hydrological changes associated with dewatering of streams, irrigation, and flood-control measures have significantly affected the composition of this forest type.

General Description of Forest-Type Group

Western hardwood gallery forests are located along streams and rivers in the Great Plains. The dominant species is the plains cottonwood. The range of the western hardwood gallery forest type (hereafter referred to as gallery forest) extends from southern Saskatchewan to northern Texas, from the Rocky Mountains in Wyoming, Montana, and Colorado to the western borders of Minnesota and Iowa, and the eastern borders of Kansas (Bradley and Smith 1986). In this report, we define "old-growth" forests as stands in which the dominant species, plains cottonwood, is over 80 years old.

Several cottonwood species and subspecies can be found in this type, although *P. deltoides* ssp. *monilifera* (Ait.) is the common variety. *Populus deltoides* ssp. *wislizenii* (Wats.) occurs in the extreme southwestern part of the gallery forest's range and is often mistaken for a variety of Fremont's cottonwood (*P. fremontii* Wats.) (Eckenwalder 1977). Hybridization does occur between plains cottonwood and narrowleaf cottonwood (*P. augustifolia* James) (found west of the Rocky Mountains), which results in *P.* × *acuminata* Rydb. This hybrid is widespread along Rocky Mountain streams from Alberta to northern Texas. *Populus* × *jackii* Sarg. is a hybrid of *P. deltoides* and *P. balsamifera* L. (a northern cottonwood species) that occurs on flood plains along the U.S.–Canada border and in eastern Wyoming (Eckenwalder 1984). Other characteristic species of the gallery forest include peachleaf willow (*S. amygdaloides* Anderss.), black willow (*S. nigra* Marsh.), sandbar willow (*S. exigua* Nutt.), winter grape (*Vitis vulpina* L.), and Virginia creeper [*Parthenocissus quinquefolia* (L.) Planch.].

Western gallery forests occur only along major rivers and streams in narrow strips that generally range from 32.8 feet to 393.6 feet [10 to 120 meters (m)] wide (Eyre 1980, Bradley and Smith 1986). These gallery forests are rarely found more than a few meters above the river level (Johnson et al. 1976, Rothenberger 1985, Johnson 1994). The major rivers associated with this forest type are the Canadian, Cimarron, Arkansas, Kansas, Republican, Platte, Niobrara, Missouri, Little Missouri, Red, and Milk. Prairie vegetation historically surrounded these gallery forests, but today much of the surrounding vegetation is under cultivation (Keammerer et al. 1975, Rothenberger 1985).

The floristics of this community are unique. Ten percent of the species found along bottom-land forests in North Dakota are usually restricted to either western or eastern temperate America but are found together in gallery forests (Keammerer et al. 1975). Young western hardwood gallery forests are composed of dense stands of willow and cottonwood, but hardwood diversity is greater in older stands where willows are a minor component (Johnson et al. 1976).

Gallery forest soil development depends greatly on flooding. The soils consist of recently deposited alluvium substrates that include deep, sandy, and clay loams with good drainage and are often nitrogen poor (Wilson 1970, Keammerer et al. 1975, Rothenberger 1985). Soil pH can range from 6.6 to 8.4 (Rice 1965, Girard et al. 1989). Soil texture is highly variable, ranging from silty clay loam to clay loam to clay to loam (Girard et al. 1989). Gallery forest soils do not appear to be modified significantly by forest vegetation (Johnson et al. 1976). The role of vegetation in soil development may be more important in the future because reservoirs and increased groundwater mining have altered the hydrology of major rivers in this forest type.

Precipitation is variable and generally increases from west to east in the range of gallery forests. Upland vegetation also changes gradually from shortgrass prairie in the west to tallgrass prairie in the east. In western North Dakota gallery forests, the precipitation can be as little as 13 to 16 inches [33 to 41 centimeters (cm)] per year (Johnson et al. 1976, Girard et al. 1987), whereas in the eastern and southern parts of the range they can receive over 30 inches (76 cm) annually. Precipitation in much of the Great Plains area, especially the western region, is less than potential evapotranspiration. Thus, the dominant woody vegetation of gallery forests depends on the water table rather than on precipitation for moisture (Keammerer et al. 1975, Johnson et al. 1976).

Summer temperatures can be extreme, exceeding 105 °F (58 °C) in Texas, Oklahoma, and southern Kansas. Surface temperature in the sandy floodplain along the Missouri in South Dakota can exceed 125 °F (69 °C) (Van Bruggen 1961). Because of the extreme Great Plains climate, few mesophytic eastern species survive on the open prairie, but some eastern herbaceous plants, such as columbine (*Aquilegia canadensis* L.), enchanter's nightshade [*Circaea quadrisulcata* (Maxim.)], and Solomon's seal [*Polygonatum biflorum* (Walt.) Ell.] find refuge in the riparian forests (Keammerer et al. 1975).

