Southern Mesic Forest (Global Rank G3?; State Rank S3)

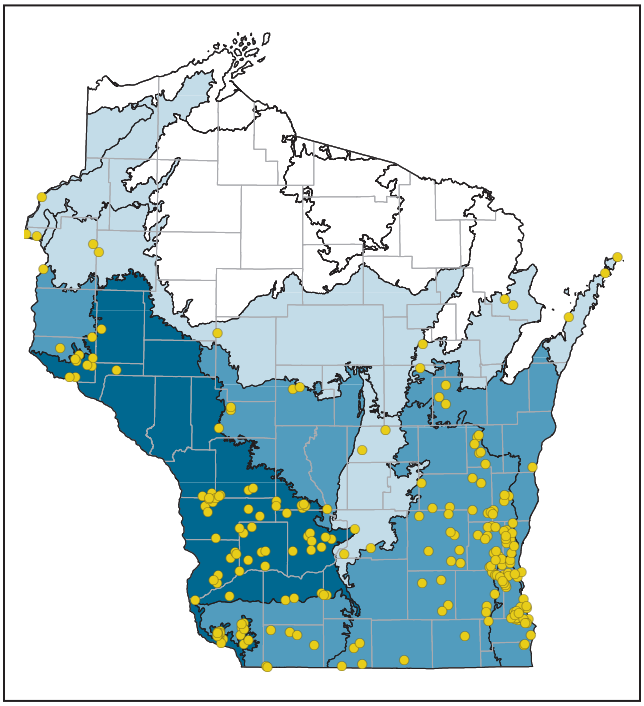
Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

Southern Mesic Forest occurs south of the Tension Zone on moist, well-drained, medium, or fine-textured soils with high nutrient availability. In the glaciated areas of Wisconsin, this community occurs on well-drained ground moraine, fine-textured end moraine, rich alluvial terraces above river floodplains, and lakeplain margins. In southwestern Wisconsin's Driftless Area, Southern Mesic Forest occupies sites that are well drained but not droughty, which were protected from fire by rivers, wetlands, bedrock escarpments, and slopes with cool, humid northern or eastern aspects. While the distribution of Southern Mesic Forest is primarily south of the Tension Zone, outliers that might be classified here do occur to the north and east.

Historically this community was extensive in parts of glaciated southeastern Wisconsin (Finley 1976). It was also common, as were drier oak-dominated forests, in portions of southwestern Wisconsin's Driftless Area, especially in the heavily forested triangle formed by the Baraboo, Kickapoo, and Wisconsin rivers.

In glaciated and heavily developed southeastern Wisconsin, this community has been severely affected by outright destruction and habitat fragmentation. Much of the forest in the nearly level, fertile parts of Wisconsin was cleared to make way for farms, cities, and industries, leaving only scattered, small remnants. In the Western Coulees and Ridges Ecological Landscape of southwestern Wisconsin's unglaciated Driftless Area, the mesic hardwood forests are more common, less isolated, and may occur in a complex vegetation mosaic of drier oak-dominated forests on the rugged upland bluffs, conifer "relicts," and the lowland forests associated with large river floodplains.

Windstorms are the most important natural disturbance and may affect areas limited to the loss of single trees to much more extensive areas caused by tornadic storms or downbursts. Ice storms may also have extensive impacts. Gaps caused by these natural disturbances may set succession back, or when they occur at small scales of less than one to several acres, provide the conditions necessary for some of the less shade tolerant members of the community to persist or flourish.



Locations of Southern Mesic Forest in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

Community Description: Composition and Structure

Southern Mesic Forest is dominated by hardwood trees, especially sugar maple (*Acer saccharum*) and American basswood (*Tilia americana*). In eastern Wisconsin near Lake Michigan, American beech (*Fagus grandifolia*) becomes an important canopy associate and may assume co-dominant status along with sugar maple and American basswood. The potential canopy associates comprise a diverse group and may include northern red oak (*Quercus rubra*), white oak (*Q. alba*), white ash (*Fraxinus americana*), red elm (*Ulmus rubra*), American elm (*U. americana*), red maple (*Acer rubrum*), black walnut (*Juglans nigra*), butternut (*J. cinerea*), bitternut-hickory (*Carya cordiformis*), and in the southwestern corner of the state, honey locust (*Gleditsia triacanthos*). Conifers are absent, although in a few areas, such as parts of the Driftless Area in the Western Coulees and Ridges Ecological Landscape, eastern white pine (*Pinus strobus*) and an occasional eastern hemlock (*Tsuga canadensis*) may occur.

In the parlance of many foresters, all forests dominated by sugar maple tend to be classified and managed as "northern hardwoods." There are some differences in understory composition and in the proportional representation of some of the canopy associates. Also, in the vast forests of northern Wisconsin, hemlock was dominant or co-dominant in many stands from which it is now absent, and these are all considered northern hardwoods.

The deep shade created by the canopy trees in undisturbed stands of sugar maple, American beech, and American basswood typically suppresses the shrub/sapling stratum until a gap opens up. Cover values of shrubs and saplings are typically low, and by mid-summer, mature stands appear quite

open beneath the canopy. Gap-phase replacement, caused by windthrow, ice accumulation damage, pest infestation, or disease, is the characteristic natural disturbance regime of Southern Mesic Forest. Gaps may quickly fill with thickets of sapling trees or shrubs such as American hazelnut (*Corylus americana*), American witch-hazel (*Hamamelis virginiana*), and muscle-wood (*Carpinus caroliniana*).

Nutrient-rich stands support striking displays of spring wildflowers such as wild leek (*Allium tricoccum*), blue cohosh (*Caulophyllum thalictroides*), woodland phlox (*Phlox divaricata*), spreading Jacob's-ladder (*Polemonium reptans*), bloodroot (*Sanguinaria canadensis*), large-flowered trillium (*Trillium grandiflorum*), May-apple (*Podophyllum peltatum*), downy yellow violet (*Viola pubescens*), and Virginia water-leaf (*Hydrophyllum virginianum*). The spring ephemerals deserve special mention. This group is well known and widely appreciated for the vibrant colors it adds to the drab and seemingly lifeless post-winter woodland landscape. The spring ephemerals complete the above-ground portion of their life cycles early in the growing season in just a few weeks before the trees leaf out. Common members of this group are spring-beauty (*Claytonia virginica*), Dutchman's breeches (*Dicentra cucullaria*), false mermaid-weed (*Floerkea proserpinacoides*), false rue anemone (*Enemion biternatum*), cut-leaved toothwort (*Cardamine concatenata*), and the trout-lilies: white (*Erythronium albidum*) and yellow (*E. americanum*). By late spring, dense stands of Canadian wood-nettle (*Laportea canadensis*), maidenhair fern (*Adiantum pedatum*), and other ferns (e.g., *Osmunda* spp., *Athyrium* spp.) have become dominant, and evidence of the vibrant ephemerals is gone.

Plants strongly associated with, and in some cases restricted to, the mesic hardwood forests of southern Wisconsin include showy orchis (*Orchis spectabilis*), heart-leaved skullcap (*Scutellaria ovata*), putty-root (*Aplectrum hyemale*), rue-anemone (*Thalictrum thalictroides*), glade fern (*Diplazium pycnocarpon*), broad beech fern (*Phegopteris hexagonoptera*), ebony spleenwort (*Asplenium platyneuron*), and silvery spleenwort (*Deparia acrostichoides*).

Among the rare herbs associated with Southern Mesic Forest—and some of these are also limited to southern Wisconsin—include bluestem goldenrod (*Solidago caesia*), snow trillium (*Trillium nivale*), goldenseal (*Hydrastis canadensis*), Carey's sedge (*Carex careyana*), great water-leaf (*Hydrophyllum appendiculatum*), nodding pogonia (*Triphora trianthophora*), twinleaf (*Jeffersonia diphylla*), and reflexed trillium (*Trillium recurvatum*). Several rare woody plants also occur in Southern Mesic Forest; the shrub, smooth black-haw (*Viburnum prunifolium*), the Wisconsin Special Concern Kentucky coffee-tree (*Gymnocladus dioica*), and the Wisconsin Threatened blue ash (*Fraxinus quadrangulata*).

The rare animals found in southern Wisconsin hardwood forests include a number of area-sensitive species that are either absent from or of very limited distribution in the far more extensive forests of northern Wisconsin. This group includes Cerulean Warbler (*Setophaga cerulean*), Hooded Warbler (*Setophaga citrina*), Kentucky Warbler (*Geothlypis formosa*), Yellow-throated Warbler (*Setophaga dominica*), Worm-eating Warbler (*Helmitheros vermivorum*), Louisiana Waterthrush (*Parkesia motacilla*), and Acadian Flycatcher (*Empidonax virescens*). Other birds breeding in southern Wisconsin's mesic hardwood forests are Wood Thrush (*Hylocichla mustelina*), Scarlet Tanager (*Piranga olivacea*), Pileated Woodpecker (*Dryocopus pileatus*), Blue-gray Gnatcatcher (*Polioptila caerulea*), Barred Owl (*Strix varia*), and Red-shouldered Hawk (*Buteo lineatus*).

When other habitats, such as ephemeral ponds, seeps and spring runs, streams, cliffs, or talus slopes, are embedded within Southern Mesic Forest, additional species (amphibians, aquatic invertebrates, wetland plants), which may include rare or sensitive habitat specialists, will find suitable

Remnant mesic hardwood forest in Milwaukee County is dominated by large oaks, maples, American basswood, and American beech. Few such remnants persist in the southeastern corner of the state, all are small and isolated, and most are fragments of formerly much more extensive forested areas. Southern Lake Michigan Coastal Ecological Landscape. Photo by Emmet Judziewicz.

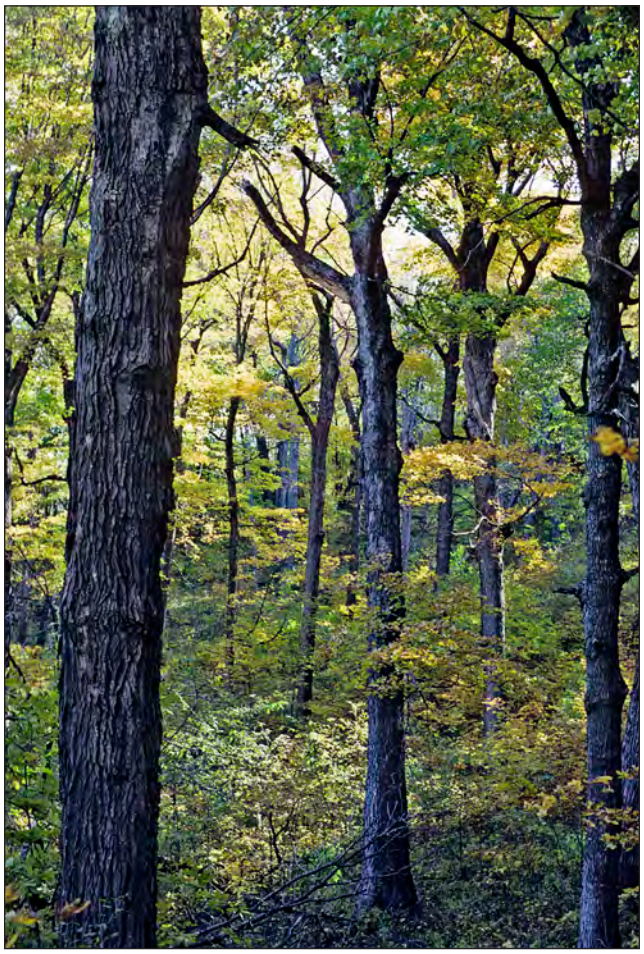
This rich maple-basswood forest on slopes above the Rush River in Pierce County supports a high diversity of herbs, including snow trillium (Wisconsin Threatened), putty-root (Wisconsin Special Concern) and Dutchman's breeches. Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

living conditions. Older stands, for example, those with deep humus and abundant coarse woody debris, are important for frogs and salamanders and some invertebrates.

Conservation and Management Considerations

Critical management issues include severe fragmentation (especially in the southeast), infestations of invasive plants, which can be overwhelming in the case of garlic mustard (*Alliaria petiolata*), exotic earthworms (the issue of soil and understory damage due to the activities of exotic earthworms is well documented and very serious in mesic hardwood forests of northern Wisconsin; the situation in the south is less clear), and negative grazing and browsing impacts due to the activities of domestic livestock and white-tailed deer (*Odocoileus virginianus*). Dutch elm disease, caused by several species of fungi but especially *Ophiostoma ulmi*, has devastated mesic forests in which red or American elm were important components. Beech bark disease (beech scale), caused by interactions of a scale insect (*Cryptococcus fagisuga*) and fungi (several species in the genus *Neonectria*) has been documented in Door County and seems likely to spread throughout the Wisconsin range of American beech. Infested stands may include resistant individuals, so there is some hope that these can be propagated and used to repopulate infested stands. An exotic beetle, the emerald ash borer (*Agrilus planipennis*), has been spreading rapidly, especially in southern Wisconsin, and will alter the composition and structure of infested stands in which ash occurs by killing most of them.

Conservation and management of Southern Mesic Forest will be most effective, especially for associated vertebrates, where this type occurs in a mosaic of other, more extensive hardwood forest communities. Public ownership of mesic hardwood forests is limited and unlikely to increase appreciably; partnerships involving NGOs and other private entities are essential if the best remaining examples are to be maintained, restored, and managed. Additional incentives, focused on the conservation of whole forest communities rather than on exploitation or resource extraction, are needed



Floristically rich southern mesic forest dominated by sugar maple, American basswood, and red oak occupies this moist cove opening to the Kickapoo River in south central Monroe County. Wilton Hemlock-Hardwoods, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Diverse old stands of sugar maple-basswood forest on an alluvial terrace just above the floodplain of the Black River. This stand supports not only a diverse herbaceous layer but several rare animals as well. Black River State Forest, Jackson County, Central Sand Plains Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

for private landowners if the loss of diversity in southern forests is to be reversed or even abated (Rogers et al. 2008, Waller and Rooney 2008).

