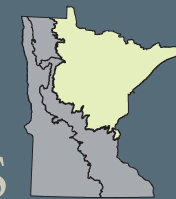
Ecological Land Classification Program
Division of Forestry

Minnesota County Biological Survey
Division of Ecological Resources

Natural Heritage and Nongame Research Program
Division of Ecological Resources

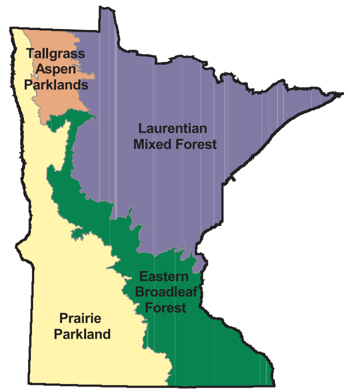
Field Guide to the
Native Plant Communities of Minnesota



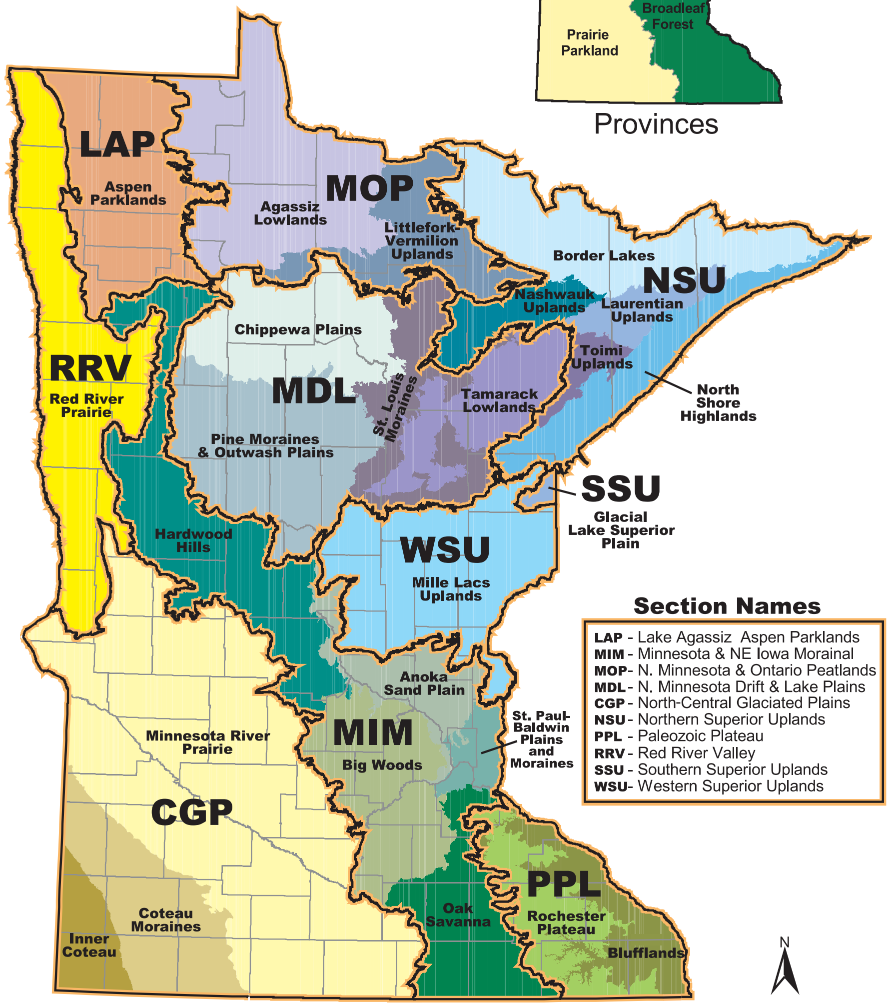
The Laurentian Mixed Forest Province

Ecological System Summaries

Ecological Provinces, Sections, & Subsections of Minnesota



Provinces



Sections and Subsections

Minnesota's Native Plant Community Classification: System Groups, Systems, and Classes

A. Upland Forests and Woodlands

Fire-Dependent Forest/Woodland System

FDn12 Northern Dry-Sand Pine Woodland
FDn22 Northern Dry-Bedrock Pine (Oak) Woodland
FDn32 Northern Poor Dry-Mesic Mixed Woodland
FDn33 Northern Dry-Mesic Mixed Woodland
FDn43 Northern Mesic Mixed Forest

FDc12 Central Poor Dry Pine Woodland
FDc23 Central Dry Pine Woodland
FDc24 Central Rich Dry Pine Woodland
FDc25 Central Dry Oak-Aspen (Pine) Woodland
FDc34 Central Dry-Mesic Pine-Hardwood Forest

FDs27 Southern Dry-Mesic Pine-Oak Woodland
FDs36 Southern Dry-Mesic Oak-Aspen Forest
FDs37 Southern Dry-Mesic Oak (Maple) Woodland
FDs38 Southern Dry-Mesic Oak-Hickory Woodland

FDw24 Northwestern Dry-Mesic Oak Woodland
FDw34 Northwestern Mesic Aspen-Oak Woodland
FDw44 Northwestern Wet-Mesic Aspen Woodland

Mesic Hardwood Forest System

MHn35 Northern Mesic Hardwood Forest
MHn44 Northern Wet-Mesic Boreal Hardwood-Conifer Forest
MHn45 Northern Mesic Hardwood (Cedar) Forest
MHn46 Northern Wet-Mesic Hardwood Forest
MHn47 Northern Rich Mesic Hardwood Forest

MHc26 Central Dry-Mesic Oak-Aspen Forest
MHc36 Central Mesic Hardwood Forest (Eastern)
MHc37 Central Mesic Hardwood Forest (Western)
MHc38 Central Mesic Cold-Slope Hardwood-Conifer Forest
MHc47 Central Wet-Mesic Hardwood Forest

MHs37 Southern Dry-Mesic Oak Forest
MHs38 Southern Mesic Oak-Basswood Forest
MHs39 Southern Mesic Maple-Basswood Forest
MHs49 Southern Wet-Mesic Hardwood Forest

MHw36 Northwestern Wet-Mesic Hardwood Forest

B. Wetland Forests

Floodplain Forest System

FFn57 Northern Terrace Forest
FFn67 Northern Floodplain Forest

FFs59 Southern Terrace Forest
FFs68 Southern Floodplain Forest

Wet Forest System*

WFn53 Northern Wet Cedar Forest
WFn55 Northern Wet Ash Swamp
WFn64 Northern Very Wet Ash Swamp

WFs55 Southern Wet Aspen Forest
WFs57 Southern Wet Ash Swamp

WFw54 Northwestern Wet Aspen Forest

Forested Rich Peatland System*

FPn62 Northern Rich Spruce Swamp (Basin)
FPn63 Northern Cedar Swamp
FPn71 Northern Rich Spruce Swamp (Water Track)
FPn72 Northern Rich Tamarack Swamp (Eastern Basin)
FPn81 Northern Rich Tamarack Swamp (Water Track)
FPn82 Northern Rich Tamarack Swamp (Western Basin)

FPs63 Southern Rich Conifer Swamp

FPw63 Northwestern Rich Conifer Swamp

Acid Peatland System*

APn80 Northern Spruce Bog
APn81 Northern Poor Conifer Swamp

*Occurs in System Groups B & D.

December 2005

C. Upland Grasslands, Shrublands, and Sparse Vegetation

Cliff/Talus System

CTn11 Northern Dry Cliff
CTn12 Northern Open Talus
CTn24 Northern Scrub Talus
CTn32 Northern Mesic Cliff
CTn42 Northern Wet Cliff

CTu22 Lake Superior Cliff

CTs12 Southern Dry Cliff
CTs23 Southern Open Talus
CTs33 Southern Mesic Cliff
CTs43 Southern Maderate Cliff
CTs46 Southern Algific Talus
CTs53 Southern Wet Cliff

Rock Outcrop System

ROn12 Northern Bedrock Outcrop
ROn23 Northern Bedrock Shrubland

ROs12 Southern Bedrock Outcrop

Lakeshore System

LKi32 Inland Lake Sand/Gravel/Cobble Shore
LKi43 Inland Lake Rocky Shore
LKi54 Inland Lake Clay/Mud Shore

LKu32 Lake Superior Sand/Gravel/Cobble Shore
LKu43 Lake Superior Rocky Shore

River Shore System

RVx32 Sand/Gravel/Cobble River Shore
RVx43 Rocky River Shore
RVx54 Clay/Mud River Shore

Upland Prairie System

UPn12 Northern Dry Prairie
UPn13 Northern Dry Savanna
UPn23 Northern Mesic Prairie
UPn24 Northern Mesic Savanna

UPs13 Southern Dry Prairie
UPs14 Southern Dry Savanna
UPs23 Southern Mesic Prairie
UPs24 Southern Mesic Savanna

D. Wetland Grasslands, Shrublands, and Marshes

Acid Peatland System*

APn90 Northern Open Bog
APn91 Northern Poor Fen

Open Rich Peatland System

OPn81 Northern Shrub Shore Fen
OPn91 Northern Rich Fen (Water Track)
OPn92 Northern Rich Fen (Basin)
OPn93 Northern Extremely Rich Fen

OPp91 Prairie Rich Fen
OPp93 Prairie Extremely Rich Fen

Forested Rich Peatland System*

FPn73 Northern Rich Alder Swamp

Wet Forest System*

WFn74 Northern Wet Alder Swamp

Wet Meadow/Carr System

WMn82 Northern Wet Meadow/Carr

WMs83 Southern Seepage Meadow/Carr
WMs92 Southern Basin Wet Meadow/Carr

WMp73 Prairie Wet Meadow/Carr

Marsh System

MRn83 Northern Mixed Cattail Marsh
MRn93 Northern Bulrush-Spikerush Marsh

MRu94 Lake Superior Coastal Marsh

MRp83 Prairie Mixed Cattail Marsh
MRp93 Prairie Bulrush-Arrowhead Marsh

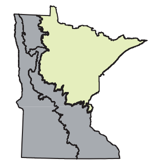
Wetland Prairie System

WPn53 Northern Wet Prairie

WPs54 Southern Wet Prairie

Field Guide to the

NATIVE PLANT COMMUNITIES *of* MINNESOTA



The Laurentian Mixed Forest Province

Ecological System Summaries

This material is excerpted from: *Field guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province*. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. Minnesota Department of Natural Resources, St. Paul. 2003.

tant in distinguishing these Classes, but there are not enough data on marshes in the MRn Region to assess the influence of water depth on species composition. Marsh communities in the MRu Region are in the Lake Superior Coastal Marsh (MRu94) Class. They typically have a dense layer of submerged plants such as eelgrass *(Vallisneria americana),* pondweeds *(Potamogeton* spp.), common coontail *(Ceratophyllum demersum),* and Canadian elodea *(Elodea canadensis)* under and between floating-leaved and emergent aquatic plants.

Succession

Marshes can develop from submerged or floating-leaved aquatic communities if depth of water is reduced by deposition of sedimentary peat, siltation, or draining, which enables persistent emergent plants to become established at the site. In situations where water levels drop and become subject to regular seasonal drawdowns, submerged and floating-leaved species may be replaced by sedges, resulting in conversion to WM communities. Marshes can develop from wet forests, peatland communities, or even upland forests in areas flooded by beaver impoundments. The creation and eventual draining of beaver ponds often result in formation of wetland complexes that contain MR communities mixed with transitional stages of other wetland communities, especially WM and aquatic communities. MR communities also sometimes develop following fire in peatlands, where peat “burn-outs” leave depressions that fill with standing water. MR communities are converted to aquatic communities in settings where water levels increase for sustained periods, drowning emergent species and favoring submerged or floating-leaved species. Increases in water level are caused most often by increased precipitation and runoff or by construction of beaver dams. Muskrats also commonly decimate marsh vegetation, leading to areas within marshes that are open and aquatic in character.

User’s Guide to Ecological System Summaries

The ecological system summaries provide information on the fifteen ecological systems recognized in the Minnesota Department of Natural Resources’ native plant community (NPC) classification. These summaries originally appeared in three field guides to the native plant communities of Minnesota, which are organized by Minnesota’s four ecological provinces (the Laurentian Mixed Forest, the Eastern Broadleaf Forest, the Prairie Parkland, and the Tallgrass Aspen Parklands provinces, with the last two provinces combined in one field guide). Although each of the three versions differs somewhat in content, there is much overlap.

Each summary typically contains a brief general description of the system, a discussion of the major ecological process or processes that influence the system, some of the characteristic plant adaptations to these processes, and information on distinctions between the floristic regions in the system (where applicable) or variation among the NPC classes in the system. The system summaries were developed to provide context and background information when using keys to the ecological systems or comparing NPC classes within a system.

In each system summary, the general description contains information on the basic structure and composition of the vegetation, on landscape setting, and on distribution of the system in the province. The major ecological processes most commonly discussed in the system summaries are nutrient cycling, moisture regime, and disturbance regime. In some system summaries, the treatment of ecological processes may include discussion of processes that span several systems (such as formation of peatlands) or successional relationships among systems. The information presented on plant adaptations includes some of the most prominent or illustrative adaptive responses of plants to the ecological processes that characterize the system.