In the central Great Plains before the 1880's, riparian forests were uncommon and widely scattered along major rivers such as the western reaches of the Arkansas and Platte (Crouch 1979, Tomelleri 1984). This was probably due to the highly variable hydrology of the Great Plains rivers and the high frequency of fires on the prairie (Wells 1968, Johnson et al. 1976). Rivers such as the Missouri and Platte would flood severely in the spring and then have little discharge during the fall (Johnson et al. 1976, Rothenberger 1985). It is not clear which factors originally influenced tree growth along major rivers (Girard et al. 1987). There is general agreement that fires were a major part of the prairie ecosystem (Wells 1968, Higgins 1986), but the frequency and effect of lightning-caused wildfires on gallery forests is unknown (Higgins 1986). Some argue that the riparian woodlands escaped fire and were adapted to it, or both, whereas others argue that homesteading and a decrease in fire frequency allowed gallery forests to expand their range (Wells 1968, Higgins 1986). Most of the early public land surveys show that forests were sparse along the major rivers.

Great Plains rivers, such as the Missouri in North Dakota, meandered more in the past than they do today. Although the Missouri still meanders, the absence of icy, scouring spring floods has prevented any significant changes in its channel morphology. Discharges of the Missouri and many other rivers are no longer seasonal but are controlled by reservoir releases (Johnson et al. 1976).

In the 1900's, tree establishment along the Arkansas and other rivers in the Great Plains increased as water removed for surface irrigation decreased the intensity of peak spring discharges (Tomelleri 1984). Many of the old cottonwoods in the gallery forests of western Kansas and eastern Colorado were established during this period. Growth of cottonwood and willow species has sharply decreased in the past 30 years because of reductions in groundwater due to mining for irrigation (Tomelleri 1984) and the construction of large reservoirs (Johnson et al. 1976).

Saltcedar (*Tamarix parviflora* L.) has crowded river channels in the southwest part of the region, reducing establishment sites for willow and cottonwood (Gesink et al. 1970). In Nebraska and other areas of the Great Plains, the loss of the old deciduous woodlands has been due largely to agricultural expansion (Rothenberger 1985).

Extensive grazing by cattle has also affected old-growth stands. Before settlement, gallery forests were grazed by bison, whose impact on pre-settlement forests was low, perhaps even negligible (Norland and Marlow 1984). Bison tend to spend less time than cattle do in watering areas. Bison also prefer open grassland to forest and favor grasses and forbs over browse. Cattle grazing and heavy deer browsing seem to have decreased saplings locally, especially elm (*Ulmus* spp.), along the Missouri River in North Dakota (Johnson et al. 1976). In contrast to undisturbed sites, more introduced species, such as prickly lettuce (*Lactuca serriola* L.), green foxtail [*Setaria viridis* (L.) Beauv.], and burdock [*Arctium minus* (Hill) Bernh.] were found in disturbed gallery forests in North Dakota, possibly as a result of past cultivation in the area (Keammerer et al. 1975). Other studies in more upland forests on the Great Plains have also shown changes in species composition associated with extensive grazing (Girard et al. 1987). Floristic composition changes with varying degrees of grazing in woody draws in North Dakota (Girard et al. 1987). Herbaceous cover was found to differ between grazed and ungrazed forests in Oklahoma. Extensive areas of Virginia wild rye (*Elymus virginicus* L.) occur in ungrazed areas and a greater abundance of giant ragweed (*Ambrosia trifida* L.), wing-stem (*Verbesina helianthoides* Michx.), pokeweed (*Phytollaca americana* L.), and Johnson-grass [*Sorghum halepense* (L.) Pers.] occur in grazed areas (Rice 1965).

Old Growth versus Younger Stands

The various trees, shrubs, and herbs found in gallery forests are listed in table 1. Woody plant composition in old gallery forests tends to vary greatly, especially the degree of dominance by cottonwood, American elm (*U. americana* L.), green ash (*Fraxinus pennsylvanica* Marsh.), and boxelder (*Acer negundo* L.). This may suggest that environmental variables not necessarily associated with stand age may influence the structure of old gallery forests. Variable patterns of erosion and sediment deposition may promote gallery forest heterogeneity in terms of tree age and spatial distribution of different plant communities (Johnson et al. 1976). Because of past disturbances, old gallery forests generally tended to occupy less area on the floodplains than younger gallery forests. This was found to be the case in North Dakota (Everitt 1968), although the situation is probably reversed today.

Plant diversity was found to be a function of stand age in gallery forests along the Missouri River in North Dakota. Diversity increased proportionally with stand age, dropping off just slightly in stands over 200 years old (Johnson et al. 1976). Old stands also had more water available due to fine textured soils with abundant organic material (Johnson et al. 1976). Moist soil conditions in old forests may account for the high diversity of herbs, shrubs, and trees.

Old stands have more dead limbs with total dead limb length ranging from 1,717 to 3,527 feet per acre [21 to 43 m per 0.04 hectare (ha) plot], standing snags ranging from 4.9 to 9.3 feet per acre (12 to 23 per ha), and a higher number of cavities ranging from 19 to 30 cavities per acre (46 to 73 cavities per ha) than younger stands. These cavities are used extensively by cavity-nesting birds such as the American kestrel, northern flicker, and red-headed woodpecker (Sedgwick and Knopf 1990).