Some of the best and most extensive conservation opportunities are within the Driftless Area (e.g., in the Baraboo Hills and along the lower Wisconsin River), but there are important stands elsewhere, especially in the southeastern quadrant of the state (the most intact of these are in the northern part of the Kettle Moraine region) and in west central Wisconsin, near the Mississippi and St. Croix rivers. Mesic forests in these areas differ from one another in their post-Pleistocene histories, soils, landforms, and to some degree, in their composition. In most of southern Wisconsin, but especially in the east, this type has been greatly reduced because of outright destruction and the conversion of forested land on fertile, well-drained ground moraine with gentle topography to agricultural or residential uses. Fragmentation pressures are very high, and many remnants are in poor condition because of past grazing, overabundant white-tailed deer, the explosive spread of invasive plants, high-grading, and the influence of activities in the surrounding landscape. Intact mesic hardwood forests are scarce now and becoming increasingly more so.

The classification of forest communities has sometimes been an issue that has presented additional challenges to conservation as resource management agencies do not always differentiate the mesic hardwood forests of southern Wisconsin from the much broader and widely used category of "northern hardwoods." The latter type is still represented by millions of acres in northern Wisconsin and the Upper Peninsula of Michigan and has been considered by some as not worthy of conservation attention because of its abundance. We would emphasize that many of the unique attributes of Southern Mesic Forest, including a high percentage of the rare species mentioned in the "Community Description" section above, are not duplicated or even present in the northern hardwood forests. In addition, there are climatic, geological, and hydrological differences between the mesic hardwood forest of the north and south. The vegetation mosaic and context of the southern hardwood forests is very different from those of the north.

It has become increasingly difficult to find intact examples of Southern Mesic Forest in good condition. The acreage of this community occurring on public lands is limited, and it is important to avoid taking the type for granted. Better incentives are needed for private landowners if they are to focus on the conservation of southern Wisconsin's forest communities to ensure that they can be better protected from the negative impacts of incompatible or short-sighted land uses.

Additional Information

For related information, see the natural community descriptions for Northern Mesic Forest, Southern Dry-mesic Forest, and Southern Hardwood Swamp. The U.S. National Vegetation Classification type most closely corresponding to Southern Mesic Forest is CEGL002062 North-central Maple – Basswood Forest (Faber-Langendoen 2001). It is likely that CEGL005013 Beech - Maple Glaciated Forest would apply to a limited acreage of mesic hardwood forests in southeastern Wisconsin. It would also apply to beech-maple hardwood forests north of the Tension Zone in close proximity to Lake Michigan though at least a few of these stands also support coniferous tree species such as eastern white pine, eastern hemlock, and northern white-cedar (*Thuja occidentalis*).

Also see:
Grimm (1984)

FROM: Epstein, E.E. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management.* Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.

For a list of terms used, please visit the **Glossary.**

For a reference list, please see the **Literature Cited.**

Southern Dry-mesic Forest (Global Rank G4; State Rank S3)

Overview: Distribution, Abundance, Environmental Setting. Ecological Processes

Southern Dry-mesic Forest is most common and best developed south of the Tension Zone, especially in the relatively rugged terrain of the Driftless Area in the Western Coulees and Ridges Ecological Landscape. As almost 70% of the Driftless Area is in Wisconsin, conservation and management opportunities are somewhat greater here than they are elsewhere in the Upper Midwest.

Southern Dry-mesic Forest is also a widespread natural community in densely populated and heavily developed southeastern Wisconsin, but extensive areas of oak-dominated forest are now limited to the northern portions of the Kettle Moraine region where the rough topography of the interlobate moraine has somewhat limited the intensive agricultural and residential uses that are now regionally prevalent. In other parts of southern Wisconsin, Southern Dry-mesic Forest now occurs mostly as scattered farm woodlots or in narrow strips on steep sideslopes bordered by agricultural fields. Apart from the Driftless Area, the northern Kettle Moraine, and a few locations in central Wisconsin, blocks of this forest community exceeding 1,000 acres are generally absent.

Community Description: Composition and Structure

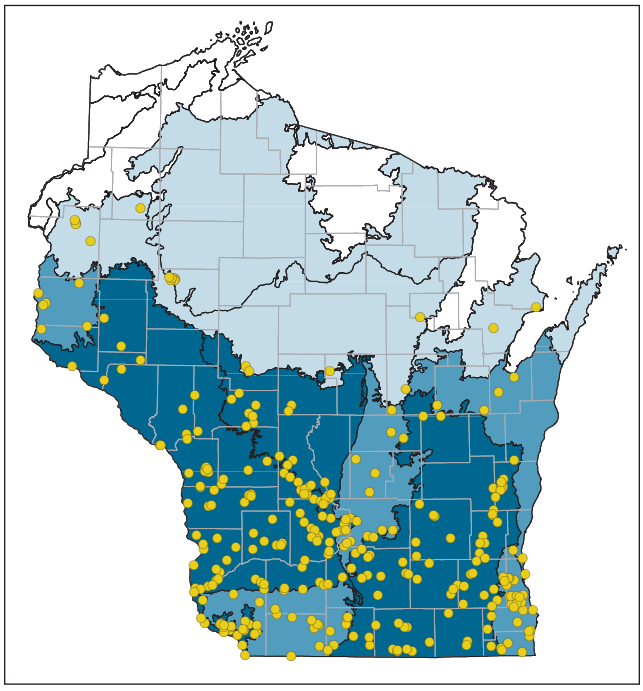
Dominant trees of relatively undisturbed, intact, mature stands are northern red oak (*Quercus rubra*), white oak (*Q. alba*), red maple (*Acer rubrum*), and sometimes American basswood (*Tilia americana*). Associates include shagbark hickory (*Carya ovata*), bitternut-hickory (*C. cordiformis*), black cherry (*Prunus serotina*), butternut (*Juglans cinerea*), and American elm (*Ulmus americana*). In the easternmost parts of southern Wisconsin, American beech (*Fagus grandifolia*) is sometimes a component of Southern Dry-mesic Forest.

Mature dry-mesic hardwood forest of red oak, white oak, and red maple. Monroe County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Saplings and small trees usually belong to the more shade-tolerant mesophytes, such as red maple, sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), bitternut-hickory, and cherries (*Prunus* spp.). Ironwood (*Ostrya virginiana*) may be common as a sapling or small tree. Though oak seedlings can often be found, sapling oaks are generally scarce and may be altogether absent.

Shrubs associated with Southern Dry-mesic Forest include American hazelnut (*Corylus americana*), gray dogwood (*Cornus racemosa*), American witch-hazel (*Hamamelis virginiana*), and maple-leaved viburnum (*Viburnum acerifolium*).

The herbaceous flora may be highly variable as the community is widely distributed and covers a broad geographic range across southern and central Wisconsin. Like other fire-dependent natural communities, the Southern Dry-mesic Forest understory has been undergoing rapid changes in recent decades (Rogers et al. 2008). Among the groundlayer species that are widespread and that might be considered "characteristic" are wild geranium (*Geranium maculatum*), broad-leaf enchanter's-nightshade (*Circaea lutetiana*), false Solomon's-seal (*Maianthemum racemosum*), pointed tick-trefoil (*Desmodium glutinosum*), hog-peanut (*Amphicarpaea bracteata*), wood anemone (*Anemone quinquefolia*), American lop-seed



Locations of Southern Dry-mesic Forest in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

(*Phryma leptostachya*), large-flowered bellwort (*Uvularia grandiflora*), lady fern (*Athyrium filix-femina*), interrupted fern (*Osmunda claytoniana*), fragrant bedstraw (*Galium triflorum*), jack-in-the-pulpit (*Arisaema triphyllum*), downy yellow violet (*Viola pubescens*), and black snakeroot (*Sanicula* spp.).

Stands occupying sites that are variable in slope, aspect, soil depth, soil type, and moisture availability are likely to support some herbs characteristic of other forest communities, including such well-known spring wildflowers as spring-beauty (*Claytonia virginica*), Virginia water-leaf (*Hydrophyllum virginianum*), and blue cohosh (*Caulophyllum thalictroides*). Adjoining dry forests may contribute an additional complement of understory species. Examples might include rough-leaved sunflower (*Helianthus strumosus*) and starry false Solomon's-seal (*Maianthemum stellatum*). In the more extensive forests of southwestern Wisconsin, stands often include features such as springs, seepages, and bedrock outcrops. This adds to the number and kinds of niches available and increases the potential to support additional species and functions.

Among the rare and uncommon plants associated with Southern Dry-mesic Forest are forked aster (*Eurybia furcata*), heart-leaved skullcap (*Scutellaria ovata*), autumn coralroot (*Corallorhiza odontorhiza*), woodland boneset (*Eupatorium sessilifolium* var. *brittonianum*), Short's rock-cress (*Arabis shortii*), and nodding pogonia (*Triphora trianthophora*).

Characteristic birds inhabiting this forest community include Scarlet Tanager (*Piranga olivacea*), Eastern Wood-Pewee (*Contopus virens*), Great Crested Flycatcher (*Myiarchus crinitus*), Red-bellied Woodpecker (*Melanerpes carolinus*), Barred Owl (*Strix varia*), White-breasted Nuthatch (*Sitta carolinensis*), Red-eyed Vireo (*Vireo olivaceus*), Yellow-throated Vireo (*Vireo flavifrons*), and Ovenbird (*Seiurus aurocapilla*). Large stands are of especially critical importance to area-sensitive species, such as the Cerulean Warbler (*Setophaga cerulean*), Hooded Warbler (*Setophaga citrina*), Worm-eating Warbler (*Helmitheros vermivorum*), Acadian Flycatcher (*Empidonax virescens*), and Wood Thrush (*Hylocichla mustelina*).

Mature stand of southern dry-mesic forest composed of large red oak, white oak, red maple, and other hardwoods features an intact ground layer and supports several rare forest interior birds. Norwalk Hardwoods, Monroe County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

The extensive oak forests of southwestern Wisconsin have proven to be of high importance to migrating passerines as the peak spring migration periods for many of these birds is somewhat synchronized with the flowering of the oaks, opening of the oak leaf buds, and the appearance of a major hatch of caterpillars—an important food source for insectivores such as the wood warblers, vireos, gnatcatchers, and others needing to replenish their energy reserves after their long journeys.

At locations in southern Wisconsin where conifers play a significant role in the overall forest composition, the diversity of resident birds can be exceptionally high. Among the locations featuring such mixed deciduous-coniferous forests are the stream gorges of the Baraboo Hills (Sauk County) and the Upper Kickapoo River Valley (Vernon and southern Monroe counties).

Other animals for which Southern Dry-mesic Forest provides important habitat include gray fox (*Urocyon cinereoargenteus*), woodland vole (*Microtus pinetorum*), eastern red bat (*Lasiurus borealis*), northern long-eared bat (*Myotis septentrionalis*), and gray rat snake (*Pantherophis spiloides*).

Conservation and Management Considerations

Along with habitat fragmentation and decreasing patch size, the composition of oak-dominated southern dry-mesic forests is changing (Nowacki and Abrams 2008). In the absence of periodic fire and under current harvest regimes, mesophytic (and sometimes rather weedy) tree species are becoming increasingly common and may eventually dominate the canopy. The primary factor responsible for this is the long-term policy of fire suppression, which has now been in place for a century or more in much of southern Wisconsin. In the absence of appropriate periodic disturbance, especially by fire, the oaks are eventually replaced by other hardwoods, and these species are often of significantly lower ecological value to forest wildlife. Red and white oak timber is also a significant source of economic value to local landowners and communities.

Prolonged periods of fire suppression, repeated episodes of high-grading (an unsustainable but all too common logging practice), infestations of gypsy moth (*Lymantria dispar*) and other invasive species, excessive browse pressure due to high white-tailed deer (*Odocoileus virginiana*) populations, and heavy pasturage by livestock have all been recent contributors to the decline of oak in southern Wisconsin forests.

The understories of stands heavily disturbed by severe windstorms, logging, or prolonged grazing may be choked by dense thickets of blackberries (*Rubus* spp.), gooseberries (*Ribes* spp.), common prickly-ash (*Xanthoxylum americanum*), or other shrubs partially protected by spines or thorns. They

Mature forest dominated by large northern red and white oaks. Note the general absence of mesophytic competitors such as red maple, black cherry, and ironwood in the stand pictured. Maintaining oaks on mesic and dry-mesic sites in the absence of fire and in the presence of dense growths of shade-tolerant shrubs and saplings has been problematic, and current logging practices used by some can aggravate this issue and speed cover type conversion. Baraboo Hills, Sauk County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

may also be heavily invaded by nonnative invasive shrubs, such as the Eurasian honeysuckles (*Lonicera tatarica*, *L. morrowii,* and the hybrid *L.* x *bella*), buckthorns (*Rhamnus cathartica* and *R. frangula*), and Japanese barberry (*Berberis thunbergii*). Invasive herbs are now serious problems in many of southern Wisconsin's hardwood forests. Problematic weedy herbs in Southern Dry-mesic Forest include garlic mustard (*Alliaria petiolata*) and dame's rocket (*Hesperis matronalis*).

Given the ongoing major threats to the dry-mesic oak forests, as well as to other communities usually considered as parts of the fire-dependent oak ecosystem, the managers' toolkit to perpetuate oaks needs expansion. To have any hope of being effective, this will need to include measures such as prescribed fire, herbicide use, manual removal of competing shrubs and saplings, underplanting of seedling oaks of local genotypes, and fencing. This is especially important on dry-mesic sites where conditions border on mesic. Some of these practices may be well beyond the means of many private woodlot owners, but an investment must be made in developing more reliable and cost-effective means of maintaining our oak forests.

Opportunities to manage for oak-dominated dry-mesic forests at large scales are best in the Driftless Area, especially in the Western Coulees and Ridges Ecological Landscape. The Baraboo Hills and some of the blufflands along southwestern Wisconsin's larger rivers (e.g., the Mississippi, Wisconsin, Chippewa, and Black) offer especially good opportunities to manage for a broad suite of southern forest, savanna, and grassland communities. In southeastern Wisconsin, the northern portion of the Kettle Moraine region, including parts of the Northern Unit of the Kettle Moraine State Forest, also offer excellent opportunities to manage for this forest type, although at somewhat reduced scales and in a portion of the ecological landscape in which savanna and prairie representation is greatly reduced or absent compared to areas farther south and west.