Most of the systems are divided into floristic regions that reflect the distribution of Minnesota’s plant species into characteristically northern, northwestern, central, southern, and prairie flora, or groups. Floristic region maps in the system summaries show the general ranges of floristic regions in the system. These maps were constructed by amalgamating the distribution maps of the NPC classes in the system. The boundaries between floristic regions are usually more diffuse than represented by boundary lines on the maps; floristic regions may overlap by 50 miles or more along some boundaries.

For systems that have been documented with substantial vegetation plot data, tables are provided listing species useful in differentiating the floristic regions. These tables can be used to help with decisions at dichotomies in keys to NPC classes that represent divisions between classes in different floristic regions. Some of the wooded systems also have tables with historical tree species compositions and disturbance regimes for the NPC classes in the system. The data presented in the tables come from analyses of Public Land Survey records from the late 1800s and early 1900s. Tree species followed by “(C)” in the tables are canopy trees and are present in the system at heights greater than 10 meters (33 feet) tall; trees followed by “(U)” are present in the understory and are less than 10 meters tall.

Notes:

► Measures of height, distance, and area in the system summaries are given in both English and metric units. English and metric equivalents are approximate because most original measurements were imprecise.

► For wooded systems, ages derived in analyses of historical growth stages and disturbance regimes are generally rounded to the nearest five years.

► Common names of vascular plants are used throughout the text of each summary. Scientific names are included with common names in tables. Scientific names are also included with common names at the first mention of a species in the text, with two exceptions. Trees are listed by common name only and rushes and sedges are always listed by both common and scientific name.

► Names of Ecological Classification System sections are abbreviated in the summaries. The full names are:

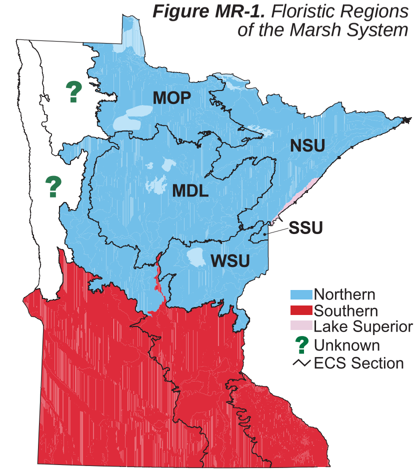
LAP – Lake Agassiz Aspen Parklands
MIM – Minnesota and Northeast Iowa Morainal
MOP – Northern Minnesota and Ontario Peatlands
MDL – Northern Minnesota Drift and Lake Plains
CGP – North-Central Glaciated Plains
NSU – Northern Superior Uplands
PPL – Paleozoic Plateau
RRV – Red River Valley
SSU – Southern Superior Uplands
WSU – Western Superior Uplands

substrates. Reflooding of exposed substrates, however, usually eliminates annuals from the site—either drowning them if water levels rise high enough or preventing them from germinating on sites that remain inundated—or restricts them to floating mats. Perennial emergent species, once established at a site, can expand rapidly by extensive rhizomes as water levels rise. Therefore, the dominant plants in most marshes are emergent species, especially those with vegetative and flowering structures that extend well above the water level and can withstand short periods of abnormally high water. These species include cattails *(Typha* spp.), bulrushes *(Scirpus* spp.), and arrowheads *(Sagittaria* spp.). Persistent high water levels typically eliminate shorter emergent species not able to remain above the water level and favor floating species such as duckweeds *(Lemna* spp. and *Spirodela polyrhiza)* and common white water-lily *(Nymphaea odorata).* With sustained high water levels, submerged species such as bladderworts *(Utricularia* spp.), common coontail *(Ceratophyllum demersum)*, and Canadian elodea *(Elodea canadensis)* become more frequent. These plants have little resistance to desiccation, however, and are usually eliminated during the next cyclic drawdown. In settings where water levels are stable because of steady inputs of groundwater, MR communities often become dominated by a single species and species diversity declines.

Floristic Regions

MR communities in Minnesota are grouped into three "floristic" regions, the Northern Floristic (MRn) Region, the Lake Superior Floristic (MRu) Region, and the Southern Floristic (MRs) Region (Fig. MR-1). Because of very limited plot data, the Floristic Regions in the MR System are preliminary; ECS Province boundaries were used to define the MRn and MRs Regions, while the MRu Region is based on influences from Lake Superior. Two of the Floristic Regions, the MRn and MRu, are represented in the LMF Province. The MRn Region spans the entire Province. The MRu Region is restricted to the St. Louis River estuary, which supports the only marsh system in Minnesota affected by water-level fluctuations in Lake Superior. The estuary has high nutrient levels, and estuarine marshes typically have higher biomass and higher species diversity than the marshes of the MRn Region. The marshes of the MRs Region occur to the south and west of the LMF Province and are probably subjected to more frequent drought and water-level drawdowns than marshes in either the MRn or MRu regions.

Figure MR-1. *Floristic Regions of the Marsh System*



Variation Within Floristic Regions

There are two plant community Classes in the MRn Region and one Class in the MRu Region. Floristic differences between the two MRn Classes—Northern Mixed Cattail Marsh (MRn83) and Northern Bulrush-Spikerush Marsh (MRn93)—appear to be related to degree of exposure to wave action. MRn83 typically occurs in ponds, bays of lakes, or sluggish streams where vegetation is at least partially protected from wave action or strong currents. MRn83 is dominated by cattails, sedges *(Carex* spp.), and forbs such as marsh cinquefoil *(Potentilla palustris),* northern bugleweed *(Lycopus uniflorus),* and tufted loosestrife *(Lysimachia thyrsiflora).* MRn93 occurs along wave-washed lake shores, on sandbars, or in stream channels. This Class is dominated by bulrushes and spikerushes *(Eleocharis* spp.), with submergent plants such as pondweeds *(Potamogeton* spp.) and watermilfoils *(Myriophyllum* spp.). Water depth may also be impor-

MR Marsh System

General Description

Communities of the Marsh (MR) System are tall forb- and graminoid-dominated wetland communities that have standing or, in the case of riverine marshes, slow-flowing water present through most of the growing season. MR communities occur statewide and are common throughout the Laurentian Mixed Forest (LMF) Province in wetland basins, along sheltered lakeshores, near stream mouths, and in river backwaters or sluggish streams. The maximum water depth is typically sustained at 20–60 inches (50–150cm) but may be higher, especially in marshes where the vegetation is rooted on floating mats. Water levels are fairly stable in settings where groundwater is a significant contributor and variable where water is supplied predominantly by precipitation and surface runoff. If water-level drawdown occurs, it coincides with drought cycles and is not seasonal as in Wet Meadow/Carr (WM) communities.

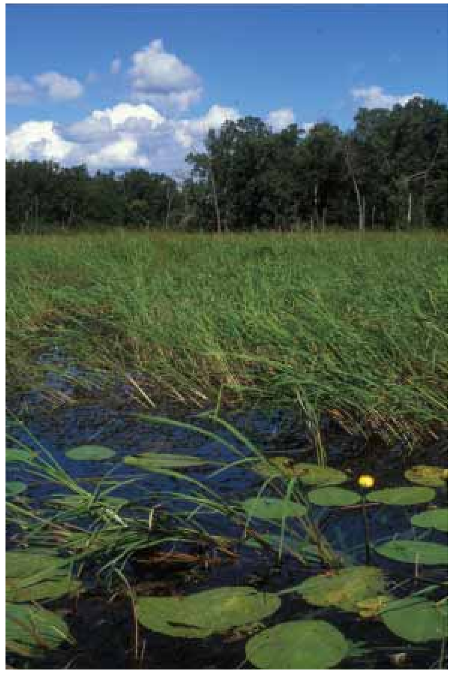


photo by S.C. Zager MN DNR

Pine River, Crow Wing County, MN

Nutrient levels are typically high in MR communities, particularly following drawdowns, which allow for oxidation of organic material in sediments and release of nutrients. Nutrient levels can be very high in riverine marshes, especially along the lower St. Louis River where regular seiches from Lake Superior reverse the flow of water and flush sediments and nutrients back upstream into estuaries and backwaters. The pH of water in MR communities is most often circumneutral to basic with high dissolved mineral content, but varies depending on properties of the substrates in the surrounding landscape. MR communities in bedrock areas in NSU have relatively low pH and dissolved minerals; marshes in the western and southern parts of the LMF Province are present in landscapes dominated by calcareous glacial deposits and are characterized by water with higher pH and mineral levels. The southern and western part of the Province also has lower precipitation and higher evaporation rates, so marshes are more likely to develop in settings fed by steady inputs of groundwater, rather than in settings dependent on direct precipitation or surface runoff for moisture. Substrates in MR communities range from mineral soil, to sedimentary peat, to floating peaty root mats. Organic matter can be abundant in substrates not exposed regularly to wave action, river currents, ice-scouring, or drawdowns and episodes of oxidation.

Plant Adaptations

The dominant plants in MR communities are tolerant of persistently deep water levels. Like many wetland plants, they have stems, leaves, and roots that contain intercellular air spaces (aerenchyma) that store oxygen and diffuse it from above-water structures to roots during water-logged conditions. Variation in species composition over time is common in marshes in response to changes in hydrological conditions. Many marsh species germinate only when seeds buried in sediments are exposed following water-level drawdown. These include annuals such as beggarticks *(Bidens* spp.) and smartweeds *(Polygonum* spp.) that germinate rapidly and profusely on freshly exposed

FD Fire-Dependent Forest/Woodland System

photo by M.L. Heinselman

Little Sioux Fire, Superior National Forest 1971

General Description

Fire-Dependent Forest/Woodland (FD) communities are common across the Laurentian Mixed Forest (LMF) Province, even after nearly 100 years of wildfire suppression. As the name implies, Fire-Dependent Forest/Woodland communities are strongly influenced by wildfires. Fires are the major source of species mortality and exert strong influence on patterns of plant reproduction by exposing mineral soil seedbeds, triggering dispersal of propagules, and increasing the amount of light reaching the ground or understory. Fires periodically remove much of the litter, duff, and other organic material from the community and can have a significant effect on nutrient cycling and nutrient availability. In the LMF Province, FD communities are characterized by prevalence of evergreen species, most visibly pines and other conifers. These species, like most of the species characteristic of FD communities, are adapted to survive repeated fires or to regenerate successfully following fire.

FD communities occur in the LMF Province on sites with coarse sandy or gravelly soils or with thin soils over bedrock. These sites are often drought prone, a condition enhanced by removal by fire of organic material, such as litter and humus, that retains soil moisture. Fires also can contribute to low nutrient availability in FD communities by releasing nutrients from plant material and making them susceptible to being leached below the plant rooting zone or carried away by runoff. In comparison with other communities, such as Mesic Hardwood Forests, in which nutrient availability changes predictably over each year and remains relatively stable from year-to-year, the random behavior of wildfires causes nutrient availability in FD communities to be episodic and unpredictable.

Plant Adaptations

Many of the plants that occur in FD communities have seeds or vegetative structures designed to survive fire or are opportunists that can take advantage of short periods when nutrients are relatively abundant and light levels are high. Plants must also survive frequent drought and potentially long periods between fires when nutrients are tied up in plant material and light levels decrease beneath increasingly dense tree canopies. Species with evergreen leaves or over-wintering leaves are particularly characteristic of FD communities; these adaptations are probably a response to low nutrient levels and enable plants to conserve scarce nutrients (in contrast to deciduous species, which lose nutrients each year when leaves are shed and must take them up again the following growing season). Many species in FD communities, including evergreens, have leaves with thickened outer membranes or other features that help to reduce water loss or even herbivory. In general, the species in FD communities have lower nutrient and water requirements and higher light requirements than plants in other forested systems.

Fire Regimes

Fires in FD communities can vary greatly in intensity, from severe crown fires to mild surface fires. Fires also range widely in frequency. Before the onset of fire suppression in the LMF Province, the most fire-prone FD communities experienced fires about every 20 years and the least-affected communities experienced fires about every 100 years. The frequency and intensity of fires in these communities appear to be inversely related and show a strong geographic pattern across the LMF Province. This pattern correlates with the pattern of climate in the Province, which is warmer and drier in the southwest and cooler and moister in the northeast (see Fire Regimes of FDn vs. FDc Communities below for more detail).

Floristic Regions

FD communities in Minnesota can be grouped into four “floristic” regions, based on general differences in species composition (Fig. FD-1). Two of these floristic regions are represented in the LMF Province: the Northern Floristic (FDn) Region and the Central Floristic (FDc) Region. Communities from the other two floristic regions, the Southern (FDs) and the Northwestern (FDw), are present occasionally along the southern and western edges of the LMF Province.

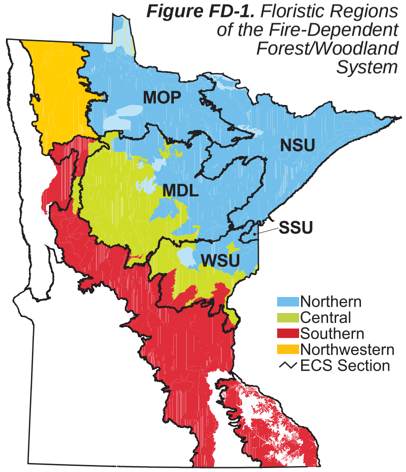


Figure FD-1. *Floristic Regions of the Fire-Dependent Forest/Woodland System*

The differences in species composition between communities of the FDn and FDc Regions relate strongly to regional differences in paleohistory, especially in duration of cover by fire-dependent pine forests. Pine forests have been present in the FDn Region for a long time. In the eastern half of the FDn Region (largely within the NSU, WSU, and SSU Sections of the LMF Province) fire-dependent pine forests replaced post-glacial spruce forests 8,500 to 10,000 years ago and have remained since that time. In the western half of the FDn Region (in MOP and MDL) it appears that pine forests have been a stable component of the landscape for a shorter period, but still have been present for more than 3,500 years. In contrast, pine forests did not begin developing in what is now the FDc Region until about 3,500 years ago. Before this time the area was occupied by southern fire-dependent forests, woodlands, and prairies. After 3,500 years ago, the component species of northern forests—including all three of Minnesota’s native pines—began migrating westward, resulting in the development of a flora that is a mixture of species with southern affinity that have persisted on the landscape and species with northern affinity that have been migrating westward.