Potential Old-Growth Reference Stands

Although no representative stands recognized as this forest type have been field verified, the following stands, cited in the literature, potentially could be recognized as representative:

1. South Dakota: scattered stands between Lake Sakakawea and Oahe Reservoir in the central Missouri River Valley (Keammerer et al. 1975, Johnson et al. 1976).

2. Alberta, Canada: southeastern part of the province along the Milk River, 18.63 miles [30 kilometers (km)] upstream from Fresno Reservoir (Bradley and Smith 1986).

3. Montana: north-central part of the State along the Milk River, 15.53 miles (25 km) down from the Fresno Reservoir (Bradley and Smith 1986).

4. North Dakota: a 0.621-mile (1-km) section along the Little Missouri River in the North Unit, Theodore Roosevelt National Park (Everitt 1968).

5. Colorado: an 18.63-mile (30-km) stretch along the South Platte River near Crook, Logan County (Sedgwick and Knopf 1986).

6. Nebraska: stands along the Lower Platte River Valley approximately 18.63 miles (30 km) southwest of Omaha (Rothenberger 1985).

Composition of Western Gallery Hardwood Forests

Cottonwood is the most characteristic tree species of this type. It is found in all the successional stages and occupies the greatest basal area at most stages (table 2). Willow species, such as peachleaf willow (*Salix amygdaloides* Anderss.), sandbar willow (*S. exigua* Nutt.), black willow (*S. nigra* Marsh.), yellow willow (*S. lutea* Nutt.), and pussy willow (*S. eriocephala* Michx.), are also characteristic of gallery forests but are dominant primarily in the early successional stages (Weaver 1960). The vegetation composition of gallery forest varies greatly because of its wide geographic extent. American elm is found throughout the range of the gallery forest type, but its importance increases in the eastern and northern parts of the forest range, especially in the late successional stages. However, Dutch elm disease has diminished the importance of American elm in gallery forests, as it has in many other community types in the Eastern United States.

Green ash is also found throughout the range, except in Texas, extreme western Oklahoma, and southern Colorado. It generally increases in importance as stands age. Green ash establishes itself in mesic conditions typical of the Eastern United States. These conditions occur only at the later stages of floodplain succession (Wilson 1970), and green ash is often the dominant species in terms of abundance (Johnson 1950). Slippery elm (*U. rubra* Muhl.)

Table 1—Trees, shrubs, and herbs found in the various regions of western gallery forests[a b]

Common trees	Common shrubs	Common herbs and grasses
Acer negundo L.	*Amelanchier alnifolia* (Nutt.) Nutt. (3)	*Ambrosia trifida* L. (1)
A. saccarinum L. (2)	*Amorpha fruticosa* L. (2)	*Anemone canadensis* L. (3)
Carya illinoensis (Wangenh.) K. Koch (1)	*Celastrus scandens* L.	*Andropogon gerardii* Vitman (2)
Catalpa speciosa Warder ex Engelm. (2)	*Clematis ligusticifolia* Nutt.	*Apocynum cannabinum* L. (2)
Celtis occidentalis L. (1, 2)	*Cocculus carolinus* (L.) DC. (1)	*Aster laevis* L. (3)
Diospyros virginiana L. (1)	*Cornus amomum* Mill. (3)	*Astragalus gracilis* Nutt. (3)
Fraxinum pennsylvanica Marsh.	*C. drummondi* Meyer	*Bromus tectorum* L. (2)*
Gleditsia triacanthos L. (2)	*C. foemina* Mill. (3)	*Carex* spp.
Juglans nigra L.	*C. racemosa* Lam. (3)	*Conium maculatum* L. (2)
Juniperus scopulorum Sarg. (3)	*C. stolonifera* Michx. (3)	*Cyperus esculentus* L. (1)
J. virginiana L. (2)	*Corylus americana* Walt. (2)	*Digitaria sanguinalis* (L.) Scop. (1)
Plantanus occidentalis L. (2)	*Elaeagnus augustifolia* L.*	*Distichlis stricta* (Torr.) Rydb. (2)
Populus deltoides var. *occidentalis* Rydb.	*Maclura pomifera* (Raf.) Schneid. (2)*	*Echinochloa crusgalli* (L.) Beauv. (2)
Prunus serotina Ehrh. (2)	*Morus alba* L. (3)	*Elymus canadensis* L.
Quercus macrocarpa Michx. (3)	*M. rubra* L. (2)	*E. virginicus* L. (1)
Salix amygdaloides Anderss.	*Parthenocissus quinquefolia* (L.) Planch.	*Equisetum* spp.
S. eriocephala Michx. (2, 3)	*Prunus americana* Marsh. (2)	*Erigeron philadelphicus* L. (3)
S. exigua Nutt. (2)	*P. virginiana* L.	*Galium aparine* L. (2)*
S. lutea Nutt. (2, 3)	*Rhamnus lanceolata* Pursh (2)	*Gaura parviflora* Dougl. (2)
S. nigra Marsh.	*Rhus glabra* L.	*Helianthus grosseserratus* Martens (2)
Sapindus drummondii Hook. & Arn. (1)	*R. trilobata* var. Barkley (2)	*H. tuberosa* L. (2)
Tamarix parviflora L.*	*Ribes missouriense* Nutt.	*Heliopsis helianthoides* (L.) (2)
T. ramosissima Ledeb..	*Rosa woodsii* Lindl.	*Kochia scoparia* (L.) Roth (2)*
Tilia americana L.	*Rubus occidentalis* L.	*Medicago lupulina* L.*
Ulmus americana L.	*Sambucus canadensis* L. (2)	*Melilotus officinalis* (L.) Lam. (3)*
U. pumila L. (2)*	*Shepherdia argentea* Nutt. (3)	*Oxalis stricta* L. (3)
U. rubra Muhl. (2)	*Smilax hispida* (Muhl.) Fern.	*Panicum virgatum* L. (3)
	Symphoricarpos occidentalis Hook.	*Phalaris arundinacea* L. (3)*
	S. orbiculatus Moench (1)	*Phlox pilosa* L. (3)
	Toxicodendron radicans Ktze.	*Phragmites communis* Trin. (2)*
	Vitis vulpina L.	*Phytollaca americana* L. (1)
	Zanthoxylum americanum L. (3)	*Poa pratensis* L. (3)*
		Rumex crispus L. (2)*
		Salsola kali L. (2)*
		Smilacina stellata (L.) Desf.
		Solidago altissima sensu Mackenz.
		Sorghum halepense (L.) Pers. (1)*
		Spartina pectinata Link. (2)
		Sporobolus airoides Torr. (2)
		Strophostyles helvola (L.) Ell. (3)
		Thalictrum venulosum Trel. (3)
		Verbesina helianthoides Michx. (1)
		Xanthium spp. (1, 2)*