As habitat fragmentation is also a serious problem for Southern Dry-mesic Forest and all other upland forest communities in southern Wisconsin, where feasible Southern Dry-mesic Forest should be conserved and managed in large patches that include other forest communities as well as bedrock outcrops, spring seeps, rivers, and streams. This will maximize ecosystem diversity and viability as conditions change over time and will provide habitat for populations of species that cannot or are unlikely to be maintained in small, isolated patches.

The Southern Dry-mesic Forests support a wealth of native plants and animals, including many that do not occur in the much more extensive and less fragmented forests of northern Wisconsin. In addition to the ecological values provided by the southern oak forests, the dominant trees are notable for their longevity and the great size they may attain and for their aesthetic appeal and high economic value. Private-public partnerships and the development of appropriate incentives will be among the key factors necessary to achieve success in conserving this forest community.

Efforts to perpetuate oaks as components of forests on dry-mesic sites may include areas that are presently treeless or with very low tree cover (e.g. fallowed or abandoned agricultural fields or pastures, ensuring that the openings do not represent a remnant natural community, such as a bedrock glade, savanna, or prairie), especially if they occur as small but hard-edged openings within areas of extensive hardwood forest. When both historical and present conditions indicate that forest vegetation is appropriate cover for such small openings, reforestation may be a better, and far more practical, choice than maintaining a non-natural opening. In addition to potentially increasing the amount of oak on the landscape, such activities could reduce the negative impacts of hard edge while increasing the area of effective

forest for many wildlife species. This could also ameliorate the practice of entering the older, more intact stands first, which can further decrease the number of large patches and already scarce developmental stages needed by some species. This is a consideration that should become a part of the oak ecosystem managers' toolkit.

Additional Information

For additional information, see the natural community descriptions for Southern Dry Forest, Southern Mesic Forest, Central Sands Pine-Oak Forest, and Northern Dry-mesic Forest. The U.S. National Vegetation Classification associations corresponding most closely to Wisconsin's Southern Dry-mesic Forest are Midwestern White Oak – Red Oak Forest CEGL002068 and Red Oak – Sugar Maple – Elm Forest CEGL005017.

Also see:
Abrams (1992)
Abrams (1998)
Abrams (2003)
Abrams (2005)
Bowles et al. (2007)
Dey et al. (2010)
Fralish 2004)
Johnson et al. (2009)
Knoot et al. (2010)
Leach and Ross (1995)
Lorimer (1984)
Nowacki and Abrams (2008)
Rodewald (2003)
Rogers et al. (2008)
Steele (2012)
WDNR (2011a)
Wood et al. (2012)

FROM: Epstein, E.E. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management*. Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.

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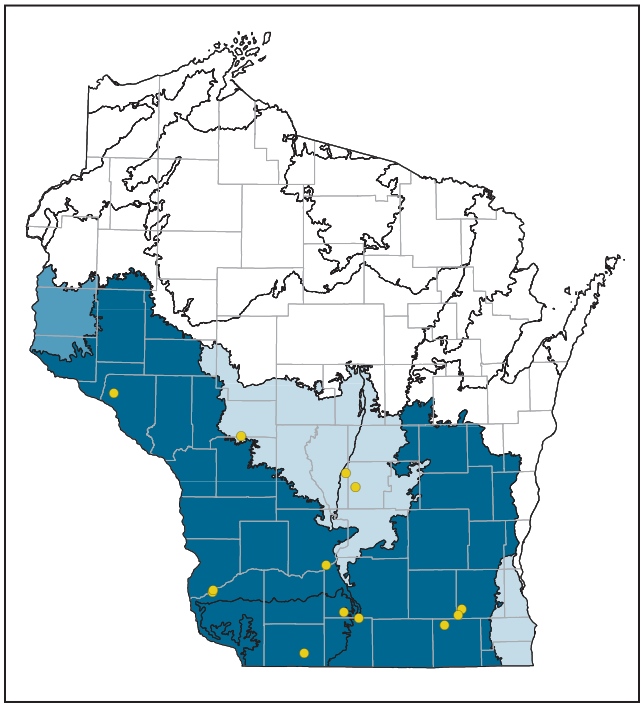
Oak Woodland (Global Rank GX; State Rank S1)

Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

Oak Woodland is an integral part of the fire-dependent oak ecosystem complex, which also includes oak-dominated savannas and forests. Structurally, canopy cover in Oak Woodland is greater than that characteristic of the true savanna communities such as the more open, sparsely timbered Oak Opening and somewhat less than or approaching the more densely canopied Southern Dry and Southern Dry-mesic Forests. Canopy cover in Oak Woodland exceeds 50% and may approach 100%. Though this community shares many attributes with savannas and dry forests, a key point in defining Oak Woodland is that the higher canopy cover in remnants or restored stands is not simply due to fire suppression and the subsequent proliferation of fire-sensitive woody species. Besides the higher density of trees and greater canopy cover, the trees in an Oak Woodland lack the short, large diameter boles prevalent in well-developed oak savanna, and the crowns do not exhibit a limb architecture characterized by widely spreading branches, nor will they necessarily have the same form as the narrow crowns entirely lacking the spreading upper limbs of an oak forest.



Locations of Oak Woodland communities in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

It is thought that frequent fires of low-intensity maintained the understory in an open condition, free of dense growths of shrubs and saplings. It is possible that browsing by large herbivores such as elk and white-tailed deer also played a role in maintaining open understory conditions in this type prior to settlement by Euro-Americans. Though little is known about the historical extent or composition of Oak Woodland, it appears that at least some of the characteristic understory plant species (certain legumes, composites, and grasses among them) may reach their greatest abundance here.

The historical range of this type would have basically coincided with the range of other Oak Savannas, especially Oak Openings and perhaps dry hardwood forests dominated by white oak, which occurred mostly south of the Tension Zone in the Central Sand Hills, Southeast Glacial Plains, Southwest Savanna, and Western Coulees and Ridges ecological landscapes.

Community Description: Composition and Structure

Because so few intact examples have been identified and even fewer described in detail, information on composition is somewhat speculative. The canopy dominants on dry-mesic, mesic, and some dry sites in southern Wisconsin are oaks, commonly including white oak (*Quercus alba*), bur oak (*Q. macrocarpa*), northern red oak (*Q. rubra*), and shagbark hickory (*Carya ovata*). Black oak (*Quercus velutina*) and/or northern pin oak

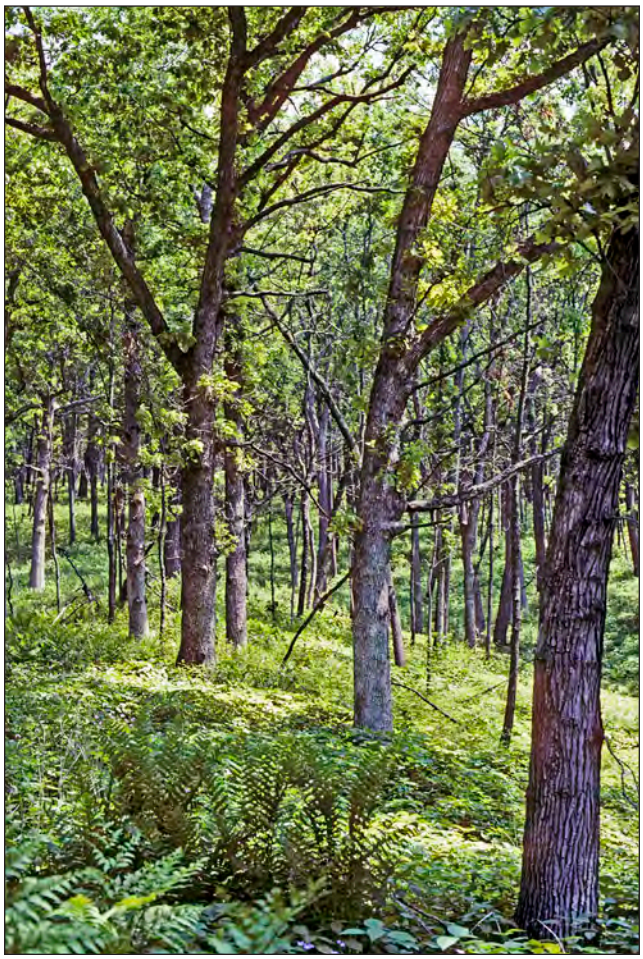
Oak woodland features high canopy closure, but the dominant oaks retain distinctive limb architecture, and the oaks' leaf mosaic allows more light to reach the ground than in stands being invaded by shade tolerant trees such as maples. Such stands are somewhat transitional between more open savannas and true forests. In some situations, they can be managed and maintained to help accommodate both forest interior animals and light-demanding understory plants that tolerate high filtered shade. Kettle Moraine State Forest – South Unit, Jefferson County, Southeast Glacial Plains Ecological Landscape. Photo by Drew Feldkirchner, Wisconsin DNR.

(*Q. ellipsoidalis*) would have been less common, and perhaps absent, on more mesic sites due to their shade intolerance and the competitive advantages some of the other oaks would have had in these environments.

The floristic associates documented by those collecting data that were later analyzed and presented in *The Vegetation of Wisconsin* (Curtis 1959) were compiled about seventy years ago. This was well after fire suppression policies had been widely implemented across the state, and therefore it is thought by some researchers that more of the understory plants representative of an Oak Woodland situation (higher canopy closure and less light reaching the surface) would still have been present and relatively easy to observe. Table VII-3 in Curtis (1959) (Appendix for Chapter 5, "Prevalent Groundlayer Species of Southern Dry Forest") would be worth taking a hard look at for clues to the composition of some oak woodlands during the mid-20th century.

Some members of the Oak Woodland flora are thought to belong to genera or families that are also common in other communities in the oak ecosystem group but represented by a different set of species (belonging to genera that include as members composites, grasses, legumes, mints, and snapdragons). Examples of species observed in and thought to be possibly representative of oak woodland environments include figwort giant hyssop (*Agastache scrophulariaefolia*), poke milkweed (*Asclepias exaltata*), American bellflower (*Campanula americana*), wood thistle (*Cirsium altissimum*), long-bracted green orchid (*Coeloglossum viride*), bracted tick-trefoil (*Desmodium cuspidatum*), purple Joe-Pye-weed (*Eupatorium purpureum*), bottlebrush grass (*Elymus hystrix*), forest bedstraw (*Galium circaezans*), broad-leaved panic grass (*Dichanthelium latifolium*), Solomon's-seal (*Polygonatum biflorum*), Short's aster (*Symphyotrichum shortii*), and yellow-pimpernel (*Taenidia integerrima*).

This white oak-red oak-black oak woodland has been "thinned from below," and several prescribed burns have reduced the heavy shade created by the previously dense understory of deciduous shrubs and saplings. Legumes, composites, and other light-demanding herbs are now thriving in the understory. Rush Creek State Natural Area, Crawford County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.



Mixed stand of white, black, and red oaks is now managed with prescribed fire to restore and maintain open understory conditions and allow for the habitat needs of the more light-demanding herbs. Oak woodland is an important part of the continuum of fire-dependent communities occurring in southern Wisconsin. Rush Creek State Natural Area, Crawford County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Understory plants associated with oak savannas such as large-flowered yellow false foxglove (*Aureolaria grandiflora*), wild lupine (*Lupinus perennis*), and starry campion (*Silene stellata*) are also of potential or even likely occurrence within some oak woodlands. Species more often found in oak forest situations such as rough-leaved sunflower (*Helianthus strumosus*) and black-seeded rice grass (*Oryzopsis racemosa*) may also occur in Oak Woodland. Keep in mind that light conditions and the degree of shading may vary considerably within different parts of an oak savanna, oak forest, or oak woodland.

Plant species of high conservation significance owing to rarity or for other reasons would probably overlap with those more often associated with Oak Openings, at least to some degree. Examples include great Indian-plantain (*Arnoglossum reniforme*), purple milkweed (*Asclepias purpurascens*), yellow giant hyssop (*Agastache nepetoides*), violet bush-clover (*Lespedeza violacea*), snowy campion (*Silene nivea*), hairy meadow parsnip (*Thaspium chapmanii*), purple meadow-parsnip (*T. trifoliatum*), and white camas (*Zigadenus elegans*).

Characteristic animals may include not only typical savanna associates such as the Orchard Oriole (*Icterus spurius*), Eastern Bluebird (*Sialia sialis*), Northern Flicker (*Colaptes auratus*), and the declining Red-headed Woodpecker (*Melanerpes erythrocephalus*) but also species more often associated with hardwood forests, such as Great-crested Flycatcher (*Myiarchus crinitus*), Eastern Wood-pewee (*Contopus virens*), Red-bellied Woodpecker (*Melanerpes carolinus*), Blue-gray Gnatcatcher (*Polioptila caerulea*), and Yellow-throated Vireo (*Vireo flavifrons*). Several area-sensitive forest interior birds, such as Cerulean Warbler (*Setophaga cerulean*), Hooded Warbler (*Setophaga citrina*), and Acadian Flycatcher (*Empidonax virescens*), have been documented in Oak Woodland during their breeding seasons. Where stand size is sufficient, community structure is appropriate, and where Oak Woodland adjoins extensive areas of dry-mesic or mesic hardwood forest, it may be possible to maintain populations of these species.

Conservation and Management Considerations

Oak Woodland occurred south of the Tension Zone where it most often occupied a position in the continuum of fire-dependent, fire-maintained natural communities between oak savannas and closed hardwood forests. In the absence of fire or other disturbances, the ground layer was quickly overtaken by shrubs and saplings, and characteristic forbs and grasses were either suppressed and reduced in vigor or disappeared altogether.

Among the numerous obstacles preventing or impeding the conservation and maintenance of Oak Woodland are fire exclusion, logging of the large canopy oaks, livestock grazing, leaf litter build-up, and an increase in shrubs, saplings, and small trees, especially infestations of species formerly excluded or suppressed because of their sensitivity to periodic fire. Colonization by highly invasive species, many of them nonnative, is also a significant problem for managers. The lack of basic information on this segment of fire dependent oak ecosystems is another problematic factor.