Plant Indicators of FDn vs. FDc Communities

Plant species that have high fidelity for FDn communities relative to FDc communities are listed in Table FD-1. These species have strongly coincidental statewide distributions that lie mostly within the LMF Province. Interestingly, when present south or west of the Province, many of these species occur primarily in wetland rather than upland habitats. Among the species with high fidelity for FDn communities are a group of evergreen species and species with over-wintering leaves that are extremely tolerant of nutrient-poor conditions and have wide tolerances for moisture; as a result these species are present in nutrient-poor coniferous wetland communities across northern Minnesota, in addition to nutrient-poor FDn communities. Many of these species, such as balsam fir and black spruce, are easily killed by fire but appear to spread readily from wetlands onto adjacent uplands following forest fires.

(OP) communities. In some cases, invasion by *Sphagnum* occurs so quickly that the site appears to succeed directly from a WM community to an Acid Peatland (AP) community. This happens primarily when the dominant sedges, with the exception of the most deeply rooted, are eliminated by rapid expansion of level *Sphagnum* carpets that lack significant development of hummocks and hollows. In this situation, the characteristic OP plants do not become established on the site before water chemistry turns acidic and nutrient poor, favoring plants characteristic of AP communities. WM communities can also succeed to WF communities if hydrological changes result in lowering of the water table, followed by an increase in dominance of shrubs and eventual establishment of tree seedlings.

for the hummocky topography characteristic of WM communities. Other species, such as willows, develop roots from stems or root collars (adventitious roots) that provide access to oxygen when other roots are submerged. Plants in WM communities must also minimize desiccation during periods of drawdown; this is accomplished by development of roots that extend deeply into permanently wet or moist substrates and by hard-walled cells (sclerenchyma) on outer surfaces of roots and rhizomes that reduce water loss. Although floating-leaved and submerged aquatic species may temporarily invade WM communities during periods of high water, they lack adaptations to prevent desiccation and are eliminated during low-water periods.

Because minerals and nutrients are plentiful in WM communities, growth of vegetation is typically luxuriant although not usually diverse. The characteristic sedges are wide-leaved species such as lake sedge that form monotypic stands and produce dense thatch. In WM communities with dense cover of lake sedge, regular oscillations in water level and thick thatch limit plant diversity by reducing habitats available for forb species. In comparison, WM communities dominated by tussock-forming species, such as tussock sedge, usually have higher vascular species diversity, with forbs growing on exposed root wads from uprooted tussocks.

Floristic Regions

Based on general differences in species composition, WM communities in Minnesota are grouped into three "floristic" regions: the Northern Floristic (WMn) Region, the Prairie Floristic (WMp) Region, and the Southern Floristic (WMs) Region (Fig. WM-1). Only the WMn Region is represented in the LMF Province. Within the Province, which is characterized by dependable precipitation and low evapotranspiration rates, WMn communities are present both in basins and along streams. West and south of the LMF Province, in areas of more sporadic precipitation and higher evapotranspiration, WMn communities occur on lakeshores or in areas that border marshes. Currently, only one Native Plant Community Class is recognized in the WMn Region. Future collection and analysis of environmental data along with vegetation data will likely lead to delineation of several Classes based on average or maximum water depth or length of inundation.

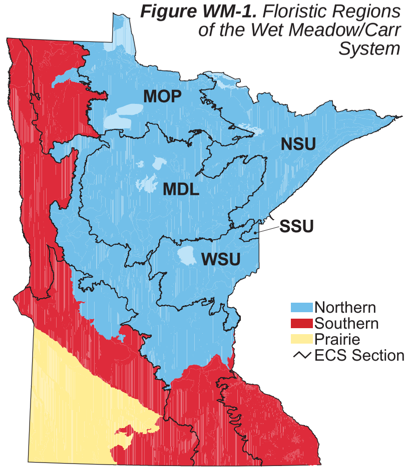


Figure WM-1. *Floristic Regions of the Wet Meadow/Carr System*

Succession

WM communities can develop from Wet Forest (WF) communities in areas flooded by beaver activity or from Forested Rich Peatland (FP) communities following catastrophic fires during severe droughts. WM communities can also develop from Marsh (MR) communities when siltation, accumulation of sedimentary peat, development of floating root mats, or lowering of water tables (commonly following disintegration of beaver dams) effectively lower the water level in relation to the substrate surface; this promotes invasion and dominance by sedges over emergent aquatic plants such as cattails (*Typha* spp.) or bulrushes (*Scirpus* spp.). In WM communities invaded by peat-producing bryophytes (particularly *Sphagnum*), nutrient levels decline and the dominant broad-leaved sedge species are replaced by fine-leaved sedges, causing conversion to Open Rich Peatland

Table FD-1*. Plants useful for differentiating the Northern from the Central Floristic Region of the Fire-Dependent Forest/Woodland System*

Region	Group	Subgroup	Common Name	Scientific Name	Frequency(%) FDn	FDc
Northern Floristic Region	Tolerant of low nutrients	Evergreen or over-wintering leaves	Balsam fir (U)	*Abies balsamea*	76	8
			Bunchberry	*Cornus canadensis*	73	11
			Twinflower	*Linnaea borealis*	55	13
			Ground-pine	*Lycopodium dendroideum/hickeyi* group	40	1
			White spruce (U)	*Picea glauca*	40	9
			Balsam fir (C)	*Abies balsamea*	29	–
			Running clubmoss	*Lycopodium clavatum*	24	–
			Black spruce (U)	*Picea mariana*	24	2
			White spruce (C)	*Picea glauca*	18	2
			Black spruce (C)	*Picea mariana*	15	–
			Common polypody	*Polypodium virginianum*	15	–
			Bristly clubmoss	*Lycopodium annotinum*	14	–
			White cedar (U)	*Thuja occidentalis*	14	–
			Goldthread	*Coptis trifolia*	13	–
			Naked miterwort	*Mitella nuda*	12	1
			Common oak fern	*Gymnocarpium dryopteris*	11	–
			Woodland horsetail	*Equisetum sylvaticum*	9	–
			White cedar (C)	*Thuja occidentalis*	7	–
			Labrador tea	*Ledum groenlandicum*	7	–
			Shining clubmoss	*Huperzia lucidula*	6	1
			One-flowered pyrola	*Moneses uniflora*	5	–
		Deciduous	Velvet-leaved blueberry	*Vaccinium myrtilloides*	40	8
			Bluejoint	*Calamagrostis canadensis*	11	–
			Palmate sweet coltsfoot	*Petasites frigidus*	11	1
			Swamp gooseberry	*Ribes hirtellum*	8	1
			Swamp red currant	*Ribes triste*	6	–
			Skunk currant	*Ribes glandulosum*	5	–
	Other		Fly honeysuckle	*Lonicera canadensis*	59	12
			Mountain maple	*Acer spicatum*	41	7
			Mountain ash (U)	*Sorbus* spp.	37	2
			Green alder	*Alnus viridis*	16	1
			Thimbleberry	*Rubus parviflorus*	10	–

(C)=canopy tree (U)=understory tree

Most of the plant species that have high fidelity for FDc communities relative to FDn communities (Table FD-2) also occur in Southern Fire-Dependent Forest/Woodland (FDs) communities or in prairies, which made up the bulk of the vegetation of the FDc Region during earlier, warmer periods of the Holocene Epoch. The majority of these species are woody species, but there are also a number of herbaceous species with southern affinity that have high fidelity for the FDc Region. Quite a few of the species that help to differentiate FDc from FDn communities are species with strong affinity for prairies, especially big bluestem *(Andropogon gerardii),* wild bergamot *(Monarda fistulosa),* and skyblue aster *(Aster oolentangiensis)*. A few plants with high fidelity for FDc relative to FDn communities are species common in transition areas between prairies and woodlands; these plants include tall thimbleweed *(Anemone virginiana),* two-flowered Cynthia *(Krigia biflora),* oval-leaved New Jersey tea *(Ceanothus herbaceus),* blue giant hyssop *(Agastache foeniculum),* and balsam ragwort *(Senecio pauperculus).*

Fire Regimes of FDn vs. FDc Communities

In addition to differences in species composition, FDn and FDc communities differ in fire regime (Table FD-3). The FDn communities can be divided into two groups based on similarities in parent material and fire regime. The first group of FDn communities (Northern Dry-Bedrock Pine [Oak] Woodland [FDn22], Northern Poor Dry-Mesic Mixed

Table FD-2 *Plants useful for differentiating the Central from the Northern Floristic Region of the Fire-Dependent Forest/Woodland System*

Region	Affinity	Common Name	Scientific Name	Frequency(%) FDn	FDc
Central Floristic Region	Central affinity	Balsam ragwort	*Senecio pauperculus*	1	24
		Blue giant hyssop	*Agastache foeniculum*	1	15
		Two-flowered Cynthia	*Krigia biflora*	–	8
		Tall thimbleweed	*Anemone virginiana*	–	6
		Oval-leaved New Jersey tea	*Ceanothus herbaceus*	–	6
	Prairie affinity	Northern bedstraw	*Galium boreale*	10	70
		Harebell	*Campanula rotundifolia*	4	31
		Hoary puccoon	*Lithospermum canescens*	1	30
		Yarrow	*Achillea millefolium*	4	29
		Big bluestem	*Andropogon gerardii*	–	25
		Smooth blue aster	*Aster laevis*	3	22
		Slender wheatgrass	*Elymus trachycaulus*	4	20
		Sky blue aster	*Aster oolentangiensis*	–	16
		Clustered muhly grass	*Muhlenbergia glomerata*	1	16
		Gray goldenrod	*Solidago nemoralis*	4	16
		Wild bergamot	*Monarda fistulosa*	–	15
		Kalm's brome	*Bromus kalmii*	–	12
		Virginia ground cherry	*Physalis virginiana*	–	12
		Wood betony	*Pedicularis canadensis*	–	9
		Alumroot	*Heuchera richardsonii*	1	9
		Heart-leaved alexanders	*Zizia aptera*	–	6
		Leadplant	*Amorpha canescens*	–	5
	Southern affinity	American hazelnut	*Corylus americana*	5	62
		Bur oak (U)	*Quercus macrocarpa*	12	59
		Poison ivy	*Toxicodendron rydbergii*	7	53
		Early meadow-rue	*Thalictrum dioicum*	10	53
		Wolfberry	*Symphoricarpos occidentalis*	8	45
		Pale bellwort	*Uvularia sessilifolia*	9	38
		Maryland black snakeroot	*Sanicula marilandica*	9	36
		Tall blackberries	*Rubus allegheniensis* & similar *Rubus* spp.	5	35
		Northern red oak (C)	*Quercus rubra*	5	23
		Black cherry (U)	*Prunus serotina*	2	22
		Gray dogwood	*Cornus racemosa*	2	22
		Hog peanut	*Amphicarpaea bracteata*	3	20
		Virginia creeper	*Parthenocissus* spp.	3	18
		Bur oak (C)	*Quercus macrocarpa*	2	15
		Erect, smooth, or Illinois carrion-flower	*Smilax ecirrata/herbacea/illinoensis* group	1	13
		Hawthorn	*Crataegus* spp.	1	13
		Starry false Solomon's seal	*Smilacina stellata*	1	12
		Woodland sunflower	*Helianthus strumosus*	–	11
	Other	Sand cherry	*Prunus pumila*	3	18
		Oval-leaved milkweed	*Asclepias ovalifolia*	–	12
		Early goldenrod	*Solidago juncea*	1	8

(C)=canopy tree (U)=understory tree

Woodland [FDn32], and Northern Mesic Mixed Forest [FDn43] occurs mostly on coarse loamy till over bedrock (primarily in NSU) and is characterized by relatively long intervals between fires. The rotation period for intense, stand-replacing fires in this group is about 170 tp 220 years, and for surface fires about 210 to 260 year; the combined rotation period for all fires is 100 to 115 years. The second group of FDn communities (Northern Dry-Sand Pine Woodland [FDn12] and Northern Dry-Mesic Mixed Woodland [FDn33]) occurs on sand and gravel deposits and has shorter intervals between fires, especially surface fires. The fire-regime for this group is intermediate between that of

photo by D. Perleberg MN DNR

Cass County, MN

General Description

Wet Meadow/Carr (WM) communities are graminoid- or shrub-dominated wetlands that are subjected annually to moderate inundation following spring thaw and heavy rains and to periodic drawdowns during the summer. The dominant graminoids are broad-leaved species such as lake sedge *(Carex lacustris)*, tussock sedge *(C. stricta)*, and bluejoint *(Calamagrostis canadensis)*. Shrubs such as willows *(Salix* spp.) and dogwoods *(Cornus* spp.) are likely to be dominant on drier sites. Peak water levels are high and persistent enough to prevent trees (and often shrubs) from becoming established. However, there may be little or no standing water present during much of the growing season. As a result, the substrate surface alternates between aerobic and anaerobic conditions. Any organic matter that accumulates over time is usually oxidized during periodic drawdowns and may even burn during severe droughts. Soils range from mineral soils to muck and peat. Silt from flooding sometimes is intermixed with organic matter in muck or peat soils. Although WM communities can be present on deep peat, they are not "peat-accumulating" communities. Rather, the peat was usually formed previously in a peat-producing community, such as a Forested Rich Peatland, that was flooded by beaver activity and converted to a WM community. Deep peat may also be present in some WM communities because of debris that has been transported into the wetland, forming sedimentary peat. Because surface water is derived from runoff, stream flow, or groundwater, it is circumneutral (pH 6.0-8.0) and has high mineral and nutrient content. WM communities are present statewide and are common throughout the Laurentian Mixed Forest (LMF) Province in wetland basins, along streams and drainage ways, in drained beaver ponds, in shallow bays, or as semi-floating mats along sheltered lake shorelines.