(1) = species found primarily in the southern range; (2) = species found primarily in the central part of the range; (3) = species found in the northern extent of the forest range; * = nonnative species.

[a] Species without numbers in parentheses are common throughout the range of the gallery forest.
[b] Nomenclature follows *Flora of the Great Plains* (Great Plains Flora Association 1986).

Table 2 (English units)—Table of old-growth attributes for western gallery hardwood forests

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per acre		
Stand density	Total: 482 (NE)[a], 117 (ND)[b], 230 (ND)[c]	Total trees: 276	54
Acer negundo L.	42 (ND)[c]		
Fraxinus pennsylvanica Marsh.	75 (ND)[b], 77 (ND)[c]		
Populus deltoides ssp. *monilifera* (Ait.) Eckenwalder	60 (ND)[b], 77 (ND)[c], 10 (CO)[d]		
Salix amygdaloides Anderss.	2 (ND)[c]		
Ulmus americana L.	28 (ND)[c]		
	Feet² per acre		
Stand basal area	Total: 279 (NE)[a], 124 (ND)[c]	Total: 202	53
A. negundo L.	1.7 (NE)[a], 19 (ND)[c]		
Celtis occidentalis L.	3.9 (NE)[a]		
Trees >1 in. for [a] *Cornus drummondii* C.A. Meyer	3 (NE)[a]		
Trees >4 in. for [c]			
F. pennsylvanica Marsh.	8 (NE)[a], 20 (ND)[c]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	186 (NE)[a], 60 (ND)[c], 15 (CO)[d]		
S. amygdaloides Anderss.	4.7 (NE)[a], 23 (ND)[c]		
U. americana L.	0.9 (NE)[a], 22 (ND)[c]		
	Years		
Age of large trees	Total: 100–141+ (KS)[e]		5
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	90+ (KS)[f], 80+ (SD)[g], 200+ (ND)[c h], 90–110 (MT/Canada)[i]	145	
Quercus macrocarpa Michx.	300–350 (ND)[c]		
S. amygdaloides Anderss.	200–250 (ND)[c]		
U. americana L.	300–350 (ND)[c]		
	Inches		
Maximum d.b.h.			
F. pennsylvanica Marsh.	27 (ND)[c]		6
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	30–41 (NE)[a], 58 (CO)[d], 72+ (KS)[f], 24–36 (ND)[h j], 76 (ND)[c]	53	
U. americana L.	41 (ND)[c]		
Standing snags	Total: 33.7 (OK)[k]		11
F. pennsylvanica Marsh.	13.2 (OK)[k]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	0.1 (OK)[k], 0.3 (CO)[d]	0.2	
U. americana L.	8.9 (OK)[k]		

Table 2 (English units)—Table of old-growth attributes for western gallery hardwood forests (continued)

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per acre		
Downed logs	Downed cottonwood cited as "common" in older forest[c]		
Decadent trees	Majority of trees cited as "decadent"[d]		
	Number		
Canopy layers	2: dense shrub layer and an open cottonwood canopy (SD)[g] "multiple synusiums" in old-growth forests (ND)[c j]		
Canopy in gaps	Canopy described as "open" Large trees widely spaced (SD, ND)[b c g j l]		
	Feet		
Other: canopy height	Total: 49–52 (CO)[m]		3
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	59–79 (ND)[c], 98 (ND)[j]	23	

CO = Colorado, KS = Kansas, MT = Montana, NE = Nebraska, ND = North Dakota, OK = Oklahoma, SD = South Dakota.