The conservation focus will be on restoration, as remnants are either overgrown with woody understory plants or have lost their most characteristic understory species due to periods of prolonged grazing or the proliferation of invasive plants. Among the benefits to be gained by restoring and maintaining oak woodland is a clearer understanding that many of the native plant species that are currently declining in unburned oak "forests" will ultimately be lost from many parts of southern Wisconsin. Managing proactively for Oak Woodland using prescribed fire could alleviate or forestall this situation, at least locally.

As community stability is inherently low (or nonexistent) in the absence of periodic fire, there is a significant lack of information on the fire regime needed to restore and maintain an understory composed of native herbs in the Oak Woodland community. As a practical consideration, identifying and mapping stands of Oak Woodland using remote sensing imagery alone would be difficult or impossible. Canopy cover alone is not a criterion that will permit the planner, researcher, or natural resource manager to delineate occurrences of Oak Woodland with much confidence.

There are several factors that will aid in the differentiation of Oak Woodland from other fire dependent oak-dominated communities, such as oak savanna or oak forest. Among the potentially important clues to consider are composition of both the canopy and understory, limb architecture of the canopy trees, position in the local landscape with respect to physical features and other plant communities (which are the sources for recolonization of lost or depleted plants and animals from nearby woodland remnants), and perhaps most critically, the amount of light that reaches the soil surface.

The Oak Woodland type is NOT meant to simply indicate an overgrown Oak Opening in need of crown thinning—though that could be an appropriate, even necessary, management action for stands where more mesophytic tree species such as red maple, cherries, ashes, or ironwood have become part of the canopy.

More field inventory is needed to better characterize the community and identify restorable sites, especially those that occupy strategic locations bordered by oak savanna and oak forest. Managers of landscapes in which oak ecosystems are prevalent may be excellent sources of information, especially in areas such as the southern Kettle Moraine in southeastern Wisconsin or at scattered locations within the Driftless Area where management to maintain and restore savannas is an ongoing activity. This may be especially true in the vicinity of rough terrain bordering big rivers where the full complement of southern Wisconsin's fire-dependent natural communities is either present or could potentially be restored to functionality. Ideally these sites will be situated so that they can be managed with prescribed fire and, as needed and appropriate, by other methods such as brushing, judicious cutting, and limited herbicide use.

A potentially significant advantage to managers and conservationists when recognizing and managing Oak Woodland is that it can bridge the gap between stands managed to maintain or restore open savanna conditions with low tree cover of 10% to 50% and closed canopy forest. At some sites, this may mimic historical conditions and at others provide habitat for at least some sensitive forest interior species (Cerulean Warbler would be one of those). It would also mitigate some of the negative impacts associated with "hard," high contrast edge (such as excessive white-tailed deer (*Odocoileus virginiana*) browse, increased rates of brood parasitism and predation, and more competition from already abundant edge-adapted species).

It is possible, even likely, that important variants of Oak Woodland occur on wet-mesic, mesic, and very dry sites. However, at this time there is a lack of data sufficient to allow for the adequate description of additional oak woodland communities. Stands on extremely dry, droughty, low nutrient sites with coarse textured soils in which the dominant oaks are mostly black oak or northern pin oak may experience somewhat different disturbance regimes (for example, more frequent, catastrophic, stand-replacing fires) and require other management approaches—especially on sites that historically supported open barrens communities. These were most often in the sand country of central Wisconsin and on the broad sandy terraces bordering major rivers in southwestern Wisconsin.

Additional Information

Information on related vegetation types can be found in the natural community descriptions in this chapter for Oak Openings, Oak Barrens, Southern Dry Forest, and Southern Dry-mesic Forest. The U.S. National Vegetation Classification type most closely resembling Oak Woodland on dry-mesic to mesic sites is CEGL002142 White Oak – Bur Oak – Northern Red Oak / American Hazelnut Woodland (Faber-Langendoen 2001). However, CEGL002134 Central Midwest White Oak – Mixed Oak Woodland, though described for areas south of Wisconsin, and a wet-mesic type CEGL002140 Burr Oak Bottomland Woodland may also fit some Wisconsin occurrences with a bit of modification.

Special thanks to Wisconsin DNR botanist Rich Henderson for shedding light on many of the unknowns and other difficulties associated with this often-ignored and somewhat nebulous segment of the fire-dependent oak ecosystem continuum.

Also see:

Bray (1958)
Delong and Hooper (1996)
Gilbert and Curtis (1953)
Grossman and Mladenoff (2007)
Leach and Ross (1995)
Packard (1993)
WDNR (2010)

FROM: Epstein, E.E. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management*. Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.

For a list of terms used, please visit the **Glossary.**

For a reference list, please see the **Literature Cited.**

Oak Opening (Global Rank G1; State Rank S1)

Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

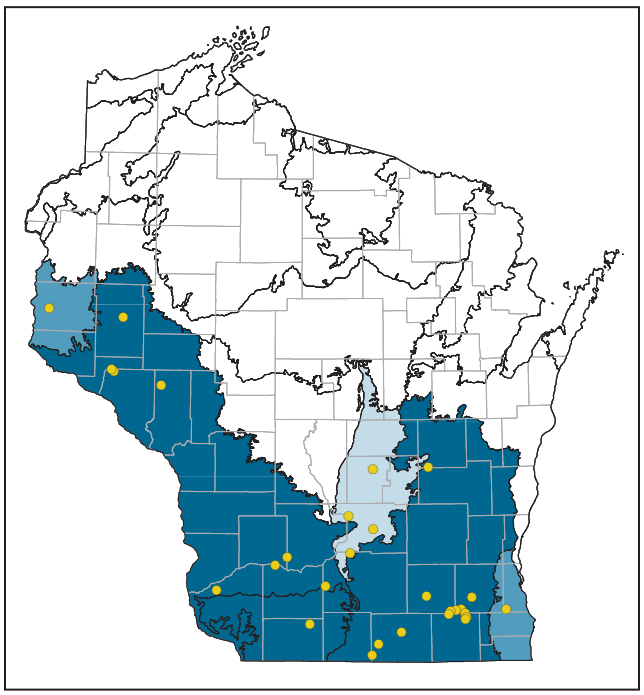
Historically, Oak Openings occurred on dry to wet-mesic sites across much of southern and western Wisconsin. Patch size and configuration varied greatly, and the community was found as isolated groves, in draws between ridges, on tongue-like peninsulas, on steep slopes partially protected by waterbodies or wetlands, and sometimes as extensive ecotonal areas separating open prairie from closed forest. According to the interpretations of Curtis (1959) and Finley (1976), Oak Openings covered approximately 5.5 million acres in southern Wisconsin at the time of the federal public land survey in the mid-19th century. Only the vast (and variable) Northern Mesic Forests in the northern part of the state were more extensive.

In 1959 Curtis wrote that "an oak savanna with an intact ground layer is the rarest plant community in Wisconsin today." This statement applies throughout the continental range of the type (Nuzzo 1986) and is even more apt now than it was a half century ago. Virtually all present conservation efforts to maintain and reestablish this type are restorations, wherein prescribed fire, mechanical removal of shrubs and saplings, mowing, and herbicides are employed to eliminate or control unwanted woody growth and invasive herbs and encourage suppressed native groundlayer plants. In some restoration efforts, it has been deemed necessary to reintroduce native plant species that have been lost.

As defined by Curtis (1959), Oak Openings are oak-dominated savanna communities in which there was at least one tree per acre but where total tree cover was less than 50%. However, he also noted that the "density (of trees) per acre was the most variable of all characteristics," a key point for managers and restoration planners. It's also worth noting that Oak Openings could grade seamlessly into communities still influenced by and ultimately dependent on periodic wildfire but characterized by increasing levels of canopy closure. A continuum of the fire-dependent "oak ecosystem" could grade from open and park-like oak openings, to a more closed oak woodland, and finally to closed canopy oak forest.

By 2012 wildfire suppression in much of the state had been policy for a century or more throughout the former range of these savannas. As a result, canopy cover is not by itself a useful criterion to define an Oak Opening, nor is it necessarily useful to identify a remnant. Multiple factors, such as the spacing and limb architecture of the dominant oaks, stand disturbance history, landscape position with respect to past fire behavior, and floristic associates (if they haven't been shaded or grazed into oblivion) are arguably of greater importance in identifying stands that have retained some savanna attributes and possess the highest restoration potential (Leach and Givnish 1998).

Few extant remnants are in good condition, and these are now mostly limited to dry, often steep, rocky or gravelly sites. Remnant condition is typically poor owing to explosive



Locations of Oak Opening communities in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

This morainal ridge in Waukesha County supports a remnant oak opening. The dominant trees are large open-grown bur oaks, with scattered white oak and shagbark hickory also present. A long history of grazing has maintained savanna structure, but the understory is now composed almost entirely of nonnative cool season grasses. Southeast Glacial Plains Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

increases in woody growth, the dominance of invasive plants, the past and present impacts of grazing, and removal of the large oaks for timber or firewood. Oak Openings on mesic sites were formerly abundant, but these have essentially been extirpated, not only from southern Wisconsin but from the entire midwestern range of the community. Lowland savannas (these would occur on alluvial river terraces above the true floodplain) are now extremely rare, and known remnants are weedy and/or badly overgrown with shrubs and saplings.

The loss of the Oak Openings has been primarily due to four factors: the implementation of widespread fire suppression policies leading to an increase in the abundance and cover of woody plants at the expense of the native herbs; conversion of lands supporting savannas to other uses and cover types; prolonged periods of heavy grazing, which maintained savanna structure but caused the decline or loss of many native floristic associates; and recent increases in the abundance of invasive plants.

Fragmentation and the great changes in the vegetation mosaic within which the Oak Openings historically occurred have undoubtedly been significant factors in this formerly abundant natural community's demise, but the absence of intact remnants and the destruction and outright loss of the associated tallgrass prairies make the Oak Openings difficult to describe with precision, let alone manage with accurately predicted outcomes.

Community Description: Composition and Structure

Bur oak (*Quercus macrocarpa*) was the dominant tree on many mesic and dry-mesic sites in southeastern Wisconsin, with white oak (*Q. alba*) a dominant or co-dominant in some stands. Black oak (*Quercus velutina*) and shagbark hickory (*Carya ovata*) were the most important associates. The bur oaks were capable of achieving great girth, and the spreading crowns were often wider than the trees were high. No other upper midwestern plant community featured this unique stand physiognomy.

Shrub cover is highly variable and is often based on the time elapsed since the last fire. Important members of the shrub layer include American hazelnut (*Corylus americana*), gray dogwood (*Cornus racemosa*), New Jersey tea (*Ceanothus americanus*), leadplant (*Amorpha cansescens*), and several native roses (*Rosa* spp.).

The herbaceous layer has the potential to support high floristic diversity as it may include plants associated with open oak woodlands, more densely canopied oak-dominated hardwood forests, and treeless prairies. Historically, representative herbs were big blue-stem (*Andropogon gerardii*), little blue-stem (*Schizachyrium scoparium*), needlegrass (*Stipa spartea*), Leiberg's panic grass (*Dichanthelium leibergii*), flowering spurge (*Euphorbia corollata*), wild bergamot (*Monarda fistulosa*), thimbleweed (*Anemone cylindrica*), American pasqueflower (*A. patens*), northern bedstraw (*Galium boreale*), bird's-foot violet (*Viola pedata*), eastern shooting-star (*Dodecatheon meadia*), Solomon's-seal (*Polygonatum biflorum*), early buttercup (*Ranunculus fascicularis*), and yellow-pimpernel (*Taenidia integerrima*). Diverse and colorful displays of composites, especially among the asters, sunflowers, and blazing stars, were noted by observers who encountered the Oak Openings prior to the widespread settlement of southern Wisconsin by Euro-American immigrants.

A relatively small number of plants and animals reach their optimal abundance in the somewhat ecotonal Oak Openings. Some of the better known examples include kitten-tails (*Besseya bullii*), yellow giant hyssop (*Agastache nepetoides*), cream gentian (*Gentiana alba*), smooth phlox (*Phlox glaberrima*), white camas (*Zigadenus elegans* var. *glaucus*), and purple milkweed (*Asclepias purpurascens*), all of which are now rare in Wisconsin. Among other plants that are known to occur in Oak Openings but that are either too rare to be useful as indicators of any particular community assemblage or structure, or which have been more strongly linked to other natural communities, are woolly milkweed (*Asclepias lanuginosa*), great Indian-plantain (*Arnoglossum reniforme*), wild hyacinth (*Camassia scilloides*), violet bush-clover (*Lespedeza violacea*), slender bush-clover (*L. virginica*), and one-flowered broom-rape (*Orobanche uniflora*).

One of the native plants adapted to the filtered shade and patchy canopy conditions of the oak opening is the globally rare kitten-tails. Photo by Robert H. Read, Wisconsin DNR.

Animals of conservation interest that have a substantial association with Oak Openings are Eastern Screech Owl (*Megascops asio*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Eastern Bluebird (*Sialia sialis*), and Orchard Oriole (*Icterus spurius*). Trees with cavities can be important maternity sites for bats and also provide cover for other species. In years when the acorn crop is heavy, species such as Wood Duck (*Aix sponsa*) and eastern fox squirrel (*Sciurus niger*) may be common.

Conservation and Management Considerations

Because of its current rarity and the highly degraded condition of most remnants, conservation of the globally imperiled Oak Openings will be almost entirely dependent on efforts to restore heavily disturbed examples, most of them with greatly impaired, diminished, or missing components of the community's characteristic composition, structure, and function.

Frequent fires of low intensity are appropriate prescriptions for this community once the maintenance stage has been achieved, but initially, mechanical removal of unwanted competing shrubs and trees, augmented by the judicious use of herbicides, are critical steps. Once the surplus woody growth has been brought under control (this may be more effectively accomplished in stages, rather than in a rapid, massive reduction of woody cover) and reestablishment of a native ground layer is underway, the reintroduction of periodic fire will be the single most important step taken in the restoration process. Stands undergoing restoration will need to be monitored closely to assess ongoing needs to control invasive species (which are now present in virtually all remnants, including managed stands), set back shrubs and saplings, and determine whether or not there is a need to reintroduce missing elements of the native ground layer, ideally from similar habitats nearby.