Plant Adaptations

The characteristic plants of WM communities have adaptations that allow them to survive waterlogged conditions, although they are generally intolerant of prolonged inundation or high (>20in [50cm]) water levels. Like many wetland plants, they have stems, leaves, and roots that contain intercellular air spaces (aerenchyma) that store oxygen and transport it from above-water structures to roots during water-logged periods. In addition, some sedges and grasses (e.g., tussock sedge and bluejoint) form dense tussocks that elevate rootlets above the water surface. These tussock-formers account changes from a bicarbonate buffered system to a humic acid buffered system. Subsequent production of humic acids by peat decomposition and living *Sphagnum* accelerates the acidification process. The higher parts of hummocks rapidly become more acidic and bog-like, while hollows usually retain more minerotrophic water chemistry and brown mosses. Eventually, the brown moss species in the hollows are replaced by oligotrophic *Sphagnum* species, completing transformation of the OP community to an Acid Peatland (AP) community. However, if inputs of minerals via groundwater or other sources are sufficient to compensate their removal by *Sphagnum*, succession to AP communities may be stopped or slowed. In comparison with OP communities, AP communities have very little contact with groundwater, have *Sphagnum* in hollows as well as on hummocks, and lack rich minerotrophic species (see table below for an explanation of minerotrophic versus bog species).

Vascular plant species that occur in bog Native Plant Communty Classes.

Because only those species listed below can persist in the ombrotrophic conditions of bogs, the occurrence of any other species can be considered an indicator of minerotrophic conditions. However, some seedlings, particularly tree species, can germinate in bogs but are short-lived and should not be considered as minerotrophic indicators.

	Common Name	Scientific Name	Northern Spruce Bog APn80	Northern Open Bog APn90
			Frequency(%)	
Tree	Tamarack	*Larix laricina*	51	62
	Black spruce	*Picea mariana*	100	82
	Jack pine	*Pinus banksiana*	4	6
Low Shrub	Bog rosemary	*Andromeda glaucophylla*	49	74
	Leatherleaf	*Chamaedaphne calyculata*	87	94
	Creeping snowberry	*Gaultheria hispidula*	44	–
	Bog laurel	*Kalmia polifolia*	91	94
	Labrador tea	*Ledum groenlandicum*	99	74
	Lowbush blueberry	*Vaccinium angustifolium*	45	12
	Velvet-leaved blueberry	*Vaccinium myrtilloides*	29	9
	Small cranberry	*Vaccinium oxycoccus*	95	94
	Lingonberry	*Vaccinium vitis-idaea*	31	–
	Dwarf misletoe	*Arceuthobium pusillum*	1	–
Forb	Stemless lady's slipper	*Cypripedium acaule*	19	–
	Round-leaved sundew	*Drosera rotundifolia*	38	35
	Heart-leaved twayblade	*Listera cordata*	3	–
	Indian pipe	*Monotropa uniflora*	28	–
	Pitcher plant	*Sarracenia purpurea*	29	59
	Three-leaved false Solomon's seal	*Smilacina trifolia*	86	18

Table FD-3. *Historic tree species composition & disturbance regimes in FDn and FDc communities*

	young forest age	young forest species	mature forest age	mature forest species	old forest age	old forest species	Stand-Regenerating Fire	Moderate Surface Fire	All Fires	Catastrophic Windthrow
	Historic Tree Species Frequency by Class and Stand Age						Historic Disturbance Rotation Periods by Class (in years)			
Northern Floristic Region						ranges →	170-220	50-260	50-115	>610
FDn12	0 - 55 yrs	**jack pine** red pine	75 - 195 yrs	**red pine** *(jack pine)*	> 195 yrs	*(red pine) (jack pine) (white pine) (white spruce)*	170	50	42	610
FDn22	0 - 55 yrs	**jack pine** *(red pine)*	75 - 115 yrs	red pine *(jack pine) (white spruce) (white pine)*	> 115 yrs	red pine jack pine *(white spruce)*	195	225	107	>1000
FDn32	0 - 55 yrs	jack pine *(quaking aspen) (paper birch)*	> 95 yrs	spruce** *(paper birch) (balsam fir) (white pine) (jack pine)*	–		170	210	100	>1000
FDn33	0 - 35 yrs	quaking aspen *(red pine) (paper birch) (jack pine)*	55 - 125 yrs	red pine *(paper birch) (white pine)*	> 125 yrs	white pine *(red pine) (paper birch) (white spruce)*	220	75	53	>1000
FDn43	0 - 35 yrs	**quaking aspen** *(jack pine) (paper birch)*	55 - 95 yrs	paper birch *(white pine) (quaking aspen) (balsam fir)*	> 115 yrs	white pine white spruce *(paper birch) (balsam fir)*	220	260	115	>1000
Central Floristic Region						ranges →	80-130	10-30	10-25	>1000
FDc12	0-55 yrs	**jack pine**	>115 yrs	jack pine red pine	–		120	30	25	>1000
FDc23	0-55 yrs	**jack pine**	75-155 yrs	**jack pine** red pine	>155 yrs	**jack pine** *(red pine)*	110	30	22	>1000
FDc24	0-55 yrs	**jack pine**	75-155 yrs	**jack pine** red pine	>195 yrs	**jack pine** *(white pine)*	130	30	23	>1000
FDc25	0-55 yrs	bur oak quaking aspen *(jack pine) (northern pin oak)*	55-135 yrs	**bur oak** *(northern pin oak)*	>195 yrs	jack pine bur oak	80	10	9	--
FDc34	0-55 yrs	quaking aspen* red pine *(white pine) (jack pine)*	95-135 yrs	**red pine** white pine	>195 yrs	**white pine** *(red pine)*	110	30	23	>1000

bold = >50% normal = 25-50% *(italics)* = 10-25% *includes big-toothed aspen **either black or white spruce

the first group of FDn communities and that of the FDc communities (which, like the second FDn group, occur primarily on sand and gravel deposits). The estimated rotation of stand-replacing fires in this second FDn group is 170-220 years, and the rotation of surface fires is estimated to be 50 to 75 years; this results in a combined frequency for all fires of about 40 to 50 years.

The FDc communities have much shorter rotation periods than either of the two groups of FDn communities. In addition, whereas the rotation periods for stand-replacing and surface fires are more similar in length in the FDn communities, in FDc communities surface fires recur at much shorter intervals than stand-replacing fires. Most of the FDc Region lies in the western parts of MDL and WSU (see Fig. FD-1). This area is characterized by woodland and forest communities (Central Poor Dry Woodland [FDc12], Central Dry Pine Woodland [FDc23], Central Rich Dry Pine Woodland [FDc24], and Central Dry-Mesic Pine-Hardwood Forest [FDc34]) that experienced stand-replacing fires every 110 to 130 years and surface fires about every 30 years; the combined frequency of all fires in these communities is estimated to be 22 to 25 years (seeTable FD-3). Along the St. Croix River Valley in the eastern part of the FDc Region, the fire-regime of the mid-1800s appears to have been strongly influenced by humans. This is also the only area in the LMF Province where fire-dependent vegetation is dominated mostly by deciduous trees rather than pines. The single FDc class that occurs in this area (Central Dry Oak-Aspen [Pine] Woodland [FDc25]) has an estimated rotation of stand-replacing fires of about 80 years. Such fires probably removed aspen and jack pines, leaving mature oaks. The rotation of surface fires in this area was very short, just 10 years, and the frequency of all fires is estimated to be 9 years.

The differences in fire regime between the FDn and FDc Regions correlate with variation in vegetation structure and composition. Most prominent are differences in the age-structure of mature and old-growth forests. For most of the FDn Region, where the rotation period for surface fires was often equal to or longer than that for stand-regenerating fires, stands were as likely to experience intense, stand-regenerating fires as moderate surface fires. Stands in this area of the LMF Province tended to become multiple-aged as they matured, with rather constant recruitment in the understory of shade-tolerant species, especially balsam fir, white spruce, and northern white cedar, along with some paper birch and white pine. The establishment of fir and spruce in the understory of FDn forests is important, because these trees are highly flammable and help to promote stand-regenerating fires. In the FDc Region, where the rotation for surface fires was much shorter than that for stand-replacing fires, individual stands commonly experienced several surface fires in the intervals between intense crown fires. These stands also became multiple-aged as they matured, but the understories had cohorts of early-successional species that regenerate vigorously following fire (in contrast to the shade-tolerant species more common in the understory in FDn communities). These understory cohorts included quaking aspen, big-toothed aspen, jack pine, and oak, in addition to progeny of overstory red and white pines.fires. These stands also became multiple-aged as they matured, but the understories had cohorts of early-successional species that regenerate vigorously following fire (in contrast to the shade-tolerant species more common in the understory in FDn communities). These understory cohorts included quaking aspen, big-toothed aspen, jack pine, and oak, in addition to progeny of overstory red and white pines.

plant, sundews, and bladderworts; and ferns and fern allies such as crested fern *(Dryopteris cristata)* and water horsetail *(Equisetum fluviatile)*, all of which are typically present in communities in the OPn Region. On the other hand, OPp communities have species common in the drier and more fire-prone landscapes of western Minnesota that are not present in the OPn Region. Examples of these species are grass-leaved goldenrod *(Euthamia graminifolia)*, Buxbaum's sedge *(Carex buxbaumii)*, and narrow reedgrass *(Calamagrostis stricta)*.

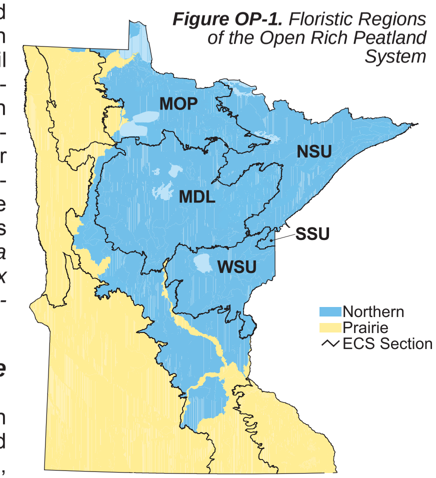


Figure OP-1. *Floristic Regions of the Open Rich Peatland System*

Variation Among Classes in the OPn Region

The plant community Classes in the OPn Region are divided into two groups based on differences in topography, substrate, and hydrology. The first group—Northern Shrub Shore Fen (OPn81) and Northern Rich Fen (Basin) (OPn92)—forms in basins underlain by fine-textured substrates with relatively low hydraulic conductivity. As a result, these peatlands are influenced primarily by stagnant (rather than flowing) groundwater. They are characterized by level or slightly concave peat surfaces and are common where irregular topography allows the development of poorly drained, isolated peat-filled depressions. They also form on floating mats adjacent to lakes, ponds, or rivers, and in lagg zones between larger peatlands and adjacent uplands. The two community Classes in this group differ from one another primarily in frequency of inundation by surface runoff or rising lake levels. Northern Shrub Shore Fens are occasionally inundated (and as a result are somewhat similar to WM communities), whereas Northern Rich Fens (Basin) are less frequently inundated.

The second group of OPn communities—Northern Extremely Rich Fen (OPn93) and Northern Rich Fen (Water Track) (OPn91)—forms on flat or slightly sloping surfaces, such as broad glacial lake plains. These communities are associated with lenses of sandy substrates that have high hydraulic conductivity. Because of the porosity of the subterranean sands, these peatlands are influenced by inputs of groundwater that create surface water flow and the formation of water tracks on the peatland surface. The elongated water tracks slope gently in the direction of drainage and sometimes form characteristic ribbed fen patterns visible on aerial photos. The water track communities differ from one another in mineral concentrations and pH. Northern Extremely Rich Fens are fed by highly calcareous groundwater and have characteristic calciphilic plants, whereas Northern Rich Fens (Water Track) have circumneutral water chemistry and lack calciphilic species.