References: [a] Rothenberger 1985, [b] Girard et al. 1989, [c] Johnson et al. 1976, [d] Sedgwick and Knopf 1986, [e] Spencer et al. 1984, [f] Tomelleri 1984, [g] Johnson 1950, [h] Everitt 1968, [i] Bradley and Smith 1986, [j] Keammerer et al. 1975, [k] Penfound 1956, [l] Girard et al. 1983, [m] Sedgewick and Knopf 1990.

Table 2 (metric units)—Table of old-growth attributes for western gallery hardwood forests

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per hectare		
Stand density	Total: 1191 (NE)[a], 289 (ND)[b], 568 (ND)[c]	Total trees: 682	54
Acer negundo L.	104 (ND)[c]		
Fraxinus pennsylvanica Marsh.	185 (ND)[b], 190 (ND)[c]		
Populus deltoides ssp. *monilifera* (Ait) Eckenwalder	48 (ND)[b], 190 (ND)[c], 25 (CO)[d]		
Salix amygdaloides Anderss.	5 (ND)[c]		
Ulmus americana L.	64 (ND)[c]		
	Meters² per hectare		
Stand basal area	Total: 279 (NE)[a], 28.5 (ND)	Total: 46.4	53
A. negundo L.	0.390 (NE)[a], 4.36 (ND)[c]		
Celtis occidentalis L.	0.895 (NE)[a]		
Trees >2.54 cm for [a]			
Cornus drummondii C.A. Meyer	3 (NE)[a]		
Trees >10.16 cm for [c]			
F. pennsylvanica Marsh.	8 (NE)[a], 20 (ND)[c]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	186 (NE)[a], 60 (ND)[c], 15 (CO)[d]		
S. amygdaloides Anderss.	4.7 (NE)[a], 23 (ND)[c]		
U. americana L.	0.9 (NE)[a], 22 (ND)[c]		
	Years		
Age of large trees	Total: 100–141+ (KS)[e]		5
P.deltoides ssp. *monilifera* (Ait.) Eckenwalder	90+ (KS)[f], 80+ (SD)[g], 200+ (ND)[c h], 90–110 (MT/Canada)[i]	145	
Quercus macrocarpa Michx.	300–350 (ND)[c]		
S. amygdaloides Anderss.	200–250 (ND)[c]		
U. americana L.	300–350 (ND)[c]		
	Centimeters		
Maximum d.b.h.			
F. pennsylvanica Marsh.	68.6 (ND)[c]	134.6	
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	76.2–104.1 (NE)[a], 147.3 (CO)[d], 182.9+ (KS)[f], 61.0–91.4 (ND)[c j], 193.0 (ND)[c]		
U. americana L.	104.1 (ND)[c]		
Standing snags	Total: 83.3 (OK)[k]	0.494	11
F. pennsylvanica Marsh.	32.6 (OK)[k]		
P. deltoides ssp. *monilifera* (Ait.) Eckenwalder	0.247 (OK)[k], 0.741 (CO)[d]		
U. americana L.	22.0 (OK)[k]		

Table 2 (metric units)—Table of old-growth attributes for western gallery hardwood forests (continued)

Quantitative attribute	Selected examples	Mean	No. of stands
	Number per hectare		
Downed logs	Downed cottonwood cited as "common" in older forest[c]		
Decadent trees	Majority of trees cited as "decadent"[d]		
	Number		
Canopy layers	2: dense shrub layer and an open cottonwood canopy (SD)[g] "multiple synusiums" in old-growth forests (ND)[c j]		
Canopy in gaps	Canopy described as "open" Large trees widely spaced (SD, ND)[b c g j l]		
	Meters		
Other: canopy height	Total: 14.9–15.8 (CO)[m]		
P. deltoides ssp. *monilifera* (Ait) Eckenwalder	18.0–24.1 (ND)[c], 29.9 (ND)[j]	7.01	3

CO = Colorado, KS = Kansas, MT = Montana, NE = Nebraska, ND = North Dakota, OK = Oklahoma, SD = South Dakota.