The list of problematic invasive plants in the degraded, weed-infested remnants is long and includes Canada thistle (*Cirsium arvense*), garlic mustard (*Alliaria petiolata*), spotted knapweed (*Centaurea biebersteinii*), black swallow-wort (*Vincetoxicum nigrum*), common buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), Japanese barberry (*Berberis thunbergii*), and the Eurasian honeysuckles (especially *Lonicera tatarica* and the hybrid *Lonicera* x *bella*). Exotic cool season grasses often dominate the ground layer of stands with a long history of livestock grazing. Prevalent among these are Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*P. pratensis*), and smooth brome (*Bromus inermis*).

Native shrubs can become abundant in remnant Oak Openings, and managers may seek to control or even eradicate them from sites undergoing restoration. Examples include several of the sumacs (*Rhus* spp.), blackberries (*Rubus* spp.), and common prickly-ash (*Zanthoxylum americanum*).

Oak Opening restoration and management will likely be most successful where other natural communities belonging to the mosaic of fire-dependent vegetation comprising the oak ecosystem are also present (such as oak woodland and oak-dominated forest types) or where the Oak Opening remnant can be embedded within native or surrogate grasslands. Opportunities to accomplish this are best offered by sites in the Driftless Area in both the Western Coulees and Ridges and Southwest Savanna ecological landscapes. Unlike many of the remnants in southeastern and south central Wisconsin (the southern Kettle Moraine being the exception), the steep slopes, shallow soils, and rougher topography of the Driftless Area have retained areas with unplowed sod, which may harbor seeds and other propagules of native species but also the native microflora and fauna associated with the uncropped substrate.

Open-grown bur oaks dominate this remnant oak opening in western Waukesha County. Grazing has maintained savanna stand structure, but the understory is now dominated almost entirely by nonnative plants. Southeast Glacial Plains Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

The southern portion of southeastern Wisconsin's Kettle Moraine region is especially significant as savanna and prairie restoration activities have been occurring there for several decades, a substantial core of public lands well suited (really critical) to these activities exists, and public interest and support for doing work of this nature is high. Excellent partnerships have developed there between public agencies and NGOs (The Nature Conservancy, Waukesha County Land Trust, Friends of the Mukwonago River, and The Prairie Enthusiasts are just a few examples) as well as with many private individuals. Somewhat parallel situations exist in parts of the Driftless Area, though a majority of the public land base there is centered on the larger river corridors. At some of the sites undergoing restoration, the Oak Openings occur within a mosaic of vegetation types that included Wet-mesic Prairie, Southern Sedge Meadow, Calcareous Fen, and Emergent Marsh.

Among the subjects needing additional research are the importance of stand size and connectivity; variability in the spatial and temporal representation of mature trees; compositional differences across the community's Wisconsin range; demographics of the prevalent oak species; representation of native shrubs; the intensity, frequency, and timing of prescribed burns; and differentiating savannas (e.g., those from

which fire has been excluded for many decades) from oak woodland and oak forest. The significance and ecological roles of animals that had been present historically but that are now absent from the range of the Oak Openings such as elk (*Cervus canadensis*), Greater Prairie-chicken (*Tympanuchus cupido*), Sharp-tailed Grouse (*Tympanuchus phasianellus*), and Passenger Pigeon (*Ectopistes migratorius*) also need to be better understood. The Northern Bobwhite (*Colinus virginianus*) might be placed with this group of extirpated species as well.

Savannas on sandy or gravelly alluvium apparently existed on outwash terraces or islands within or in close proximity to several of the major river floodplains, especially in southwestern Wisconsin. To date, documentation of the composition, structure, and function of such alluvial savannas has been very limited, but this is an item that merits further investigation in the near future as good restoration opportunities may exist on some of the public lands bordering rivers such as the Mississippi, Wisconsin, Chippewa, Black, St. Croix, and others.

Wisconsin has a major role to play in the restoration and management of this globally imperiled natural community and is a legitimate focus of land management activities at appropriate sites scattered across southern and central Wisconsin.

Additional Information

For additional information, see the descriptions of Oak Woodland, Oak Barrens, Pine Barrens, Southern Dry Forest, Southern Dry-mesic Forest, Sand Prairie, Dry Prairie, Dry-mesic Prairie, and Mesic Prairie. In parts of southeastern Wisconsin, the descriptions of Wet-mesic Prairie, Southern Sedge Meadow, Calcareous Fen, and Emergent Marsh might also offer information of interest. The U.S. National Vegetation Classification (US NVC) type most closely corresponding to Wisconsin's Oak Openings is GEGL02020 North-central Bur Oak Openings (Faber-Langendoen 2001). The US NVC type CEGL005284 Chinquapin Oak Limestone – Dolomite Savanna is generally found farther south, e.g., in Missouri, but there is at least one good quality occurrence in Wisconsin on dolomite bluffs near the Mississippi River.

Michigan and Ontario have described CEGL005120 Lakeplain Wet-mesic Oak Openings. This extremely rare natural community is possible in the southeastern corner of Wisconsin and northeastern Illinois within the Chiwaukee Prairie-Illinois Beach complex. There is also at least one occurrence of a wet-mesic savanna in south central Wisconsin, south of Madison (obviously this stand would not fit the "lakeplain" concept). More study is needed to appropriately describe and classify this stand. The proposed state name is Wet-mesic (Alluvial) Swamp White Oak Savanna with a state rank of S1.

Also see:

Bowles and McBride (1998)
Brawn (2006)
Bray (1960)
Bronny (1989)
Haney and Apfelbaum (1990)
Haney and Apfelbaum (1994)
Henderson (2005)
Henderson and Epstein (1995)
Hujik (1995)
Kline (1997)
Leach and Ross (1995)
Leach and Givnish (1999)
Nuzzo (1986)
O'Connor et al. (2009)
Packard (1988)
Packard (1993)
Stout (1946)
WDNR (2010)
White (1986)

FROM: Epstein, E.E. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management*. Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.

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For a reference list, please see the **Literature Cited.**

Dry-mesic Prairie (Global Rank G2G3; State Rank S2)

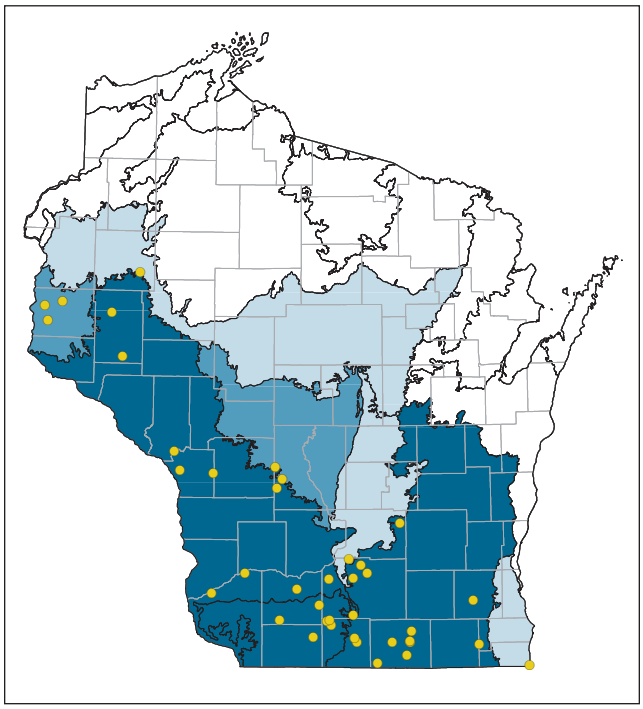
Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

Dry-mesic Prairie is a native grassland community that occurs south of the ecoclimatic Tension Zone. Along with the other tallgrass prairie communities, Dry-mesic Prairie has been almost eliminated from the Upper Midwest, and the remaining occurrences are mostly small and isolated, presenting difficult challenges for conservationists, planners, and site managers. Historical abundance is difficult to estimate for this natural community. Curtis (1959) estimated that ca 30% (or 630,000 acres) of Wisconsin's prairie cover was Dry-mesic Prairie before Euro-American settlement. Estimates of present abundance are less uncertain as only a few hundred acres of this rare natural community are known to persist across its statewide range.

In glaciated southeastern Wisconsin, the landforms supporting this community include outwash, extinct glacial lakebeds, and till plains. Several occurrences are known from drumlins and the lower slopes and bases of end and recessional moraines. Soils are generally somewhat sandy and include sandy loams, loamy sands, and fine sands. Nutrient levels are moderate to low. Dry-mesic Prairie is found on less droughty sites than Dry Prairie or Sand Prairie but supports some of the same species as those communities.

In the unglaciated Driftless Area of southwestern Wisconsin, Dry-mesic Prairie occurs on the lower slopes and at the bases of sandstone or dolomite bluffs and on sandy terraces flanking the large river floodplains. At a few locations, Dry-mesic Prairie has been found on large sandy or gravelly islands within river floodplains. In glaciated southeastern Wisconsin, Dry-mesic Prairie was most strongly associated with either coarse-textured end or recessional moraine or with sandy outwash.

Historically, Dry-mesic Prairie occurred with other native grasslands such as Dry and Mesic prairies and with other fire-dependent natural communities such as oak savanna and oak forest. On river terraces, the community mosaic within which Dry-mesic Prairie was embedded often included Sand Prairie and Oak Barrens or, more rarely, Pine Barrens.



Locations of Dry-mesic Prairie in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

Community Description: Composition and Structure

The dominant grasses are generally of tall or medium stature, with some representation by the shorter species. The most characteristic graminoids are big blue-stem (*Andropogon gerardii*), yellow Indian grass (*Sorghastrum nutans*), needle grass (*Stipa spartea*), prairie dropseed (*Sporobolus heterolepis*), and few-flowered panic grass (*Dichanthelium oligosanthes*). Grasses that are strongly to moderately associated with Dry-mesic Prairie include switch grass (*Panicum virgatum*), Canada wild-rye (*Elymus canadensis*), and several additional panic grasses (*Dicanthelium* spp.).

The forb component is more diverse in the dry-mesic than in the dry or mesic prairies and may include species that are associated with these other prairie communities. Prevalent forbs include sky-blue aster (*Symphyotrichum oolentangiense*), hoary puccoon (*Lithospermum canescens*), false boneset (*Kuhnia eupatorioides*), rough blazing-star (*Liatris aspera*), thimbleweed (*Anemone cylindrica*), whorled milkweed (*Asclepias verticillata*), purple prairie-clover (*Dalea purpurea*), stiff sunflower (*Helianthus pauciflorus*), grooved yellow flax (*Linum sulcatum*), prairie cinquefoil (*Potentilla arguta*), and gray goldenrod (*Solidago nemoralis*).

Among the numerous rare plants associated with Dry-mesic Prairie are the U.S. Threatened prairie bush-clover (*Lespedeza leptostachya*), clustered poppy mallow (*Callirhoe triangulata*), Hill's thistle (*Cirsium hillii*), field dodder (*Cuscuta pentagona*), pale purple coneflower (*Echinacea pallida*), cream gentian (*Gentiana alba*), American feverfew (*Parthenium integrifolium*), prairie-turnip (*Pediomelum esculentum*), pink milkwort (*Polygala incarnata*), rough rattlesnake-root (*Prenanthes aspera*), hairy wild petunia (*Ruellia humilis*), and white camas (*Zigadenus elegans* ssp. *glaucus*). Several of these species are globally rare (e.g., clustered poppy mallow, Hill's thistle, and prairie bush-clover), and some of the Wisconsin

populations are of especially high conservation significance because of large population size and high site viability.

Animals of conservation importance because of their rarity or strong association with this natural community include mammals, birds, reptiles, and invertebrates. Examples are American badger (*Taxidea taxus*), Franklin's ground squirrel (*Spermophilus franklinii*), plains pocket gopher (*Geomys bursarius*), Bobolink (*Dolichonyx oryzivorus*), Dickcissel (*Spiza americana*), Eastern Meadowlark (*Sturnella magna*), Henslow's Sparrow (*Ammodramus henslowii*), Northern Bobwhite (*Colinus virginianus*), Northern Harrier (*Circus cyaneus*), and Western Meadowlark (*Sturnella neglecta*), gophersnake (*Pituophis catenifer*), Blanding's turtle (*Emydoidea blandingii*), and the regal fritillary (*Speyeria idalia*).

As so many of the better quality Dry-mesic Prairie remnants are small or linear, many of the vertebrates mentioned are likely to persist only in prairies that occur within or adjacent to more extensive areas of compatibly managed herbaceous cover. The same may hold true for some of the specialized invertebrates, such as those that are highly dependent on one or a few plant species for their continued existence. Populations of such plants would have to be multiple, large, secure, or exist in close proximity to ensure that the loss of any single plant population would not lead to the subsequent loss of some animals as well.

Some native grassland species do make use of shrubs and thickets as nest sites, feeding areas, hunting perches, and song perches. These include rare species such as Loggerhead Shrike (*Lanius ludovicianus*), Bell's Vireo (*Vireo bellii*), and Northern Bobwhite.

Conservation and Management Considerations

Historically, Dry-mesic Prairie occurred with other native grasslands and oak savannas south of the Tension Zone. In common with all of the fertile and productive tallgrass prairie communities, Dry-mesic Prairie has been greatly reduced

This small but diverse prairie occurs on a west-facing slope between two sandy terraces bordering the Mississippi River. Important grasses are big blue-stem, little blue-stem, yellow Indian grass, and needle grass. A number of showy native forbs also occur here. Midway Prairie State Natural Area, La Crosse County, Western Coulees and Ridges Ecological Landscape. Photo by Thomas Meyer, Wisconsin DNR.

Dry-mesic prairie. Dane County, Western Coulees and Ridges Ecological Landscape. Photo by Thomas Meyer, Wisconsin DNR.

DNR biologist Cathy Bleser conducting surveys at extensive grassland composed of patches of dry-mesic prairie embedded within non-native, formerly pastured "surrogate grasslands" near Barneveld. Iowa County, Southwest Savanna Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

in extent due to conversion of former prairie to agricultural cropland, residential areas, or tree plantations. Prolonged exposure to heavy grazing generally favors nonnative plants.

Currently, many of the sites supporting Dry-mesic Prairie remnants occur within travel or utility corridors. Isolation of these remnants limits their ability to support area-sensitive species. Over time the loss of species with poor dispersal abilities is increasingly likely. Once a species is lost from a remnant, many of the grassland natives will have difficulty recolonizing isolated sites without active intervention.