Succession

OP communities can develop from WM communities if conditions become suitable for accumulation of organic matter and rooting contact with mineral soil is reduced. If peat continues to accumulate over time, the peat surface and water table become elevated and the rate of water flow and inputs of minerals to the plant-rooting zone are gradually reduced. Conditions then become favorable for invasion by minerotrophic *Sphagnum* species. Once *Sphagnum* is present, it further reduces available minerals by absorbing them—particularly calcium—and replacing them with hydrogen ions, causing the peat surface to become increasingly acidic. The site then becomes suitable for more acid-tolerant *Sphagnum* species, and pH continues to fall. Below pH 5.5, the water chemistry in the understories of FP communities. OP communities have much smaller seasonal water-level oscillations than WM communities, providing conditions more favorable for formation and accumulation of peat. WM communities can be present on relatively deep sedimentary peat deposits or on deep peat on sites formerly occupied by peat-forming communities. Differences in species composition and vegetation, however, distinguish OP and WM communities even when deep peat is present in WM communities. OP communities (with the exception of Northern Shrub Shore Fens [OPn81]) are usually dominated by fine-leaved graminoids, mosses, or ericaceous shrubs such as leatherleaf, while WM communities are dominated by broad-leaved graminoids, lack significant moss cover, and lack ericaceous shrubs.

Plant Adaptations

The plants characteristic of OP communities are adapted to full sunlight, sustained water levels, low nutrient levels, and high mineral levels. This environment is well suited to dominance by sun-loving herbaceous species, brown mosses, and minerotrophic *Sphagnum* species. The lack of shade from trees and shrubs favors dominance in the ground layer by shade-intolerant species, especially graminoids (in comparison with FP communities, which have more abundant forbs and shrubs in the understory). Like many wetland plants, the characteristic species in OP communities, such as sedges *(Carex* spp.) and buckbean *(Menyanthes trifoliata)*, have stems, leaves, and roots with intercellular air spaces (aerenchyma) that store oxygen and transport it from above-water structures to roots during water-logged periods. Other plants, such as bog birch *(Betula pumila),* grow on aerated hummocks, or in the case of tufted bulrush *(Scirpus cespitosus)* form hummocks that elevate the plant above persistently anaerobic peat surfaces. Generally, desiccation is not a problem for plants in OP communities because the plant-rooting zone is almost always wet, and remains moist even during periods of drought when the water table drops below the peat surface.

As in other peatland Systems, plants in OP communities are visibly affected by low-nutrient conditions and often have adaptations enabling them to exist on the limited nutrients in substrates and surface water. Particularly evident are reduced growth forms. Many of the characteristic shrubs and graminoids are very short. The dominant graminoids tend to have very narrow leaves (typically <$^{1}/_{3}$ inch (3mm) wide), with species such as fen wire grass *(Carex lasiocarpa),* candle-lantern sedge *(C. limosa),* creeping sedge *(C. chordorrhiza),* and white beak rush *(Rhynchospora alba)* most common. OP communities are also characterized by insectivorous plants, including pitcher plant *(Sarracenia purpurea),* sundews *(Drosera* spp.), and bladderworts *(Utricularia* spp.), that supplement their intake of both nitrogen and phosphorus by capturing and digesting insects. Although nutrients are low in OP communities, concentrations of minerals such as calcium can be very high near groundwater discharge points, particularly in the western parts of the LMF Province where peatlands are underlain by calcareous glacial deposits. Plants that thrive in areas of calcareous groundwater discharge include tufted bulrush, Kalm's lobelia *(Lobelia kalmii),* and grass of Parnassus *(Parnassia* spp.), along with the rare species twig rush *(Cladium mariscoides)* and hair-like beak rush *(Rhynchospora capillacea).*

Floristic Regions

Based on geographic variation in species composition, OP communities in Minnesota are grouped into two "floristic" regions: the Northern Floristic (OPn) Region and the Prairie Floristic (OPp) Region (Fig. OP-1). All of the OP communities in the LMF Province are in the OPn Region, with the exception of the Salol Peatland in Roseau County along the western border of MOP. Communities in the OPp Region are at the western climatic limit in Minnesota of peatland formation and are subject to fires and water stress during periods of drought. Therefore, they lack some of the characteristic OP species less tolerant of drought, including ericaceous shrubs, such as leatherleaf, bog rosemary, and small cranberry *(Vaccinium oxycoccos);* insectivorous plants such as pitcher

photo by K.A. Rusterholz MN DNR

Tettegouche State Park, Lake County, MN

General Description

Mesic Hardwood Forest (MH) communities are present in the Laurentian Mixed Forest (LMF) Province on upland sites with moist soils, usually in settings protected from fire. They are characterized by continuous, often dense, canopies of deciduous trees, including sugar maple, basswood, paper birch, and northern red oak, and understories with shade-adapted shrubs and herbs. Plants in MH communities have access to predictable supplies of water and nutrients, but they are often limited by light because of the dense forest canopy. Typical sites are buffered from seasonal drought by fine-textured, moisture-retaining soils or dense subsoil layers that perch snowmelt and rainfall. At the same time, soils are well drained and do not experience water logging or saturation except after spring snowmelt or heavy rains. Consequently, plants in MH communities rarely experience diminished respiration due to soil anoxia. Essential nutrients, especially nitrogen, are mineralized from decaying organic matter at twice the rate of that in either Fire-Dependent Forest/Woodland (FD) or Wet Forest (WF) communities. As a result, nutrients in dead plant material quickly become available again for uptake by plants. Resource availability in MH communities follows an annual or seasonal pattern that is more predictable than in FD forests, where nutrients are released mainly following episodic fires. Tree mortality in MH communities is also rather constant, with stand-regenerating disturbances such as wildfires and windthrow uncommon. The death of established trees most often involves individual canopy trees or small patches that are affected by minor windthrow, disease, or other fine-scale disturbances.

Plant Adaptations

Competition for light appears to have strong influence on the species composition of MH communities. Older forests commonly have several, nearly closed layers of woody plants, including well-defined forest canopies, subcanopies, and shrub layers. These layers combine to produce cover that is often continuous, filtering most of the sunlight before it reaches herbaceous plants and seedlings on the forest floor. Measurements of light intensity have been reported on forest floors in closed-canopy sugar maple stands of just 0.1% to 2% of that of direct sunlight. As a result, the species characteristic of the System tend to be extremely tolerant of shade, at least in their juvenile stages, or develop rapidly in early spring, capturing and storing most of their annual energy needs before trees become fully leaved.

In MH communities, nutrients and organic matter accumulate at the soil surface in leaf litter and humus. This contrasts with FD communities, for example, where nutrients are leached deeply into the soil and the humus layer is periodically consumed by fire, and with WF and Floodplain Forest (FF) communities, which are sinks for nutrients transported from uplands in groundwater or runoff. Deeply rooted plants in MH communities extract base elements such as calcium, magnesium, and potassium from deep in the mineral soil and deposit them on the surface in plant litter. Species such as sugar maple, basswood, and elm, which are abundant in many stands, shed leaves with high amounts of nutrients, contributing to high nutrient content in the humus. As a result, much of the plant activity in MH forests is concentrated around the soil surface and rich humus layer. Many of the herbaceous plants are rooted almost entirely in humus, and woody plants have a high proportion of their roots near the surface. Several species characteristic of MH communities have adaptations, such as decumbent growth forms or extensive rhizome systems, that allow them to expand laterally through these upper soil layers in search of unexploited nutrients and light reaching the forest floor.

Soils and Soil Moisture

The distribution of MH communities in the LMF Province is strongly correlated with the presence of impermeable horizons about 20 to 30 inches (50 to 75cm) below the soil surface that perch snowmelt or rainfall. Close to 80% of the vegetation plots from MH communities in this analysis occurred on soils with impermeable lower horizons, and more than 80% of sites with impermeable soil layers were occupied by MH communities to the exclusion of other communities. These soil layers are impermeable either because they are firmly packed or because of accumulation of clay particles. Soils above the impermeable horizons typically are saturated in the spring, keeping humus wet and promoting rapid green-up of ground-layer plants, which helps to deter spring fires.

Plant communities in the MH System vary strongly along a gradient of soil moisture and nutrients from drier and poorer sites to wetter and richer ones. In this classification, the moisture and nutrient gradient is divided into three segments: dry-mesic, mesic, and wet-mesic. The mesic segment consists of communities dominated by northern hardwood species such as sugar maple, basswood, paper birch, and ironwood. These trees are also present but less dominant in wet-mesic and dry-mesic MH communities. Dry-mesic MH forests are intermediate in moisture between mesic MH forests and forests in the FD System. Dry-mesic MH communities are occasionally exposed to light surface fires when adjacent to fire-prone sites and tend to be dominated by northern red oak mixed with northern hardwood species and often have scattered red pine or white pine. Wet-mesic MH forests are intermediate between mesic MH forests and forests in the WF System. Wet-mesic MH communities usually consist of mixed stands of quaking aspen, balsam poplar, black ash, American elm, white spruce, and balsam fir.

Floristic Regions

MH communities in Minnesota are grouped into four “floristic” regions, based on general differences in species composition (Fig. MH-1). Two of these Floristic Regions are represented in the LMF Province: the Northern Floristic (MHn) Region and the Central Floristic (MHc) Region. Communities from the other two Floristic Regions, the Southern (MHs) and the Northwestern (MHw), are present only occasionally along the southern and western edges of the LMF Province.

In comparison with communities of the MHc Region, MHn communities are wetter, falling mainly in the mesic and wet-mesic segments of the moisture gradient in the MH System. About 66% of the vegetation plots in the MHn Region are in mesic communities, while 34% are in wet-mesic communities. There are no dry-mesic community classes in the MHn Region; all “northern” dry-mesic community classes are in the FD System rather than in the MH System. In the MHn Region in general, upland habitats protected from fire are present in settings with wet soils or with numerous lakes or peatlands. This may explain, in part, why many of the plants characteristic of MHn communities also oc-

OP Open Rich Peatland System

photo by B.A. Coffin MN DNR

Winter Road Lake Peatland, Lake of the Woods County, MN

General Description

Open Rich Peatland (OP) communities are graminoid- or low shrub–dominated wetlands on actively forming deep (>16in [40cm]) peat. The dominant graminoids most often are fine-leaved sedges *(Carex* spp.); shrubs, when present, typically include ericaceous species such as leatherleaf *(Chamaedaphne calyculata)* and bog rosemary *(Andromeda glaucophylla)*, along with bog birch *(Betula pumila)*. Mosses are common in OP communities, with *Sphagnum* species characteristic on hummocks and brown mosses characteristic in wet hollows. OP communities are widespread in the Laurentian Mixed Forest (LMF) Province, where cool climate, abundant precipitation, and the presence of poorly drained basins and glacial lake plains provide suitable conditions for peat development. They are particularly prominent in MOP and in the Tamarack Lowlands Subsection in MDL. OP communities also occur locally south of the LMF Province in settings where groundwater discharge is sufficient to offset higher rates of evapotranspiration caused by warmer temperatures.

Peat Characteristics and Hydrology

(For a discussion of general peatland formation in Minnesota, see Peatland Formation under the Forested Rich Peatland System on page LMF-FP1.) The peat in OP communities is moderately decomposed (hemic) and formed from graminoids and brown mosses. OP communities occur in peatland settings influenced by inputs of groundwater. Concentrations of minerals such as calcium are often abundant in groundwater that has percolated through till and can reach very high levels in areas with calcareous till deposits, which are typical in the western part of the LMF Province. Therefore, OP communities often have high concentrations of minerals (and high species diversity) in comparison with Acid Peatland (AP) communities. OP communities, however, are not rich in nutrients, especially nitrogen and phosphorus.

The water inputs to OP communities come primarily from regional or local groundwater. These supplies are steady and maintain fairly constant water levels near the peat surface, in contrast to Forested Rich Peatland (FP) and Wet Meadow/Carr (WM) communities. The continuous saturation of peat substrates in OP communities creates anaerobic conditions that prevent establishment of trees and tall shrubs. As a result, OP communities lack the shaded habitats and shade-tolerant plant species characteristic

photo by B.C. Delaney MN DNR

Carlton County, MN

General Description

River Shore (RV) communities occur along the shorelines of rivers and streams throughout Minnesota in the riparian zone between annual low water level and the upper limit of impacts from currents and ice-scouring. RV communities are inundated annually during spring flooding and following heavy rains. Most RV communities are sparsely vegetated because of absence of well-developed soils and frequent disturbance from flooding, ice-scouring, and strong currents. They are usually narrow, not more than a few meters wide. Substrates range from silt to loose sand, gravel, cobbles, and bedrock. Soil development is minimal. The RV System includes plant communities on slumping clay river embankments well above high water levels and dry streambeds of intermittent streams, as well as river shoreline zones. RV communities are common throughout the Laurentian Mixed Forest Province except in the large peatland landscapes of the Agassiz Lowlands Subsection in MOP and the Tamarack Lowlands Subsection in MDL.

Structure and Disturbance Regime

The vegetation of RV communities usually has a distinct upper zone and one or more lower zones. These zones are caused by differences in severity of erosion and in timing of exposure of sediments as river levels drop during the growing season. The upper zone often experiences severe erosion from ice-scouring and strong currents during spring breakup and flooding. Consequently, perennial plant species cover is sparse in upper zones, consisting of only a few species tolerant of inundation and physical fragmentation. Annual species, however, can become common on exposed sediments after floodwaters recede. The lower beach zones, which are exposed later in the growing season, support terrestrial forms of perennial aquatic species and other species that can survive long periods of inundation or produce seeds that remain viable buried for long periods in sediments.

The most common pattern of disturbance in RV communities is repeated erosion and deposition of materials by currents and ice-scouring. These disturbances result in removal of organic matter and nutrients from substrates along river shores, as well as removal or burial of vegetation.