References: [a] Rothenberger 1985, [b] Girard et al. 1989, [c] Johnson et al. 1976, [d] Sedgwick and Knopf 1986, [e] Spencer et al. 1984, [f] Tomelleri 1984, [g] Johnson 1950, [h] Everitt 1968, [i] Bradley and Smith 1986, [j] Keammerer et al. 1975, [k] Penfound 1956, [l] Girard et al. 1983, [m] Sedgewick and Knopf 1990.

occurs throughout the eastern part of the region. Siberian elm (*U. pumila* L.), an introduced species from Asia, is common throughout the gallery forests. Persimmon (*Diospyros virginiana* L.) and pecan [*Carya illinoense* (Wangenh.) K. Koch] are found primarily in the southern part of the gallery forest range in Oklahoma, Texas, and eastern Kansas (Brumwell 1951). Hackberry (*Celtis occidentalis* L.) is found throughout the range except for the western region. Sycamore (*Platanus occidentalis* L.) is also a common floodplain tree that occurs in the southeastern part of the gallery forest range. Black walnut (*Juglans nigra* L.) and basswood (*Tilia americana* L.) are common in the older forests in the eastern range. Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) is common in the northwestern part of the range, and eastern redcedar (*J. virginiana* L.) is common in the central and eastern parts. The range of redcedar has been expanding due to a decrease in fire frequency across the Great Plains (Rothenberger 1985).

Saltcedar, a species introduced from Eurasia for windbreak plantings, has dramatically increased in abundance within the past 50 years, especially in eastern Colorado, New Mexico, and western Kansas and Oklahoma. The increase in establishment sites for saltcedar seems to be due primarily to a decrease in springtime flash floods and water level fluctuations (Gesink et al. 1970).

The most common shrubs and lianes found throughout this type are winter grape, Virginia creeper, and poison ivy [*Toxicodendron radicans* (L.) Kuntze]. Another important shrub is hazelnut (*Corylus americana* L.), common in North Dakota and the eastern parts of South Dakota, Nebraska, Kansas, and northeastern Oklahoma. Roughleaf dogwood (*Cornus drummondii* C.A. Meyer) is quite common in gallery forests in the southeastern part of their range, but its basal area is minimal due to its small size: between .99 and 3.11 inches (2.5 and 7.9 cm in diameter at breast height) (Gesink et al. 1970, Rothenberger 1975). Osage-orange [*Maclura pomifera* (Raf.) Schneid.] is a common native tree in eastern Texas and Oklahoma, but now occurs north and west of its native range into southeastern South Dakota. Buffalo berry [*Shepherdia argentea* (Pursh) Nutt.] and Saskatoon serviceberry [*Amelanchier alnifolia* (Nutt.) Nutt.] occur commonly in the northern part of the gallery forest range.

The oldest stands always contain very old, large, relic cottonwoods but few young cottonwoods because of their inability to reproduce in the shade (Everitt 1968, Keammerer et al. 1975). Green ash is becoming a more important component in northern gallery forests along the Missouri River as establishment sites for cottonwood, willow, elm, and boxelder decrease due to flood control (Johnson et al. 1976). In some North Dakota gallery forests, Rocky Mountain juniper is becoming an increasingly dominant tree in the older forests (Everitt 1968).

Age of trees and geographic location, which vary greatly, help determine the dominant canopy of a western gallery forest. A bottom-land forest in Oklahoma along the South Canadian River, for example, is dominated by green ash, with cottonwood a major secondary species and willow absent as a major species (Rice and Penfound 1956). In the same area, sandy flats along the river are nearly barren except for sandbar willow, cottonwood, and saltcedar. In western Kansas, early pioneers of the late 1800's cited only four woody species commonly present along the Arkansas River: plains cottonwood, sandbar and peachleaved willow, and false indigo (*Amorpha fruticosa* L.). Today, peachleaved willow and false indigo are rarely found in this area (Tomelleri 1984), though both can be found in eastern Kansas (Gesink et al. 1970).

Boxelder is a small tree that is commonly found but often in poorly drained areas with frequent standing water (Rothenberger 1985). Gallery forests in the eastern portion of the range, with higher terraces above the floodplain, may have a mixture of bur oak (*Quercus macrocarpa* Michx.) with the more mesic tree species, such as elm and ash, forming the boundary between forest and prairie (Keammerer et al. 1975).

The shrub component in old gallery forest is generally described as impenetrable because the extremely dense shrub and vine cover make walking difficult (Johnson 1950). Sumac (*Rhus* spp.) can be dominant in the Missouri River forests in South Dakota when human disturbance is absent (Johnson 1950). Gallery forests in North Dakota and eastern Colorado have a high cover of wolfberry (*Symphoricarpos occidentalis* Hook) and Wood's rose (*Rosa Woodsii* Lindl.), as well as a dense understory of green ash saplings (Sedgewick and Knopf 1986, Girard et al. 1989). Woody vines can be particularly abundant in moist areas in the older forests, including winter grape, poison ivy, virgin's-bower (*Clematis virginia* L.), and Virginia creeper. Chokecherry (*Prunus virginiana* L.) and Russian-olive (*Elaeagnus augustifolia* L.), an exotic but now naturalized species in the region, can occasionally attain tree size in northern gallery forests. Chokecherry is found in the older, more mesic forest stands and Russian-olive in younger cottonwood stands (Johnson et al. 1976). Old forests in North Dakota rarely have a closed crown cover, allowing sufficient light for a highly prolific herb and shrub component (Keammerer et al. 1975).