Active management is required to maintain this community, including the use of prescribed fire, mechanical brush removal, and the judicious use of herbicides. Management is likely to be more successful where the remnants can be buffered and embedded within other managed grasslands and savannas. The proximity of extensive surrogate grasslands and open wetlands can help maintain populations of some area-sensitive prairie animals. At larger scales, especially, it may be more feasible to include important microsites such as rock outcrops, sandblows, springs, and seepage ponds.

Invasive herbs adversely affecting this community include Kentucky bluegrass (*Poa pratensis*), Canada bluegrass (*P. compressa*), smooth brome (*Bromus inermis*), Canada thistle (*Cirsium arvense*), white sweet-clover (*Melilotus albus*), and yellow sweet-clover (*M. officinalis*). Nonnative invasive shrubs include autumn olive (*Elaeagnus umbellata*), several Eurasian honeysuckles (especially *Lonicera tatarica*, *L. morrowii*, and the hybrid *Lonicera* x *bella*), common buckthorn (*Rhamnus cathartica*), and multiflora rose (*Rosa multiflora*). Woody natives can be problematic, especially sumacs (*Rhus* spp.), cherries (*Prunus* spp.), eastern red-cedar (*Juniperus virginiana*), and box elder (*Acer negundo*). Note that the total elimination of the shrub component is not necessarily desirable, especially for those large sites containing multiple grassland communities, complex topography, and natural firebreaks. Such decisions need to be made on a site-specific basis, especially when the shrubs are native, generally noninvasive, and provide food and cover for native wildlife. Examples are gray dogwood (*Cornus racemosa*), American plum (*Prunus americana*) and Canadian plum (*P. nigra*), native roses (*Rosa* spp.), and hawthorns (*Crataegus* spp.). At those sites where rare species such as Loggerhead Shrike, Bell's Vireo, and Northern Bobwhite still occur, management plans need to carefully weigh the pros and cons of retaining shrubs; they certainly should not be eliminated from native grassland situations everywhere.

Most Dry-mesic Prairie remnants occur in areas where agriculture is now the dominant land use. Remnants on some of the large river terraces, for example, along the Mississippi River, continue to be reduced in size, fragmented and isolated by center pivot irrigation-based agriculture and residential development, and encroached upon by invasive plants.

As the vast majority of the land within the range of this community is privately owned, partnerships with NGOs and individuals are essential to achieve effective conservation. The Prairie Enthusiasts, the Wisconsin Chapter of The Nature Conservancy, and the Mississippi Valley Conservancy are among the effective nongovernmental organizations working on the conservation of prairies in southern Wisconsin.

Additional Information

For additional Information, see the natural community descriptions for Dry Prairie, Mesic Prairie, Sand Prairie, Oak Openings, and Oak Barrens. In the "Selected Habitats" section of this chapter, refer to Surrogate Grasslands and Sand Barrens. The U.S. National Vegetation Classification community most closely resembling Wisconsin's Dry-mesic Prairie is CEGL002214 Midwest Dry-mesic Prairie (Faber-Langendoen 2001).

Also see:
Packard and Mutel (1997)

FROM: Epstein, E.E. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management*. Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.

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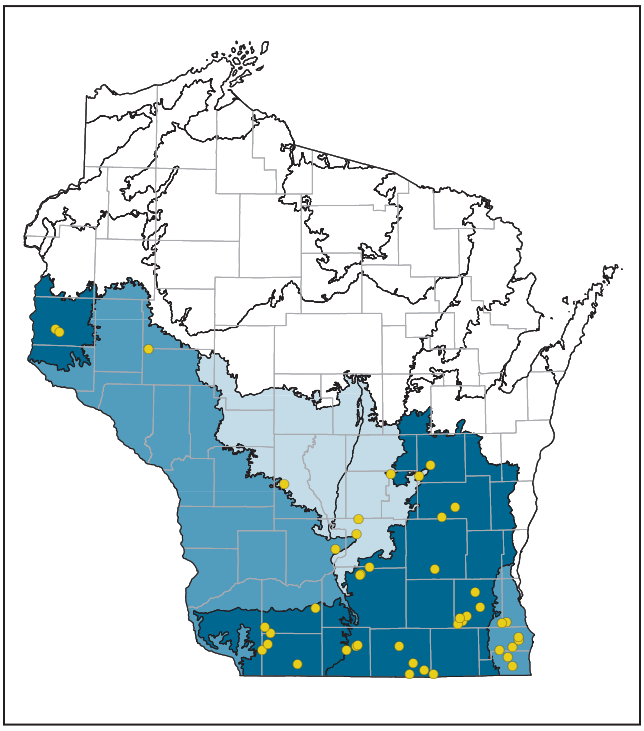
For a reference list, please see the **Literature Cited.**

Mesic Prairie (Global Rank G1G2; State Rank S1)

Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

Mesic Prairie was historically the most abundant of the tallgrass prairie communities in southern Wisconsin, where it was estimated to have covered approximately 840,000 acres (Curtis 1959, Finley 1976). Sites supporting Mesic Prairie featured nutrient-rich loamy soils, level to gently rolling topography, adequate moisture, and good drainage. Frequent wildfire was the primary disturbance factor responsible for maintaining Mesic Prairie, though periodic drought and at times grazing by wild ungulates were sometimes important factors. The most extensive tallgrass prairies occurred in areas lacking natural firebreaks, where there were few lakes, streams, or wetlands to obstruct fires ignited by lightning strikes or native Americans. Major landforms supporting extensive areas of Mesic Prairie included well-drained ground moraine and silt-capped ridgetops in the Driftless Area.

Today Mesic Prairie is one of the rarest native grassland communities in Wisconsin and across continental North America. The few remnants are small, isolated, often weedy, and tend to occur in narrow strips along roads, railroad tracks, or in utility corridors and are highly vulnerable to further degradation and decline. A few stands are known from cemeteries established in the late 19th or early 20th centuries. The landscape mosaic within which tallgrass prairie remnants are embedded today is typically composed of intensively cropped agricultural lands, some of which are rapidly urbanizing. This is especially acute in southeastern and west central Wisconsin.



Locations of Mesic Prairie in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

Community Description: Composition and Structure

The dominant plants are grasses and a diverse and showy assemblage of forbs. Important tall grasses, which grew to heights of 2–3 meters or more, were big blue-stem (*Andropogon gerardii*), yellow Indian grass (*Sorghastrum nutans*), needle grass (*Stipa spartea*), and switch grass (*Panicum virgatum*). Shorter grasses, such as prairie dropseed (*Sporobolus heterolepis*), little blue-stem (*Schizachyrium scoparium*), and several of the panic grasses (e.g., Leiberg's panic grass, *Dichanthelium leibergii*) are often present and may be common in some stands. The diverse forb layer is vibrant as it typically includes good representation from groups such as the asters, goldenrods, sunflowers, blazing stars, and legumes. Representative forbs of Mesic Prairie include compass-plant (*Silphium laciniatum*), prairie rosinweed (*S. integrifolium*), rough blazing-star (*Liatris aspera*), thick-spike blazing-star (*L. pycnostachya*), heath aster (*Symphyotrichum ericoides*), smooth aster (*S. laeve*), stiff sunflower (*Helianthus pauciflorus*), showy tick-trefoil (*Desmodium canadense*), Illinois tick-trefoil (*D. illinoense*), purple prairie-clover (*Dalea purpurea*), rattlesnake-master (*Eryngium yuccifolium*), flowering spurge (*Euphorbia corollata*), prairie thistle (*Cirsium discolor*), northern bedstraw (*Galium boreale*), wild bergamot (*Monarda fistulosa*), yellow coneflower (*Ratibida pinnata*), heart-leaved golden alexanders (*Zizia aptera*), common spiderwort (*Tradescantia ohioensis*), and violet wood-sorrel (*Oxalis violacea*).

Cover values for woody plants would have been low under the disturbance regime of frequent fire that typically maintained the community but increased rapidly as fire suppression policies were implemented across southern Wisconsin by Euro-American immigrants. Shrubs associated with Mesic Prairie included New Jersey tea (*Ceanothus americanus*), prairie willow (*Salix humilis*), lead-plant (*Amorpha canescens*), American hazelnut (*Corylus americana*), and Carolina rose (*Rosa carolina*). Stands from which fire had been excluded for long periods were quickly overrun by shrubs and sapling trees. Problematic plant species for land managers trying to maintain or restore Mesic Prairie are some of the native sumacs such as smooth sumac (*Rhus glabra*) or staghorn sumac (*R. typhina*) and dogwoods like gray dogwood (*Cornus racemosa* and red osier dogwood (*C. stolonifera*) and nonnative highly invasive shrubs such as the Eurasian buckthorns such as common buckthorn (*Rhamnus cathartica*) and glossy buckthorn

(*R. frangula*), honeysuckles (especially Tartarian (*Lonicera tatarica*), Asian fly (*L. morrowii*), and hybrid Bell's (*Lonicera* x *bella*) honeysuckle), and multiflora rose (*Rosa multiflora*).

Some rare plants associated with mesic prairie are pale green orchid (*Platanthera flava*), the U.S. Threatened and Wisconsin Endangered prairie white-fringed orchid (*P. leucophaea),* Wisconsin Endangered wild hyacinth (*Camassia scilloides*), Wisconsin Threatened pale purple coneflower (*Echinacea pallida*), American feverfew (*Parthenium integrifolium*), prairie-turnip (*Pediomelum esculentum*), and hairy fimbristylis (*Fimbristylis puberula*). Mead's milkweed (*Asclepias meadii*) formerly grew in the mesic prairies of southwestern Wisconsin but is now considered extirpated as a wild plant in Wisconsin.

Remnants that have retained high cover values for native grasses and forbs continue to provide habitat for many prairie insects (Panzer et al. 1995) dependent on native prairie vegetation, but some of the vertebrates, especially those that are somewhat area-dependent such as the Great Prairie-Chicken (*Tympanuchus cupido*), Northern Harrier (*Circus cyaneus*), Short-eared Owl (*Asio flammeus*), and American badger (*Taxidea taxus*) are present and persist only if the surrounding area offers extensive areas of open grassland, including core areas that are not cultivated annually. Other noteworthy animals associated with Mesic Prairie are Franklin's ground squirrel (*Spermophilus franklinii*), Henslow's Sparrow (*Ammodramus henslowii*), Bobolink (*Dolichonyx oryzivorus*), and Dickcissel (*Spiza americana*). Rare invertebrates inhabiting mesic prairies include the regal fritillary (*Speyeria idalia*), liatris borer moth (*Papaipema beeriana*), silphium borer (*P. silphii*), phlox moth (*Schinia indiana*), and red-tailed prairie leafhopper (*Aflexia rubranura*).

Conservation and Management Considerations

The attributes of high soil fertility, gentle topography, the absence of trees, John Deere's invention of the first commercially successful steel moldboard plow in 1837, and a large influx of Euro-American settlers (many of them farmers) led to the rapid loss of virtually all of our mesic prairies in less than half a century. Once an implement capable of breaking and turning over the tough prairie sod was available, outright destruction was the overriding factor in the precipitous decline of North America's tallgrass prairies. Because of favorable growing conditions and high productivity for crops, the mesic prairies were among the first of our natural communities to disappear. Today, no more than a few hundredths of one percent of this community's former acreage in Wisconsin persists, a situation which is unfortunately paralleled throughout the continental range of these native grasslands.

Because so many of the persisting remnants are small, isolated, and bordered by intensively cultivated agricultural lands, developed residential areas, roads, or railroad tracks, they are exceptionally vulnerable to damage from herbicide spray, salt residue, nutrient-enriched runoff, and infestations of invasive plants. Where rights-of-way are managed with herbicides or road-grading equipment, the remnants are quickly degraded, and the diversity within them is quickly lost. Grazing, mowing, fire suppression, and tree planting are also disturbances that pose serious threats to mesic prairies. Grazed stands eventually become dominated by nonnative cool season grasses, including smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), Canada bluegrass (*P. compressa*), timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), and reed canary grass (*Phalaris arundinacea*).

Long term, the best conservation opportunities occur where small remnants can be embedded within extensive

Good examples of mesic prairie vegetation are now virtually nonexistent. Rich silt loam soils and level topography led to the almost total destruction of the deep-soil, tallgrass prairies and their conversion to crop land. Extant remnants are all small, isolated, and vulnerable to disturbance and degradation by further species loss, the spread of invasive plants, herbicide drift, and neglect. Ipswich Prairie occupies an abandoned railroad right-of-way in the cornscape that now covers much of Grant and Lafayette counties. Southwest Savanna Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Only small fragments of mesic tallgrass prairie persist today. Most of them are in transportation rights-of-way where they are highly vulnerable to inadvertent damage or outright destruction. Hammond Cemetery Prairie, St. Croix County, Western Prairie Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

areas of open vegetation composed of other prairie types, sedge meadows, and "surrogate" grasslands. This may be especially effective where "prairie pastures" (lands that have a history of livestock grazing but that have never been plowed) are relatively abundant, though these are most often found in areas of steep topography or where bedrock is close to the surface. Occasionally a (narrow) zone of mesic prairie occurs at or near the base of a slope, on the margins of a wetland, or on a narrow ridgetop with a deep loess cap. Meanwhile, it is imperative that the prairie biota, especially plants and invertebrates, are thoroughly surveyed and that the data are analyzed and applied to restoration efforts wherever viable grassland management opportunities at large scales occur.

Sites where it may be feasible to consider the restoration and maintenance of Mesic Prairies at larger scales include Military Ridge and some of the historic prairie areas just to the south, mostly in southwestern Wisconsin's Driftless Area, the Scuppernong Basin in the Southern Kettle Moraine Region in the southeastern part of the state, the Western Prairie Habitat Restoration Area near the Minnesota border in Pierce and St. Croix counties, and, straddling the Wisconsin-Illinois border along Lake Michigan, the Chiwaukee Prairie-Illinois Beach State Park complex.

We also encourage state and local governments, other institutions engaged in land management and protection, NGOs, and private individuals to take on the task of preserving and properly managing as many of the small remnants scattered across southern Wisconsin as is possible.