Floristic Regions

The floristic composition of RV communities has not been systematically surveyed in much of Minnesota, so there are currently no recognized Floristic Regions within the RV System.

cur in WF and Forested Rich Peatland (FP) communities.

Communities in the MHc Region are mainly represented in the mesic and dry-mesic segments of the moisture gradient in the MH System. In this analysis, about 52% of the vegetation plots in the MHc Region are in mesic communities, and 43% are in dry-mesic communities; just 5% of the plots are in wet-mesic communities. In the MHc Region, upland habitats protected from fire tend to occur in very rugged terrain with well-developed drainages and river valleys. Proximity to rivers and streams may explain why many plants characteristic of MHc communities also occur in FF communities.

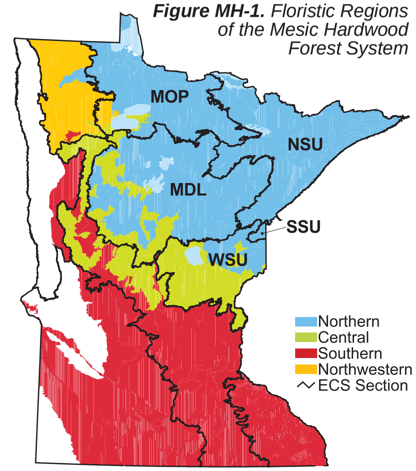


Figure MH-1. *Floristic Regions of the Mesic Hardwood Forest System*

Plant Indicators of MHn and MHc Communities

Plant species with high fidelity for MHn relative to MHc communities are listed in Table MH-1. MHn communities are much more likely than MHc communities to have plants characteristic of the WF and FP systems, for example common oak fern *(Gymnocarpium dryopteris),* yellow birch, naked miterwort *(Mitella nuda),* white spruce, swamp red currant *(Ribes triste),* and bunchberry *(Cornus canadensis).* Another noticeable difference between MHn and MHc communities is the greater diversity of conifers in MHn, including white cedar, balsam fir, and white spruce, in addition to white pine and red pine. MHc communities rarely have conifers in the tree canopy; if present, conifers are limited to occasional white pines, or rarely, red pines.

Many of the plant species that have high fidelity for MHc relative to MHn communities are common in Southern Mesic Hardwood (MHs) communities and, in fact, have higher affinity for MHs than MHc communities (Table MH-2). Among these species are black cherry, white oak, bitternut hickory, butternut, and sharp-lobed hepatica *(Anemone acutiloba)*. The low number of species in the MH System with high affinity for the MHc Region relative to the MHn or MHs Regions strongly suggests that the MHc Region is mainly a zone of transition between the MHn and MHs Regions. That is, MHc communities are composed of mixtures of plants from the MHn and MHs Regions, rather than plants that are unique to the MHc Region. The few species that have their highest frequency within the MH System in MHc communities are pointed-leaved tick trefoil *(Desmodium glutinosum),* large-flowered trillium *(Trillium grandiflorum),* blue beech, smooth juneberry *(Amelanchier laevis),* black-fruited rice grass *(Oryzopsis racemosa),* and poke milkweed *(Asclepias exaltata).* Several species with high affinity for MHc forests are also common in FF communities, including nodding fescue *(Festuca subverticillata),* greenbrier (*Smilax tamnoides),* and honewort *(Cryptotaenia canadensis).*

Disturbance Regimes of MHn vs. MHc Communities

MH communities historically had low to very low rates of catastrophic disturbance from fires and windstorms, with rotation periods in excess of 400 years and often greater than 1,000 years, and there were not strong differences between the MHn and MHc Regions in rotation periods (Table MH-3). Moderate disturbances from light surface fires and patchy windthrow were frequent to occasional, with rotation periods generally ranging from 40 to 300 years. Such moderate disturbances were more common among MHc than MHn communities, probably because of a warmer and drier climate in the southern and western parts of the LMF Province.

Table MH-1. Plants useful for differentiating the Northern from the Central Floristic Region of the Mesic Hardwood Forest System

Region	Group	Common Name	Scientific Name	MHn Frequency (%)	MHc Frequency (%)
Northern Floristic Region	Wet Forest or Forested Rich Peatland Affinity	Balsam fir (U)	*Abies balsamea*	2	6
		White spruce (U)	*Picea glauca*	25	2
		Bunchberry	*Cornus canadensis*	24	3
		Common oak fern	*Gymnocarpium dryopteris*	23	–
		Naked miterwort	*Mitella nuda*	22	2
		Yellow birch (C)	*Betula alleghaniensis*	19	1
		Swamp red currant	*Ribes triste*	19	2
		Palmate sweet coltsfoot	*Petasites frigidus*	17	–
		Alpine enchanter's nightshade	*Circaea alpina*	16	3
		Yellow birch (U)	*Betula alleghaniensis*	15	1
		White spruce (C)	*Picea glauca*	14	–
		Balsam fir (C)	*Abies balsamea*	13	–
		Drooping woodreed	*Cinna latifolia*	13	1
		Woodland horsetail	*Equisetum sylvaticum*	12	1
		Long beech fern	*Phegopteris connectilis*	11	–
		Meadow horsetail	*Equisetum pratense*	10	2
		Shining firmoss	*Huperzia lucidula*	10	1
		Mountain ashes (U)	*Sorbus* spp.	10	–
		Big-leaf white & northern white violet	*Viola blanda/macloskeyi* group	9	1
		Balsam poplar (U)	*Populus balsamifera*	8	–
		Red-osier dogwood	*Cornus sericea*	7	–
		White cedar (C)	*Thuja occidentalis*	7	–
		Speckled alder	*Alnus incana*	6	–
		White cedar (U)	*Thuja occidentalis*	6	–
		Kidney-leaved violet	*Viola renifolia*	6	–
	Other	Groundpine	*Lycopodium dendroideum/hickeyi* grp.	31	2
		Trailing blackberries	*Rubus flagellaris* & similar *Rubus* spp.	10	2
		Thimbleberry	*Rubus parviflorus*	9	–
		White baneberry	*Actaea pachypoda*	6	–
		Goldthread	*Coptis trifolia*	6	1

(C) = canopy tree (U) = understory tree

Table MH-2. Plants useful for differentiating the Central from the Northern Floristic Region of the Mesic Hardwood Forest System

Region	Group	Common Name	Scientific Name	MHn Frequency (%)	MHc Frequency (%)
Central Floristic Region	Southern Mesic Hardwood Forest Affinity	Black cherry (U)	*Prunus serotina*	5	45
		Bitternut hickory (U)	*Carya cordiformis*	–	26
		White oak (C)	*Quercus alba*	–	9
		Bitternut hickory (C)	*Carya cordiformis*	–	8
		White oak (U)	*Quercus alba*	–	7
		Sharp-lobed hepatica	*Anemone acutiloba*	–	6
		Butternut (C)	*Juglans cinerea*	–	5
	Central Mesic Hardwood Forest Affinity	Pointed-leaved tick trefoil	*Desmodium glutinosum*	3	55
		Large-flowered trillium	*Trillium grandiflorum*	8	51
		Blue beech (U)	*Carpinus caroliniana*	4	35
		Smooth juneberry	*Amelanchier laevis*	3	15
		Black-fruited rice grass	*Oryzopsis racemosa*	–	10
		Poke milkweed	*Asclepias exaltata*	–	9
	Floodplain Forest Affinity	Nodding fescue	*Festuca subverticillata*	7	32
		Virginia waterleaf	*Hydrophyllum virginianum*	1	11
		Honewort	*Cryptotaenia canadensis*	–	9
		Greenbrier	*Smilax tamnoides*	–	9
		Prickly ash	*Zanthoxylum americanum*	–	9
		Gregarious black snakeroot	*Sanicula gregaria*	–	6
		Side-flowering sandwort	*Arenaria lateriflora*	–	5
	Other	Wild geranium	*Geranium maculatum*	–	32
		Common enchanter's nightshade	*Circaea lutetiana*	3	27
		Lopseed	*Phryma leptostachya*	3	20
		Maidenhair fern	*Adiantum pedatum*	1	18
		Two-leaved miterwort	*Mitella diphylla*	3	18
		Tall blackberries	*Rubus allegheniensis* & similar spp.	2	16
		White ash (U)	*Fraxinus americana*	–	8
		Woodland sunflower	*Helianthus strumosus*	–	7
		White ash (C)	*Fraxinus americana*	–	5

(C) = canopy tree (U) = understory tree

stantly washed by waves and generally lacks plants; however, in small, shallow lakes subject to drawdown, a series of lower zones are often present on exposed sediments and populated by plants that disperse quickly to the site or germinate from seeds buried in sediments. Zonation is especially pronounced on sand shores along Lake Superior, which characteristically have lower, middle, and upper zones. The lower zone, as in smaller lakes, is constantly influenced by waves and generally lacks vascular plants. The middle zone is washed by waves mainly during storms and is sparsely vegetated; its upper boundary is marked by a line of driftwood and other flotsam. The upper zone experiences wave action only during the most severe storms; it is more often exposed to spray and blowing sand. Grass- and shrub-dominated dune areas are present beyond the upper zone on Lake Superior sand beaches.

LK communities tend to be dynamic; they grow, shrink, shift, or even disappear as water levels change seasonally and over years and decades. These dynamics complicate the delineation of the upper and lower boundaries of LK communities, particularly their interface with aquatic communities dominated by emergent, submergent, and floating-leaved aquatic plants. The position of shoreline communities along small, shallow ponds varies annually with seasonal fluctuations in water. Spring-fed lakes on outwash plains in Minnesota experienced low water levels in the 1930s, exposing broad sand beaches that were inundated again in the 1950s as water levels rose to more typical levels. Even large lakes, especially those that are part of river systems, may experience significant changes in water level, both seasonally and over periods of several years.

Disturbances caused by waves, wind, ice, and fluctuation in water level cause dynamic changes in vegetation composition. Species common one year may be uncommon or absent the next, and sites that are rich in species one year may be barren the next. Such unpredictable and harsh disturbance regimes favor annual plants and perennials that develop from detached and floatable parts, including rhizomes and tubers. Because of frequent erosion and alternating inundation and exposure of sediments, many characteristic lakeshore species are weedy. LK communities in Minnesota are especially susceptible to being overrun by the invasive species reed canary grass *(Phalaris arundinacea).*

Floristic Regions

The structure and floristic composition of LK communities vary according to geographic location as well as substrate. In this classification, LK communities are grouped into two "floristic" regions: the Inland Lake Floristic (LKi) Region and the Lake Superior Floristic (LKu) Region. The floristic composition of LKi communities has not been surveyed systematically in much of Minnesota. There are several vascular plant groups that appear to be well represented in LKi communities, including *Polygonum* species and members of the mint family (Lamiaceae). Additional surveys are needed to identify characteristic plant species and patterns of variation in species composition in LKi communities across Minnesota. LKu communities have vascular plant species that are rare or absent along inland lakeshores, including several rare arctic-alpine disjunct species. These species are butterwort *(Pinguicula vulgaris)*, birds-eye primrose *(Primula mistassinica),* Hudson Bay eyebright *(Euphrasia hudsoniana),* alpine bistort *(Polygonum viviparum),* and pale sedge *(Carex pallescens)*. The sand beach and dune communities on Minnesota Point along Lake Superior support several species that are rare or absent from LKi communities as well as the rocky or gravelly shores that characterize the rest of the Lake Superior shoreline in Minnesota. These species include beachgrass *(Ammophila breviligulata),* beach pea *(Lathyrus japonicus),* spike trisetum grass *(Trisetum spicatum),* and coast jointweed *(Polygonella articulata).* The shrub, ninebark *(Physocarpus opulifolius)*, is common on rocky shores along Lake Superior but is rare along inland lakes.

LK Lakeshore System

photo by Paul Sundberg

Palisade Head, Lake Superior, Tettegouche State Park, MN

General Description

Lakeshore (LK) communities occur along the shorelines of lakes and ponds throughout Minnesota in the zone between annual low water level and the upper limit of storm waves and spring ice-scouring. Most LK communities are sparsely vegetated because of absence of well-developed soils and frequent disturbance by waves, ice, and wind. They are usually narrow, not more than a few meters wide, although width varies considerably depending on the nature of the water body and its basin. Small ponds in shallow basins where the water level declines greatly during the summer months have broad lakeshore zones. Along Lake Superior, powerful storm waves and ice-scouring produce relatively broad beaches and associated dune areas. Small lakes with relatively stable water levels have narrow shoreline communities, as do bays and other sheltered areas in large lakes. LK communities are common across much of the Laurentian Mixed Forest Province, the exception being landscapes with few lakes, such as the large poorly drained peatlands in MOP and the Tamarack Lowlands Subsection in MDL.

Substrates in LK communities range from organic mucks and silt to loose sand, gravel, and bare rock. In general, soil development is limited to accumulation of organic material in cracks and crevices in bedrock and spaces between cobbles and boulders. Storm waves and lake currents, especially along Lake Superior, reshape the distribution of substrate particles such as silt, sand, gravel, and even cobbles. Scouring by large pieces of ice pushed ashore during spring breakup can remove existing vegetation and push sand, gravel, and cobbles into beach ridges. During winter along Lake Superior, ice from spray and fog often coats vegetation, making woody twigs and branches brittle and subject to breaking in strong winds.