The herbaceous and grass species found in gallery forests vary greatly with geographic location. The prairie grasses, forbs, and shrubs that occur adjacent to this forest type are generally found within the transition zone between forest and prairie. Big blue-stem (*Andropogon gerardii* Vitman) and other tallgrass species are found within gallery forests in Kansas (Weaver 1960) and Oklahoma, mixed tall and shortgrass prairie species, as well as sand sagebrush (*Artemisia filifolia* L.), are found near gallery forests of eastern Colorado (Sedgwick and Knopf 1986), and shortgrass species are found in the transitional area between northern gallery forests and grassland (Johnson et al. 1976). Herbaceous ground cover also varies with grazing intensity, as was found in Oklahoma bottom-land forests (Rice 1965) and North Dakota riparian woodlands (Girard et al. 1987). Green ash and American elm are particularly susceptible to grazing damage (Girard et al. 1987). Today, much of the land bordering gallery forests is agricultural (Rothenberger 1985, Sedgwick and Knopf 1990).

Old-Growth Quantitative Attributes

Table 2 lists the major quantitative attributes found in old-growth western gallery forests. The total density of tree stems varies greatly among sites, as well as among species. The number of trees per acre ranged from 117 to 482 (289 to 1191 per ha) in Nebraska along the Platte River. Although peachleaved willow is one of the few woody species to establish itself in the early successional stages, its density and basal areas are quite limited in the old-growth type, ranging from 1.1 square feet per acre (0.0413 m^2 per ha) in Nebraska along the Platte, to 5.4 square feet per acre (0.203 m^2 per ha) along the Missouri in North Dakota. In North Dakota gallery forests, both peachleaved willow and cottonwood increase in importance with increasing proximity to the river's edge, regardless of the age of the stand. The opposite relationship is found for green ash, boxelder, and American elm (Johnson et al. 1976). Old forests can have an extremely thick layer of green ash saplings, ranging from 400 to 2,400 stems per acre (488 to 5,930 stems per ha), and over 400 American elm and boxelder saplings per acre (988 per ha) (Johnson et al. 1976, Girard et al. 1989). Few cottonwood and willow saplings were found in gallery forests of various ages in North Dakota due to their inability to reproduce under their own dense shade (Johnson et al. 1976).

Although green ash can outnumber cottonwood, and American elm can come close, neither rival the basal area cottonwood contributes to old-growth stands due to the massive size of old trees with diameters close to 6 feet (1.83 m). Bur oak is often found to be the oldest tree in this type with some trees over 300 years old. However, as stands age it becomes increasingly difficult to determine tree age, especially for cottonwood because of its porous growth rings (Everitt 1968) and the increased decay inside older trees. Growth cores generally underestimate actual age (Bradley and Smith 1986).

In a Nebraska study, the absolute frequency of lianes (number of lianes per total number of trees) is higher for this forest than for upland and transitional type forests (Rothenberger 1985). Nearly 36 percent of all woody species in these western hardwood gallery forests are vines.

Downed woody debris and standing snags are characteristic of old-growth gallery forests, with downed wood, especially cottonwood, frequently cited as "common." Standing snags range from 33.7 trees per acre (83.3 trees per ha) in bottom-land forests of Oklahoma to 0.3 cottonwood trees per acre (0.741 per ha) in northeastern Colorado.

Canopy height can range from 59.06 feet to 98.4 feet (18 to 30 m) for cottonwood trees found along the Platte River in Nebraska (Rothenberger 1985). The forests here have multiple layers, although two layers are most distinct: the open canopy and a dense, shrubby, "impenetrable" undergrowth.

Historic versus Present-Day Forests

Before the era of extensive flood control, which began in the 1960's, drought and overgrazing were cited as causing deterioration of an old bottom-land forest in Oklahoma (Penfound 1953). Historically, the forests did not establish readily along rivers due in part to the extremely variable nature of the environment, as well as fire (Gesink et al. 1970, Tomelleri 1984, Rothenberger 1985). Along the South Canadian River in Oklahoma and the Missouri River in South Dakota, flash flooding and shifting sand uprooted establishing plants (Ware and Penfound 1949, Van Bruggen 1961). Drought, high evaporation rates, and the intense heat of the sandy flats also inhibit germination of many species. Cottonwood, willow, and saltcedar are able to establish during the flood season and grow extensive root systems and tall stems quickly, improving their chances of survival. Saltcedar, unlike willow and cottonwood, is able to disperse seeds throughout the growing season, which increases its competitive ability in such areas (Ware and Penfound 1949).