Additional Information

For additional information on somewhat similar natural communities, see the descriptions for Dry-mesic Prairie, Wet-mesic Prairie, Wet Prairie, Calcareous Fen, Southern Sedge Meadow, and Oak Opening. In the U.S. National Vegetation Classification, the community corresponding most closely to Mesic Prairie is CEGL002203 Big Bluestem – Yellow Indiangrass – (Prairie Dropseed) – Blazingstar Species – Gray-head Prairie Coneflower Herbaceous Vegetation (Faber-Langendoen 2001).

Also see:
Henderson and Krause (1995)
Sample and Mossman (1997)

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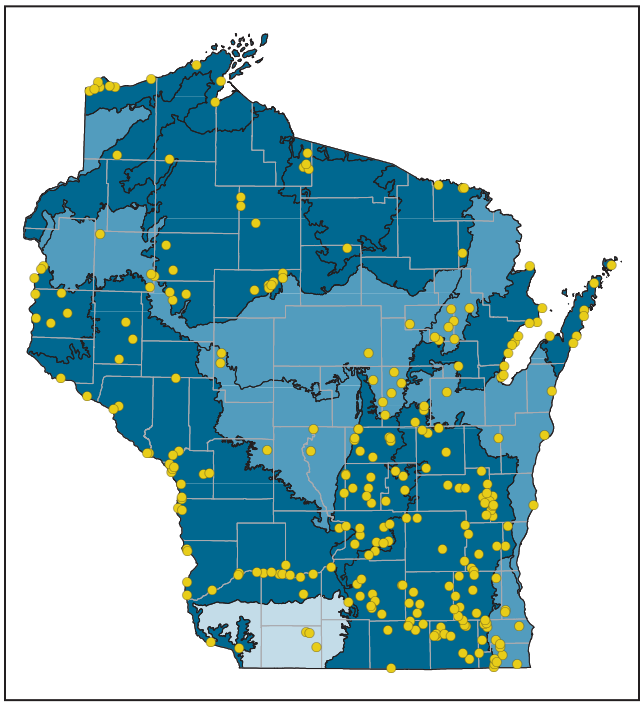
Emergent Marsh (Global Rank G4; State Rank S4)

Overview: Distribution, Abundance, Environmental Setting, Ecological Processes

The Emergent Marsh community occurs statewide. It is best developed in shallow topographic basins, on the margins of shallow ponds, in protected bays of lakes and impoundments, in riverine lakes, and in river backwaters. Beds of Emergent Marsh are generally established in permanent standing water of less than 2 meters in depth. Many of the dominant plants form clones (Wetzel 2001), and the vegetation may be strongly zoned by water depth. It is common for a single species to dominate large areas of more or less equal depth, though water clarity, substrate type, and disturbance history also influence the distribution of characteristic marsh plants. Depth gradients and terms such as "shallow marsh" or "deep marsh" are used in some vegetation classifications to identify marsh types or variants. Marshes in protected bays along the shores of the Great Lakes have been separated out as distinct entities in some state and provincial vegetation classifications (Albert 2003, Kost et al. 2007).

Factors that affect the extent and composition of Emergent Marsh include basin or floodplain morphology, hydrologic regime, current velocity, water chemistry, and water clarity. Emergent Marsh occupies poorly drained basins created by the actions of past glaciers and that now retain some standing water virtually year-round. Marshes also occupy the backwaters of major rivers and protected bays and shorelines of lakes and streams shielded from high energy wind, wave, and ice events. In the unglaciated Driftless Area of southwestern Wisconsin, marshes occur almost entirely within the lower portions of the floodplains of low gradient streams and rivers. If basin morphology is such that the slope of the bottom is gradual, the emergent species may be replaced by macrophytes with floating or submersed leaves. Both temporal and spatial overlap between emergent, floating-leaved, and submergent species may occur, so delineations of distinct communities may be difficult and imprecise. As water levels change, species dominance may shift seasonally as well as over periods of years or decades.

Ground and surface water characteristics vary greatly in different parts of the state, influenced by the nature of the bedrock, the underlying soils, and chemical composition of the glacial deposits. Some regions support lakes and low-gradient streams with extremely hard water (e.g., areas in northeastern Wisconsin in the Northern Lake Michigan Coastal and Northeast Sands ecological landscapes), and other areas support lakes and some streams with soft water (for example, in the extensive areas of glacial outwash in the Northern Highland and Northwest Sands ecological landscapes). The estuarine marshes found along the Great Lakes coasts are dynamic and have unique hydrological attributes that affect wetland development, maintenance, and succession.



Locations of Emergent Marsh in Wisconsin. The deeper hues shading the ecological landscape polygons indicate geographic areas of greatest abundance. An absence of color indicates that the community has not (yet) been documented in that ecological landscape. The dots indicate locations where a significant occurrence of this community is present, has been documented, and the data incorporated into the Natural Heritage Inventory database.

Community Description: Composition and Structure

The dominant herb genera are often robust and graminoid in form and may include cat-tails (*Typha* spp.), bulrushes (*Schoenoplectus* spp., *Scirpus* spp.), bur-reeds (*Sparganium* spp.), spike-rushes (*Eleocharis* spp.), water sedge (*Carex aquatilis*), and common lake sedge (*C. lacustris*). Prairie cord grass (*Spartina pectinata*) sometimes co-occurs with marsh associates rather than with species characteristic of prairies and sedge meadows. Among the common broad-leaved emergent species are some of the arrowheads (*Sagittaria* spp.), common water-plantain (*Alisma subcordatum*), and pickerel-weed (*Pontederia cordata*). Other common emergent marsh plants are water horsetail (*Equisetum fluviatile*), sweet-flag (*Acorus calamus*), and three-way sedge (*Dulichium arundinaceum*). Marshes dominated by wild rice, American lotus-lily (*Nelumbo lutea*), floating-leaved, or submergent species are treated separately elsewhere in this chapter.

Rare marsh plants include clustered bur-reed (*Sparganium glomeratum*), Torrey's bulrush (*Schoenoplectus torreyi*), Robbins' spike-rush (*Eleocharis robbinsii*), small yellow water-

Vast marshes and a network of sloughs and abandoned channels occur over thousands of acres on the lower Wolf River just above Lake Poygan. Winnebago County, Southeast Glacial Plains Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

This extensive emergent marsh within the St. Louis River estuary is one of only two freshwater estuaries in NOAA's nationwide system of National Estuarine Research Reserves. Douglas County, Superior Coastal Plain Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

crowfoot (*Ranunculus gmelinii*), marsh horsetail (*Equisetum palustre*), and floating marsh-marigold (*Caltha natans*). Water-purslane (*Didiplis diandra*) is perhaps better grouped with species of Submergent Marshes, but it does occur on exposed shorelines under certain conditions.

Emergent marshes provide critical nesting, foraging, and staging habitats for many birds, especially waterfowl, rails, herons, egrets, bitterns, grebes, terns, and shorebirds. Some songbirds, such as Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), Marsh Wren (*Cistothorus palustris*), and Swamp Sparrow (*Melospiza georgiana*), use marshes as their primary nesting and feeding habitats. Marshes are also of high significance to herptiles and invertebrates, and mammals such as common muskrat (*Ondatra zibethicus*), American beaver (*Castor canadensis*), American mink (*Neovison vison*), and North American river otter (*Lontra canadensis*) are at least partially dependent on emergent marshes.

At the location pictured here, this extensive emergent marsh near the confluence of the Rat and Lower Wolf Rivers is heavily dominated by cattails. Elsewhere, other important marsh plants include bulrushes, arrowheads, and bur-reeds. Winnebago County, Southeast Glacial Plains Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Conservation and Management Considerations

Management issues include maintaining the integrity of site hydrology, water quality, and water quantity. The spread of invasive species has become a significant management problem, especially in dynamic ecosystems such as those in Green Bay. Poor water quality due to excessive inputs of nutrients and sediments has affected emergent marsh composition and structure in regions such as southeastern Wisconsin and in the impoundments of major rivers in southwestern and central Wisconsin. Pollution from industrial contaminants is significant in urban-industrial areas such as the Milwaukee Harbor, Lower Green Bay, and the St. Louis River Estuary.

Among the problematic marsh plants are highly invasive species such as purple loosestrife (*Lythrum salicaria*), narrow-leaved cat-tail (*Typha angustifolia*), hybrid cat-tail (*T.* x *glauca*), reed canary grass (*Phalaris arundinacea*), and common reed (*Phragmites australis*). Common carp (*Cyprinus carpio*) can physically uproot and damage the emergent vegetation and increase water turbidity, reducing the depths at which aquatic plants can receive sufficient light to thrive and develop properly.

Restoration of marsh habitats in areas that were formerly drained or otherwise damaged has been an important focus of wildlife and fish management programs across Wisconsin and in many other parts of the continental United States. Horicon Marsh, in east central Wisconsin, has been a wetland restoration and reclamation project and, at approximately 32,000 acres, is promoted as the largest cat-tail marsh in North America. Such activities are laudable and have played significant roles in the recovery of many birds, mammals, and other species dependent on these restored or re-created habitats. However, the local and landscape level effects of proposals to convert stands of wetland communities such as sedge meadows, fens, shrub swamps, and lowland forests to marshes need to be carefully weighed to ensure that the habitats provided

by these other communities are not diminished to the point where they will also require restoration activities in an attempt to avoid the loss of their many dependent native plant and animal species. Local, regional, and continental perspectives are useful for and needed by conservationists when weighing alternative management possibilities.

Additional Information

For additional information, see the descriptions for Wild Rice Marsh, Submergent Marsh, Oligotrophic Marsh, Floating-leaved Marsh, and American Lotus-lily Marsh. In the U.S. National Vegetation Classification (US NVC), Emergent Marsh is treated broadly, but they define several similar types: CEGL002026 Bulrush – Cattail – Burreed Shallow Marsh; CEGL002229 Midwest Mixed Emergent Deep Marsh; CEGL002233 Midwest Cattail Deep Marsh; CEGL0092221 River Bulrush Marsh (Faber-Langendoen 2001). The US NVC types are not sharply defined and may demonstrate considerable overlap, even when co-occurring in the same basin. There is also potential overlap with Floating-leaved and Submergent marsh types.

Also see:
Hipp (2008)
Judziewicz (2014)
Kahl (1993)
Keddy and Reznicek (1986)
Keough et al. (1999)
Nichols et al. (1991)
Nichols (1999)
Singer et al. (1996)
Skawinski (2010)
Skawinski (2014)
Wetzel (2001)

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Aquatic Features

There are numerous ways to classify lakes and streams but no universal standard that will serve all purposes. The classification of waterbodies presented here was developed in the 1980s for use by the Scientific Areas Preservation Council (NAPC) and the State Scientific Areas program as a tool that would enable them to classify, identify, evaluate, and select representative waterbodies to ensure that all types of aquatic communities or assemblages found within the state could be evaluated and considered for representation within the Wisconsin DNR's State Natural Areas system.

Terms used by the State Natural Areas program to name, define, and classify the types of waterbodies tracked by Wisconsin DNR's Natural Heritage Inventory (NHI) (and used on the NHI program's Natural Community Working List as of 07/2016; Table 7.1) are defined below.

Lakes and Ponds: Lentic Systems (Standing Waters)

Water Source

- **Seepage Lake** – The sources of water are groundwater infiltration, overland flow, and precipitation. These are essentially landlocked waterbodies, usually lacking defined inlets and outlets.
- **Drainage Lake** – The primary source of water is via one or more inlet streams. Water exits the system by an outlet stream. Other water sources include one or more of those mentioned above under Seepage Lake.
- **Spring Lake** – Springs contribute substantially to lake volume. Features such as spring runs or spring ponds may discharge waters directly into a spring lake, or springs located beneath the lake discharge their waters directly into the lake from below.
- **Riverine Lake** – Riverine lakes and ponds (these are differentiated only by size, with "lakes exceeding 10 acres; ponds occupying less than 10 acres) occur within the floodplains of large rivers. They may be periodically connected to the main channels of rivers and streams and therefore behave as parts of a river when water levels are high and have direct connections to flowing waters and behave like seepage lakes when water levels in the rivers are low and they are temporarily isolated.
- **Impoundment** – Impoundments are defined by the state of Wisconsin as waterbodies for which over one-half of the maximum depth is due to the presence of a dam. As the hydrology of such modified systems is significantly altered by the dams, and they are typically managed to meet human needs and desires (e.g., for power production, to improve navigation potential, or for recreation purposes), waterbodies meeting the state definition of "impoundment" are treated as "Selected Habitats."

Impoundments for which dams are responsible for less than one-half of the maximum depth are hybrids, but the presence of a dam, even with a low head of water, will alter flow characteristics, thermal properties, and prevent the movement of fish and other aquatic organisms from one segment of an impounded stream to another.

The floodplain of the lower Black River features extensive bottomland hardwood forests, marshes, running sloughs, and scattered ponds. During periods of high water, this riverine lake is directly connected to the mainstem of the river. Van Loon State Wildlife Area, La Crosse and Trempealeau counties, Western Coulees and Ridges Ecological Landscape. Photo by Wisconsin DNR staff.

Lake Pepin is a huge natural drainage lake on the Mississippi River. Sandy alluvium deposited by the Chippewa River constricted the Mississippi's main channel, creating the lake. Pepin County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Only a few photos in our archives were suitable for use as illustrating specific lake or stream types. Some of the key defining characteristics for these waterbodies (such as depth, temperature, and alkalinity) cannot be represented well by a photograph. Future iterations of this document will include additional graphics, including tabular data and schematics, that will contribute to conveying some of the differences used to separate aquatic types clearly.

- **Ephemeral Pond** – Ephemeral ponds possess attributes of both terrestrial and aquatic ecosystems. Early on, most of the material we had used to describe ephemeral ponds was based on the vascular flora, but some of this type's unique characteristics are related to the life histories of highly specialized animals, especially invertebrates. The description of Ephemeral Pond may be found on page 168.