Patterns of Vegetation and Dynamics

The strong influences of waves, ice, and wind produce characteristic zonal patterns in LK communities. Many LK communities have well-defined upper and lower zones. The upper zone is affected by waves or ice-scouring only during storms. On broad sand or gravel beaches, plants in the upper zone tend to grow in a series of linear aggregations, each containing a different assortment of species and each resulting from a different storm earlier in the growing season. On bedrock shores, plants are largely restricted to crevices in the rock or depressions with shallow soil deposits. The lower zone is con-

MH -continued- Mesic Hardwood Forest System

Table MH-3. *Historic tree species composition & disturbance regimes in Mesic Hardwood Forest Classes.*

	Historic Tree Species Frequency by Class and Stand Age						Historic Disturbance Rotation Periods by Class (in years)		
	young forest age	young forest species	mature forest age	mature forest species	old forest age	old forest species	Stand-Regenerating Fire	Moderate Surface Fire + Patchy Windthrow	Catastrophic Windthrow
Northern Floristic Region						ranges →	430-1000+	130-1000+	800-1000+
MHn35	0 - 55 yrs	paper birch quaking aspen *(sugar maple)* *(northern red oak)*	95 - 205 yrs	paper birch *(sugar maple)* *(white spruce)*	> 295 yrs	white pine sugar maple *(paper birch)*	970	130	>1000
MHn44	0 -35 yrs	**quaking aspen**	95 - 195 yrs	white spruce *(quaking aspen)* *(paper birch)* *(balsam fir)*	> 195 yrs	white spruce quaking aspen *(paper birch)* *(balsam fir)*	430	160	960
MHn45	0 - 75 yrs	sugar maple *(yellow birch)* *(paper birch)*	95 - 155 yrs	white spruce white cedar *(sugar maple)* *(yellow birch)*	> 195 yrs	white spruce *(yellow birch)* *(sugar maple)*	none	>1000	none
MHn46	0 - 35 yrs	**quaking aspen**	> 95 yrs	quaking aspen *(white spruce)* *(American elm)*	---		600	160	800
MHn47	0 - 55 yrs	sugar maple *(paper birch)*	75 - 195 yrs	sugar maple *(paper birch)*	> 195 yrs	sugar maple white pine	>1000	300	>1000
Central Floristic Region						ranges →	370-1000+	40 -160	380-1000+
MHc26	0-35 yrs	**quaking aspen*** *(paper birch)*	55 - 135 yrs	paper birch *(quaking aspen*)* *(red oak)*	> 135 yrs	quaking aspen* *(paper birch)* *(white spruce)* *(red oak)* *(white pine)*	370	160	910
MHc36	0-35 yrs	**red oak** *(basswood)* *(quaking aspen*)*	> 95 yrs	sugar maple *(basswood)* *(American elm)*	---		1000	40	380
MHc37	0-35 yrs	quaking aspen *(paper birch)* *(American elm)* *(basswood)*	55 - 135 yrs	sugar maple *(basswood)* *(American elm)* *(red oak)* *(paper birch)*	> 135 yrs	*(quaking aspen)* *(American elm)* *(sugar maple)* *(white spruce)*	515	70	>1000
MHc47	0-55 yrs	*(basswood)* *(bur oak)* *(quaking aspen)* *(paper birch)* *(sugar maple)*	55 - 155 yrs	*(basswood)* *(bur oak)* *(sugar maple)* *(paper birch)*	> 155 yrs	basswood *(bur oak)* *(white pine)* *(sugar maple)*	>1000	140	>1000

bold = >50% normal = 25-50% *(italics)* = 10-25% *includes big-toothed aspen

FF Floodplain Forest System

photo by N.E. Aaseng MN DNR

Kettle River, Pine County, MN

General Description

Floodplain Forest (FF) communities are present on occasionally or annually flooded sites on terraces and floodplains of streams and rivers. FF communities are dominated by deciduous trees tolerant of saturated soils, prolonged inundation, and frequent erosion or deposition of sediment. Common species include characteristic floodplain trees such as silver maple, American elm, cottonwood, and black willow, and wet and mesic forest trees such as black ash, green ash, basswood, and white spruce. The understory often is open, with few shrubs or saplings. Ground-layer cover is highly variable, ranging from areas of bare silt or sand to dense patches of wood nettle *(Laportea canadensis)* or ostrich fern *(Matteuccia struthiopteris).* Pools or mucky depressions in old channels are characteristic of more actively flooded sites. FF communities are associated with streams and rivers throughout the Laurentian Mixed Forest (LMF) Province but are generally not as extensive as those associated with rivers in the Eastern Broadleaf Forest or Prairie Parkland Provinces, which have larger rivers with broader floodplains.

Flooding along streams and rivers is fed by surface flow as well as base flow that enters stream and river beds as groundwater. Most of the surface flow reaches streams or rivers over frozen or saturated ground in the spring, initiating flooding in the lower reaches of the watershed. After spring flooding, base flow maintains river levels and stable, high water tables on terraces and floodplains. Flooding imposes several physical challenges on plants in FF communities, including inundation, erosion, sedimentation, and severe scarring of tree trunks by flood-transported ice and debris. Flooding also results in chemical or physiological stresses, especially lack of the oxygen necessary for plant metabolism and decomposition of litter. Although the annual pattern of flooding is predictable, the timing, duration, and energy vary from year to year. Flooding causes a rather constant shifting of sediment and features such as point-bars, meander scrolls, levees, and backwaters that control where understory plants occur in the community.

Plant Adaptations

Among forested Systems, the FF System is unique in its development around an annual disturbance regime. Each episode of flooding causes the death of many understory plants and leaves behind exposed mineral substrates with abundant moisture and nutrients for plant regeneration. The characteristic plants of FF communities have a variety

Landscape Setting and Disturbance Regime

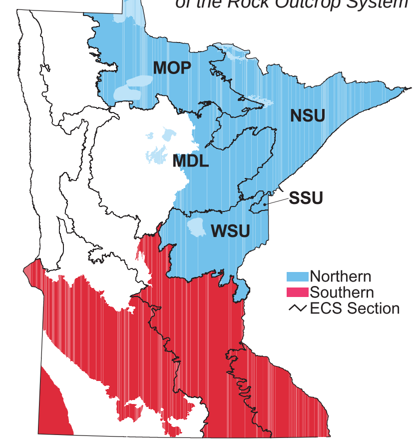


Figure RO-1. *Floristic Regions of the Rock Outcrop System*

In the landscape as a whole, RO communities are small features, rarely covering more than 25 acres (10ha) and most often less than 5 acres (2ha). They are commonly surrounded by communities of the Fire-Dependent Forest/Woodland (FD) System and occasionally by Mesic Hardwood Forest (MH) communities. Because of their small size, RO communities are strongly affected by disturbances in adjacent forests or woodlands. Removal of forest canopies by fire or windstorm results in warmer and drier conditions on adjacent bedrock outcrops. Evidence of fire such as charcoal or scarred stumps is present on many rock outcrops. Fire, with frequent drought and scarce soils, plays a role in maintaining the open vegetation characteristic of RO communities. Light or moderate fires reduce woody plant cover and consume litter and humus. Severe fires can remove virtually all vascular plant cover for long periods through incineration of both plants and accumulated soil deposits. Major fires often expand RO communities into adjacent forests and can create new outcrop openings in woodlands with shallow soils over bedrock. RO communities are relatively stable over time because of limited habitat for plant establishment and prevalence of species that persist from year to year once established on a site. In the absence of fire or other major disturbances such as extreme drought, they can eventually succeed to woodland or forest communities.

Floristic Regions

Communities in the RO System are divided into two regions based on geographic variation in climate, bedrock type, and plant species composition (Fig. RO-1). One of these regions, the Northern Floristic (ROn) Region, is entirely within the LMF Province. The other, the Southern Floristic (ROs) Region, is present to the south in the Eastern Broadleaf Forest and Prairie Parkland Provinces. Plants with high fidelity for RO communities in the ROn Region include pale corydalis *(Corydalis sempervirens),* bristly sarsaparilla *(Aralia hispida),* fringed false buckwheat *(Polygonum cilinode),* Douglas' knotweed *(P. douglasii),* umbel sedge *(Carex umbellata),* Back's sedge *(C. backii),* and rock spikemoss *(Selaginella rupestris).* Within the ROn Region, outcrop communities are divided into plant community Classes based on amount of woody plant cover.

RO Rock Outcrop System

photo by N.E. Aaseng MN DNR

Voyageurs National Park, St. Louis County, MN

General Description

Rock Outcrop (RO) communities are open or shrub-dominated plant communities on horizontal or sloping bedrock exposures. They are common in landscapes with thin soils over bedrock. Crustose and foliose lichens typically cover exposed rock surfaces, with fruticose lichens also common. Vascular plant cover is sparse to patchy, depending on the amount of fracturing of the bedrock surface and accumulation of soil in cracks, crevices, and shallow depressions. Outcrops with minimal fracturing and little accumulation of soil are dominated by lichens, with scattered shrubs and herbaceous plants. Shrub-dominated communities are typical on bedrock with greater accumulations of soil. In the Laurentian Mixed Forest (LMF) Province, RO communities are most common in the North Shore Highlands and Border Lakes Subsections in NSU where Precambrian bedrock is frequently at or just below the surface. RO communities are somewhat less common in the Laurentian Uplands and Nashwauk Uplands Subsections in NSU and the Littlefork-Vermilion Uplands Subsection in MOP, and are widely scattered, although common locally, in WSU and in the Agassiz Lowlands Subsection in MOP. RO communities are often present as openings within larger areas of woodland or forest vegetation, and whether a site is classified as an RO community rather than a woodland or forest is often a matter of scale.

Plant Adaptations

Species in RO communities are adapted to greater environmental extremes than species in surrounding terrestrial communities. Many plants on bedrock outcrops are adapted to frequent desiccation because of low moisture-holding capacities of substrates and exposure to direct sunlight and strong winds. Plants must also withstand rapid fluctuations in substrate temperatures, which are significantly colder at night than in surrounding forests and much warmer during mid-afternoon on sunny days. Limited availability of nutrients in outcrop habitats strongly influences community composition and diminishes growth rates of plants. Wind can have a visible impact on the growth forms of trees and shrubs, causing stunting, stem die-back, and misshapen trunks. Characteristic wind-sculpted “krummholz” forms are common, especially in exposed settings along lakeshores and on summits and ridge tops, where wind speeds are often high. Species in RO communities commonly reproduce by vegetative structures such as rhizomes, runners, or stolons, and tend to persist from year to year once established at a site; species that disperse and reproduce by seed alone are much less common.

of adaptations and strategies for withstanding inundation and sedimentation. All are good colonizers and most are extremely mobile during some part of their life cycle, often using flowing water to disperse to new sites. Many are capable of extreme dominance, creating nearly pure colonies to the exclusion of other plants.

The dominant trees on regularly and severely flooded sites—silver maple, American elm, cottonwood, and black willow—are all capable of rapid growth and root sprouting. All are extremely resistant to physical battering caused mostly by spring ice floes. Older trees are often multiple-stemmed, having re-sprouted from damaged main trunks. It is also common to see ice-scarred trunks with little more than a few inches of intact cambium supporting a full, live crown. Trees limited to upland habitats generally have seeds with mechanisms that delay germination until the next advantageous growing period, usually the following spring. In floodplain settings, the dominant species shed seeds that germinate immediately, usually early in the growing season after floodwaters have receded, leaving exposed mineral soil. These seeds survive well in pools but can die within hours if desiccated. Carpets of germinating tree seedlings (up to a million per acre) are a common feature of floodplains by late summer and fall, but in spite of this, it is exceedingly rare to see established seedlings and saplings beneath the canopy. The cover of established seedlings and saplings in FF communities is one-quarter to one-half that of any other forested System in Minnesota. Successful recruitment of seedlings and saplings occurs most often when the seedlings are embedded within thickets of sandbar willow *(Salix exigua)* or cottonwood.

Other strategies for dealing with inundation and sedimentation include survival during flooding as seeds or vegetative propagules. Nearly 10% of the plants recorded in FF plots are annuals or biennials, the highest proportion recorded for any System with persistent vegetation in this classification. Beggarticks *(Bidens* spp.), cleavers *(Galium aparine),* clearweeds *(Pilea* spp.), kidney-leaved buttercup *(Ranunculus abortivus),* stickseeds *(Hackelia* spp.), and dotted smartweed *(Polygonum punctatum)* are the most frequent annual or biennial plants in FF communities. Some understory plants, including bulb-bearing water hemlock (*Cicuta bulbifera),* knotty rush *(Juncus nodosus),* and river bulrush *(Scirpus fluviatilis)*, are capable of vegetative reproduction via bulblets, tubers, or corms that detach from the parent plant, float downstream, and root where they become stranded. Other species, such as creeping lovegrass (*Eragrostis hypnoides),* grow prostrate on mud flats, rooting at every node and producing small plants that, if detached, are capable of colonizing new sites. Others, such as dark green bulrush *(Scirpus atrovirens),* are capable of producing roots and leafy “tufts” when their stems bend and touch the water. Still others, including water parsnip *(Sium suave)* and water smartweed *(Polygonum amphibium),* produce highly dissected aquatic leaves when submerged and “normal” leaves upon emergence. Many species develop adventitious roots, an adaptation to either standing water or siltation. Individuals with this adaptation, when present on sites where sediment has accumulated over several years, often have successive whorls of adventitious roots that correspond to previous soil-surface levels.