Although gallery forests were widely scattered and rather sparse in the past, the small stands were important to early settlers and pioneers in eastern Colorado and western Kansas for firewood and construction (Gesink et al. 1970). When travel along the Santa Fe and Oregon Trails was at its peak, the north side of the Arkansas River was virtually bare of all trees, in part due to the heavy usage of timber by pioneers who traveled on this side of the river (Tomelleri 1984). Today there is a decrease in wooded area along the Arkansas River from east to west due to increased cultivation and grazing pressure in this region as well as increased mining of ground water for irrigation (Gesink et al. 1970).

The reduction in fire frequency in these areas today has led, in part, to a general expansion of shrubs and mesic species, especially in upland areas with historically high fire frequencies. The increase of eastern redcedar, a fire-sensitive species, along the Platte in Nebraska is attributed to decreased fire frequency in the area (Rothenberger 1985).

Historically, the establishment and growth of cottonwood forests were highly correlated with the river dynamics (Johnson et al. 1976, Rothenberger 1985, Bradley and Smith 1986). The current lack of spring flooding due to the presence of reservoirs is cited for the absence of young cottonwood stands along the Missouri, the Platte in Nebraska and Colorado, and the Milk in Montana. Flood control increases channel downcutting, reducing both floodplain width and "meandering." The high deposition that takes place in these meander areas, especially during floods, provides an adequate seedbed for cottonwood and willow species (Johnson et al. 1976). Minor flooding today can be caused by ice jams, but differences in peak flows are caused primarily by dam releases. Periodic flooding probably limits the distribution of American elm and green ash to the higher terraces of the floodplain. These higher terraces develop over many years of deposition around the established pioneer species of willow and cottonwood. The variability in historic meandering rates along the Missouri may help explain the varied age and composition of these forests (Johnson et al. 1976).

A study done in North Dakota along the Little Missouri River found that young cottonwood forests occupied more area than old-growth forests. This apparently was due to destruction of older forests by river channel migration, which constantly precluded formation of new suitable sites for seedling establishment (Everitt 1968). Today, with increased flood control and a subsequent decrease in meandering and channel migration, the situation probably would be reversed, with less area occupied by younger forests. A study done in southern Alberta above a series of dams along the Milk River and below the dams in northern Montana found that cottonwood recruitment was very low below the dams due to reduced peak flows, frequency of floods, rates of sedimentation, and meandering (Bradley and Smith 1986). Areas above the dams had higher densities of cottonwood along meandering areas. Cottonwoods produce viable seeds yearly in the spring, but successful establishment is sporadic and associated with a 5-year flooding cycle. Disruption of these flooding events has implications for the maintenance of this forest type (Bradley and Smith 1986).

Although historic accounts of wildlife present in gallery forests are limited, an expedition traveling in 1820 along the Platte River in northeastern Colorado observed bison, prairie wolves, antelope, and wild horses. The bottom-land habitat along rivers, such as the Platte, Missouri, and Arkansas, was probably poor for species requiring year-round water since these rivers would be periodically dry, usually in the fall and winter (Crouch 1979, 1984). Today these areas may provide better habitat for some wildlife because of increased year-round flow due to flooding control. However, the steady loss of large, old cottonwoods, coupled with poor regeneration, will affect cavity-nesting birds (Sedgwick and Knopf 1990) and other wildlife in these gallery forests (Rothenberger 1985).

Future Ramifications

The decrease in flooding and a corresponding decrease in the meandering rate caused by flood-management practices have changed the western hardwood gallery forest in terms of both its extent and its composition. Gallery forests are now limited to areas where trees were established before flood control, and species dominance in old forests is changing from cottonwood and willow to green ash. On a local scale, cultivation and increased grazing in these areas have also restricted forest distribution and changed overall composition (Johnson et al. 1976, Rothenberger 1985). Additionally, the presence of reservoirs and increased irrigation seems to have decreased the growth rate of the residual old trees as evidenced by significantly narrower growth rings in cottonwoods after reservoir installation along the Missouri (Johnson et al. 1976). In some western areas, loss of water to irrigation has killed some trees. Overall, flood control has decreased gallery forest area and landscape diversity along Great Plains rivers. This has jeopardized wildlife dependent on gallery forests for habitat, winter cover, and relief from summer heat. In general, survival of cottonwood on prairie rivers today is far from certain (Bradley and Smith 1986).

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Western hardwood gallery forests are found across an extremely large, diverse geographical area that encompasses the Great Plains in the United States and Canada. Remnant forests of this type still exist in the "Prairie Peninsula," which historically projected an eastern finger into Ohio. The forests are restricted to floodplains of major rivers and are in sharp contrast to the surrounding prairie. The name "gallery" forest refers only to forests that form a corridor of trees along river systems in the region. Disturbances associated with flooding, such as water and ice scouring as well as soil deposition, are required for the establishment of cottonwood and willow stands, pioneer species of this type. Today, the historic hydrology of all Great Plains rivers has drastically changed with the creation of dams and other flood-control measures. The western hardwood gallery forest has changed as well, with composition shifting from shade-intolerant species, such as cottonwood and willow, to shade-tolerant species, such as green ash. Consequently, there is little regeneration of this forest type.

Keywords: Cottonwood, gallery forests, old growth, willow.