Thermal Stratification

- **Deep Lake** – In deep lakes, a thermocline develops during the summer and again in late fall or early winter. In the spring and fall, this zone of abrupt temperature difference breaks down, allowing for the mixing of bottom and surface waters and the redistribution of oxygen and nutrients.
- **Shallow Lake** – Shallow lakes do not stratify thermally. Water temperatures remain relatively constant from surface to bottom. These lakes may become oxygen depleted as the water warms and decomposition exceeds primary production. Oxygen depletion may also occur during the winter when ice and snow cover the lake surface, inhibiting photosynthesis. "Freezeout" conditions may then prevail with significant loss of aquatic life.
- **Meromictic Lake** – This is a very rare lake type in Wisconsin. Thermal and chemical stratification are permanent. Meromictic lakes usually have very small surface areas (only a few acres is typical) but great depth, sometimes exceeding 20 meters. The surface waters are somewhat protected from wind and other forces that could potentially contribute to the mixing of waters at different depths by size, local topography, and dense surrounding forest vegetation. (See Eggleton 1986, Fry 1986, Edinger et al. 2014.)

Chemical Attributes

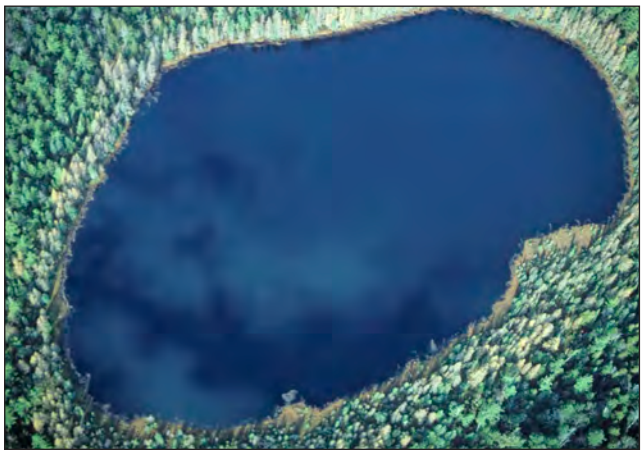
- **Hardness/Alkalinity**
  - **Hard water** – Total alkalinity is greater than 50 ppm. Hard water lakes are somewhat buffered from acidification by the presence of hydroxyl, carbonate, and/or bicarbonate ions.
  - **Soft water** – Total alkalinity is less than 50 ppm. Soft water lakes are vulnerable to acidification due to their low capacity to buffer acids.
- **Other chemical characteristics sometimes used as aids in lake classification:** pH, specific conductance, marl (calcium carbonate) deposition.

Miscellaneous Attributes

(These have been, and sometimes are, used to describe lakes but not necessarily to classify them.) The physical factors mentioned below may play major roles in the plant and animal life a given waterbody will support.

- Size
- Basin Morphology
- Shoreline Configuration
- Biotic Assemblages (e.g., fish, invertebrates)
- Proximity to other waterbodies or wetlands apart from classification as drainage versus seepage systems

Aerial view of Lake Alva, a deep, soft, seepage lake in collapsed glacial outwash that is the centerpiece of an outstanding natural features complex. Northern Highland-American Legion State Forest, Vilas County, Northern Highland Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.



Aerial view of a shallow, softwater, seepage lake (a bog pond) on the Winegar Moraine. Both the lake and the narrow fringe of open peatland vegetation support rare plants, and the older adjoining forest is inhabited by many rare animals. Catherine Lake, Iron County, North Central Forest Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Rivers and Streams: Lotic Systems (Flowing Waters)

Gradient (Correlates Roughly with Substrate Particle Size and Stream Velocity)

- **Fast** – Stream gradient exceeds 20 feet per mile.
- **Slow** – Stream gradient is less than 20 feet per mile.

Temperature

- **Warm** – Maximum summer water temperatures exceed 25 degrees Celsius.
- **Cold** – Maximum summer water temperatures are less than 22 degrees Celsius.
- **Cool** – Summer water temperatures are between 22 and 25 degrees Celsius, and this can affect the fish species present (both coldwater and warmwater species may be present in "cool" streams, but there is little or no overlap in the species composition between coldwater and warmwater streams. The aquatic macroinvertebrate specialists

The floodplain of the lower Wolf River supports large stands of bottomland hardwoods laced with running sloughs. Other key features of this complex ecosystem are riverine lakes, small ponds, and patches of marsh, sedge meadow, and shrub swamp. All of these habitats and the high diversity of associated species are ultimately dependent on the health and function of the Wolf's mainstem. Waupaca County, Southeast Glacial Plains and Central Lake Michigan Coastal ecological landscapes. Photo by Eric Epstein, Wisconsin DNR.

Table 7.1. *Wisconsin Natural Heritage Working List of Aquatic Types.*

ELCODE	Scientific Name	Global Rank	State Rank
LAKES AND PONDS			
CLEPH390WI	Ephemeral Pond	GNRQ	SU
CLDRA340WI	Lake—Deep, Hard, Drainage	GNR	S3
CLSEE342WI	Lake—Deep, Hard, Seepage	GNR	S2
CLDRA344WI	Lake—Deep, Soft, Drainage	GNR	S1
CLSEE346WI	Lake—Deep, Soft, Seepage	GNR	S3
CLSEE347WI	Lake—Deep, Very Soft, Seepage	GNR	S3
CLBOG360WI	Lake—Hard Bog	GNR	S2
CLMER376WI	Lake—Meromictic	GNR	S1
CLDRA348WI	Lake—Shallow, Hard, Drainage	GNR	SU
CLSEE350WI	Lake—Shallow, Hard, Seepage	GNR	SU
CLDRA352WI	Lake—Shallow, Soft, Drainage	GNR	S3
CLSEE354WI	Lake—Shallow, Soft, Seepage	GNR	S4
CLDRA349WI	Lake—Shallow, Very Hard, Drainage (Marl)	GNR	S2
CLBOG362WI	Lake—Soft Bog	GNR	S4
CLSPR375WI	Lake—Spring	GNR	S3
CLUNI380WI	Lake—Unique	GNR	SU
CLRIV374WI	Riverine Lake/Pond	GNR	SU
CLSPR370WI	Spring Pond	GNR	S3
SPRINGS AND STREAMS			
CRSPR302WI	Springs and Spring Runs, Hard	GNR	S4
CRSPR304WI	Springs and Spring Runs, Soft	GNR	SU
CRSTR310WI	Stream—Fast, Hard, Cold	GNR	S4
CRSTR312WI	Stream—Fast, Hard, Warm	GNR	SU
CRSTR314WI	Stream—Fast, Soft, Cold	GNR	SU
CRSTR316WI	Stream—Fast, Soft, Warm	GNR	SU
CRSTR320WI	Stream—Slow, Hard, Cold	GNR	SU
CRSTR322WI	Stream—Slow, Hard, Warm	GNR	SU
CRSTR324WI	Stream—Slow, Soft, Cold	GNR	SU
CRSTR326WI	Stream—Slow, Soft, Warm	GNR	SU

See Appendix 7.A for global and state ranking definitions.

working with the Natural Heritage Inventory program said that definitions of "coolwater" systems as used by Wisconsin DNR fisheries researchers would also work for aquatic invertebrates (Bill Smith, Wisconsin DNR, personal communication).

Note that "cool" is not yet used in the NHI aquatic features classification, but we are recommending that it be added.

Hardness/Alkalinity

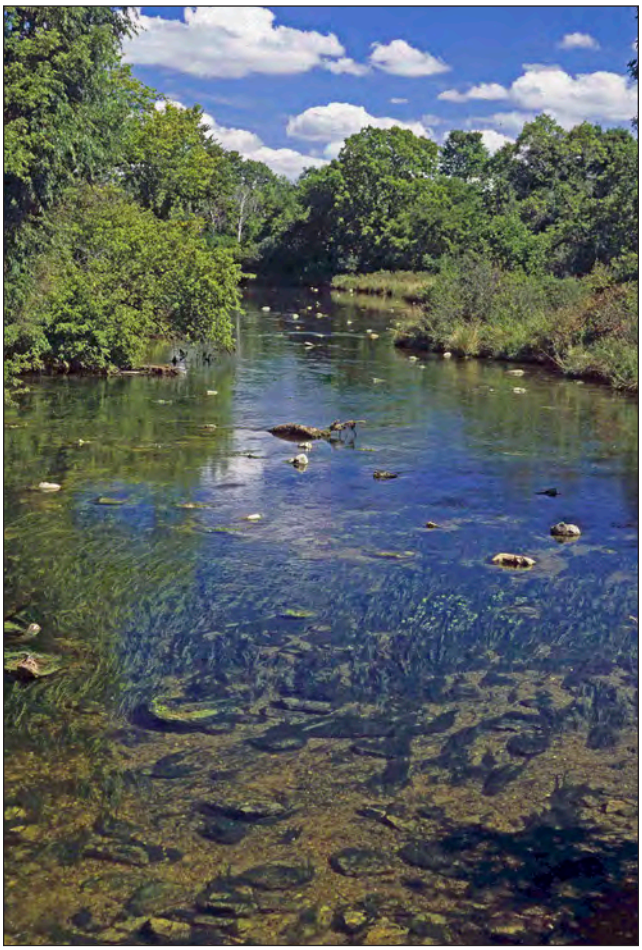
- **Soft** – Total alkalinity is less than 50 ppm.
- **Hard** – Total alkalinity is greater than 50 ppm.

Additional Terms Needing Definition

Large River: Large River is not currently recognized as a distinct entity in the NHI Aquatic Features classification, but it should be considered for addition to the Aquatic Features Working List (WDNR 2016c) as these waterbodies are of the

Lower reaches of Perry Creek, a spring-fed coldwater stream tributary to the Black River, flows over sandstone bedrock south of Black River Falls. An unusual assemblage of aquatic invertebrates is associated with the moss-covered rock in this gorge, which also provides nesting sites for rare birds. Black River State Forest, Jackson County, Central Sand Plains Ecological Landscape. Photo by William A. Smith.

This spring-fed coldwater stream supports native brook trout (Salvelinus fontinalis) *and other organisms requiring clean, cold, highly oxygenated water. Clear Creek, Fort McCoy Military Reservation, Monroe County, Western Coulees and Ridges Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.*



A prized recreational resource, this segment of the Mukwonago River is classified as a Slow, Hard, Warmwater Stream that supports extremely high aquatic diversity. It is one of the most important and irreplaceable streams in heavily developed southeastern Wisconsin. Southeast Glacial Plains Ecological Landscape. Photo by Thomas Meyer, Wisconsin DNR.

highest significance for the exceptional ecological diversity they support as well as for the ecosystem services, economic benefits, and recreational resources they provide.

Large Rivers are defined by Wisconsin DNR as those segments of rivers with a mean annual flow of at least 40 cubic meters per second and include the Mississippi and certain segments of the Wisconsin, Chippewa, Black, St. Croix, Wolf, Menominee, Rock, Red Cedar, Flambeau, and Fox rivers.

Marl, Marl Lake: Marl is basically an unconsolidated rock composed of calcium carbonate, clay, and silt. "Marl Lakes" occur in parts of Wisconsin (e.g., east central and northeast) where groundwater provides abundant quantities of calcium carbonate, which may be precipitated from the water column, accumulating on the lake bottom and sometimes encrusting the aquatic vegetation. In Marl Lakes, the aquatic vegetation is composed in large part of members of the Characeae (*Chara*, *Nitella*) and Potamogetonaceae (Wiik et al. 2013). Additional data are needed on the potentially unique biota associated with the unusual conditions associated with Marl Lakes. Recent work has found that Marl Lakes are vulnerable to eutrophication (Wiik et al. 2015) and that it is therefore important to reduce external inputs of nutrients and sediments as early as possible.

Additional Information

For additional information on and approaches to Aquatic Ecosystem Classification, also see:

Cowardin et al. (1979)
Frissell et al. (1986)
Lammert et al. (1997)
Lyons (2005)
Lyons (2006)
Lyons et al. (2009)
Maxwell et al. (1995)
Rosgen (1994)
Weitzel et al. (2003)
Wetzel (2001)
Wisconsin Wildlife Action Plan (2015): http://dnr.wi.gov/topic/wildlifehabitat/actionplan.html or http://dnr.wi.gov/, keywords "wildlife action plan." For information from the updated Wildlife Action Plan (WAP) specifically dealing with aquatic ecosystems, see http://dnr.wi.gov/files/pdf/pubs/nh/nh0983_4_4_1.pdf or Section 4.4.1 in the 2015 WAP.

Sources used to provide additional information on aquatic ecosystems include the following (the full citations may be found in the "Literature Cited"):

Amoros and Bornette (2002)
Angermeier and Schlosser (1995)
Baker and Barnes (1998)
Bayley (1995)
Belk (1998)
Broch (1965)
Burne and Griffin (2005)
Calhoun and deMaynadier (2008)
Center for Watershed Protection (2003)
Colburn (2004)
Comer et al. (2005)
Crow and Hellquist (2000a)
Crow and Hellquist (2000b)
DiMauro and Hunter (2002)
Drever (1982)
Eggleton (1986)
Engel (1985)
Fassett (1930)
Fry (1986)
Gibbs (1998)
Higgins et al. (1998)
Jass and Klausmeier (2006)
Jennings et al. (1999a)
Jennings et al. (1999b)
Jennings et al. (2009b)
Kahl (1993)
Kershner (1997)
Lillie (2003)
Lyons (1992)
Lyons (1996)
Lyons et al. (1996)
Miller et al. (2014)
Nichols (1999)
Nichols and Vennie (1991)
Nilsson and Berggren (2000)
Richter et al. (2003)
Sapper (2008)
Scheffer (2001)
Schmude (2012)
Skawinski (2010)
Skawinski (2014)
Sparks (1995)
Stewart et al. (2001)
Strayer and Findlay (2010)
Swindale and Curtis (1957)
The Nature Conservancy (1997)
Walker et al. (2013)
Wang et al. (1997)
Wang et al. (2001)
Ward (1998)
WDNR (2016c)
Weigel (2003)
Weitzel et al. (2003)
Wilcox (1995)
Wiik et al. (2013)
Wiik et al. (2015)
WGNHS (2013)
Wisconsin Initiative on Climate Change (2010)

FROM: Epstein, E.E.. Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 *in The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management.* Wisconsin Department of Natural Resources, PUB-SS-1131H 2017, Madison.