The most important physiological stress on plants in FF communities is lack of oxygen for plant respiration. During the flood stage, anoxia affects above-ground portions of woody plants as well as their roots. Woody vegetation is least susceptible to death from anoxia when plants are dormant, because of low respiration rates in inactive tissues. This may be one reason why leaves are slow to emerge in the spring and why the perennial understory vegetation in FF communities develops much later than in surrounding terrestrial forests. Equally important, floodplains and river terraces have persistently high water tables, a property shared with Wet Forest and Wet Meadow/Carr communities. Deep soil layers are continuously saturated, anaerobic, and chemically reducing. Rooting in these layers is limited to plants that can supply oxygen to their roots, mostly by means of specialized gas-conducting cells (aerenchyma).

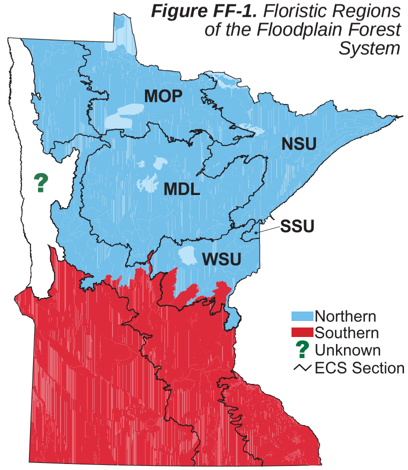
Nutrient Cycling

The processing of organic matter and release of essential nutrients is quite different in FF communities than in upland forests and in peatlands. In comparison with other forest systems, FF communities produce much more organic matter, which is augmented by organic litter washed from uplands into streams and rivers. The residence time of organic matter on floodplains is exceedingly short in comparison with that of peat in wetland forests or leaf litter in upland forests. The bulk of the organic matter deposited on floodplains is processed in a single season. A substantial amount or processing happens in backwaters and pools where aquatic invertebrates reduce leaves to particles that can remain in suspension or to compounds soluble in water. Another fraction is incorporated into the mineral soil, mostly by earthworms. The soils of floodplains have about twice the incorporated organic matter (2-6%) of upland forest soils. Any unprocessed organic material on the soil surface tends to be washed away by subsequent floods. Therefore, FF communities, unlike upland forests, have no bank or reserves of organic matter.

Floristic Regions and Variation Within the FF System

Based on geographic variation in species composition, FF communities in Minnesota are divided into two “floristic” regions: the Northern Floristic (FFn) Region and the Southern Floristic (FFs) Region (Fig. FF-1). The FFn Region covers most of the northern half of Minnesota, including the LMF Province. The FFs Region covers the southern half of Minnesota. FFs communities are present only occasionally in the LMF Province.

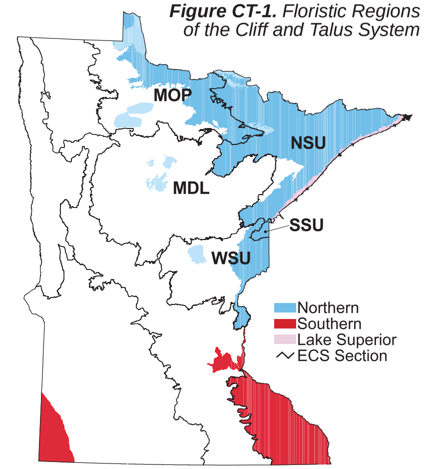
Figure FF-1. *Floristic Regions of the Floodplain Forest System*



FFn communities are divided into two classes based on variation in flooding regime and the effect of this variation on community composition. Communities on sites affected by annual episodes of severe flooding are classified as Northern Floodplain Forests (FFn67). Such sites typically include low areas on true river floodplains that are flooded annually in the spring, experience devastating summer flooding, are not ex-posed until late in the growing season, are sandy, lack surface organic material, and have rooting zones closer to the permanent water table. Communities on sites subjected only to occasional flooding are classified as Northern Terrace Forests (FFn57). These sites typically include river terraces above normal flood stage or riparian areas along smaller streams or rivers that lack true floodplains. Northern Terrace Forests also develop on higher sites on fluted river floodplains characterized by elongated low channels and elevated mounds. In contrast to sites that support Northern Floodplain Forests, sites where Northern Terrace Forests develop are flooded only occasionally in the spring, are exposed early in the growing season, are silty, can have thick deposits of surface organic matter, and are well above the permanent water table.

the CTu Region support an additional set of species that occur in Minnesota mainly along the Lake Superior shore and are therefore rare in the CTn Region. These plants include spike trisetum *(Trisetum spicatum),* Arabian whitlow grass *(Draba arabisans),* Hudson Bay eyebright *(Euphrasia hudsoniana),* ninebark *(Physocarpus opulifolius),* shrubby cinquefoil *(Potentilla fruticosa)* and encrusted saxifrage *(Saxifraga aizoon).*

Figure CT-1. *Floristic Regions of the Cliff and Talus System*



es where soil has accumulated and roots are able to take hold, and cliffs composed of highly fractured bedrock tend to have highest plant cover. On wet cliffs, vascular plants may also root in thick mats of mosses and lichens that cover broad areas of bedrock. Most cliffs have less than 25% cover of trees or shrubs, although woody plant cover is variable, with some cliffs having nearly continuous tree canopy cover. On talus slopes, vascular plant cover is influenced by stability of talus and amount of soil accumulated between talus blocks. Because of shifting substrates, woody cover is usually less than 50% and many talus slopes have no trees or shrubs.

CT communities in the LMF Province provide habitat for several rare vascular plant species in Minnesota, including characteristically arctic or alpine species with disjunct populations in Minnesota, such as large-leaved sandwort *(Arenaria macrophylla)* and Norwegian whitlow grass *(Draba norvegica)* as well as several boreal species. These cold-climate species are most prevalent on sheltered cliffs along the Lake Superior shore and on large north-facing cliffs in other parts of northeastern Minnesota. Other rare plants have been documented on dry cliff and talus communities on warm, south- and west-facing exposures. These sites often have plants common in southern Minnesota, but generally rare in the LMF Province. Many CT communities, especially the drier ones, have plant species common also in Rock Outcrop (RO) communities.

Plant Adaptations and Growth Forms

Plants in CT communities are tolerant of greater environmental extremes than species in surrounding terrestrial communities. Many plants on cliffs and talus slopes are well adapted to desiccation because of low moisture-holding capacities of substrates and exposure to direct sunlight and strong winds. They must also withstand rapid fluctuations in substrate temperatures, which are significantly colder at night than in surrounding forests and, in some settings, much warmer during mid-afternoon on sunny days. Limited availability of nutrients on many cliffs and talus slopes strongly influences community composition and slows growth rates of plants. Wind and gravitational stresses have a visible impact on the growth forms of trees and shrubs, causing stunting, stem die-back, and misshapen trunks. Characteristic wind-sculpted "krummholz" forms are common, especially on upper cliff faces and adjacent cliff tops where wind speeds are often high.

Species in CT communities commonly reproduce by vegetative structures such as rhizomes, runners, or stolons, and tend to persist from year to year once established at a site; species that disperse and propagate primarily by seed are less common. The combination of limited habitat for plant establishment and growth, low rates of natural disturbances, and prevalence of species that persist once established contribute to high levels of community stability over time. Fracturing of large pieces of rock from cliff faces are major, although rare, events that disrupt community equilibrium. Cliffs along streams and lakes—especially Lake Superior—may have high rates of erosion from currents and waves.

Floristic Regions

Communities in the CT System are divided into three regions based on geographic variation in climate, bedrock type, and plant species composition (Fig. CT-1). Two of the regions, the Northern Floristic (CTn) Region and the Lake Superior Floristic (CTu) Region, are entirely within the LMF Province. The third, the Southern Floristic (CTs) Region, is present to the south in the Eastern Broadleaf Forest and Prairie Parkland Provinces. Plants with high fidelity for the CTn and CTu Regions relative to the CTs Region include fragrant fern *(Dryopteris fragrans),* fragile fern *(Cystopteris fragilis),* black-fruited sedge *(Carex eburnea),* slender cliff brake *(Cryptogramma stelleri),* Appalachian firmoss *(Huperzia appalachiana),* nahanni oak fern *(Gymnocarpium jessoense),* Rocky Mountain woodsia *(Woodsia scopulina),* alpine woodsia *(W. alpina),* smooth woodsia *(W. glabella)*, and common polypody *(Polypodium virginianum).* Cliff communities in


photo by K.A. Rusterholz MN DNR

Big Island, Pelican Lake, St. Louis County, MN

General Description

Wet Forest (WF) communities occur commonly in narrow zones along the margins of lakes, rivers, and peatlands; they also occur in shallow depressions or other settings where the groundwater table is almost always within reach of plant roots but does not remain above the mineral soil surface for long periods during the growing season. Because of a cool climate characterized by regular precipitation and slow rates of evaporation, WF communities are common across the Laurentian Mixed Forest (LMF) Province. They are dominated most often by black ash or white cedar, with understories characterized by patches of shrubs such as speckled alder *(Alnus incana)* or mountain maple *(Acer spicatum)*, mosses and upland forest herbs on raised hummocks, and sedges and wetland forbs in wet or mucky hollows.

WF communities are strongly shaped by steady fluxes of water and nutrients supplied to deep soil layers by moving groundwater. In basins or depressions connected to annually recharged shallow aquifers, the supply of groundwater peaks early in the growing season but persists at some level through much of the summer. In settings connected to deeper aquifers that discharge groundwater throughout the year, the supply of water and nutrients is steady through the growing season. The groundwater moves laterally below the surface but often upwells to create springs, seeps, or spring runs within and adjacent to WF communities. Varied microtopography and variation in groundwater supply on sites fed by shallow aquifers result in the alternating presence of water-logged and dry conditions in upper soil layers. This variability in soil moisture in both space and time is a hallmark of the WF System and controls the availability of the oxygen needed for roots to respire, for decomposition of organic litter, and for release of nutrients in forms usable by plants.

Plant Adaptations

As in other wetland systems, deep soil layers in WF communities are continuously saturated, anaerobic, and chemically reducing. Although a potential source of water for plants, deep soil layers have few roots other than those of plants that can supply oxygen to roots through specialized gas-conducting cells (aerenchyma). As a consequence, rooting is shallow in WF communities. Roots are concentrated above or near the top of the water table, and canopy trees are susceptible to windthrow. In response to water-table fluctuations, trees, shrubs, and other perennial plants must tolerate root loss from anoxia because of prolonged water-table elevation and must be able to develop and extend roots more deeply again as water levels fall. Some characteristic WF plants have adapted to this problem by producing both normal roots and adventitious roots with gas-conducting cells.

Soils & Nutrients
Soil surfaces in WF communities are saturated in the spring, but dry out later in the growing season. This pattern of alternately wet and dry soil surfaces has two important consequences. First, it creates a thin surface layer of highly decomposed organic matter, or muck. Muck is physically and chemically distinct from the humus of upland communities (such as Mesic Hardwood Forest [MH] communities) in its ability to absorb water, adsorb metals toxic to plants, and release nutrients. Second, the soils are not saturated continuously enough to build up thick layers of peat as in Acid Peatland (AP), Forested Rich Peatland (FP), and Open Rich Peatland (OP) communities. In instances where WF communities occur on thick layers of organic matter, they have usually replaced a peatland community and the production of organic matter is roughly in equilibrium with decomposition.

The rate and pattern of release of nutrients from mucky soils in WF communities, especially nitrogen, strongly influence plant species composition and growth. Nitrogen is mineralized in mucky soils at annual rates that are only about one-half to one-tenth of rates in upland forest soils. In addition, although WF and MH communities commonly occur within feet of each other, availability of nitrogen is seasonally reversed in the two systems. In upland forests, nitrogen is mineralized to produce ammonium (NH_4^+) immediately in the spring, and most of the ammonium is quickly converted by nitrification to nitrates (NO_3^-). Therefore, about half of the annual supply of nitrogen is available in late May and early June in MH forests. Because of waterlogged and cold soils, very little nitrogen is mineralized in WF forests in spring. After soils have warmed in early summer, available nitrogen is produced at a steady but slow rate during the growing season, almost completely in the form of ammonium. Nitrification is an aerobic process, so significant production of nitrate does not begin in WF communities until the surface dries, usually in mid-August or September. Therefore, in contrast to MH communities, nitrogen available for plant uptake does not reach peak levels in WF communities until late summer. Furthermore, WF communities tend to lose more nitrogen than MH communities, with as much as 10% of annually mineralized nitrogen converted to nitrogen gas that is released to the atmosphere.

Floristic Regions
There are three floristically distinct groups of WF communities. These groups have strong geographic affinities and are recognized as separate Floristic Regions within the WF System (Fig. WF-1). The Northern Floristic (WFn) Region covers almost the entire LMF Province. The Southern Floristic (WFs) Region lies mostly within the Eastern Broadleaf Forest Province, but extends into the southeastern quarter of the LMF Province. The Northwestern Floristic (WFw) Region is mostly within the Tallgrass Aspen Parklands Province, with scattered examples in the extreme western part of the LMF Province.

The differences in species composition among the WFn, WFs, and WFw Regions appear to be strongly influenced by regional floristic variation in surrounding landscapes. This may be because WF communities are often present in narrow, linear zones of transition between uplands and adjacent lakes, rivers, and peatlands, so are regularly exposed to colonization by plants from adjacent, more extensive communities. Regional floristic variation in the WF System also appears to be related to regional differences in groundwater hydrology, especially differences in local relief and groundwater head,

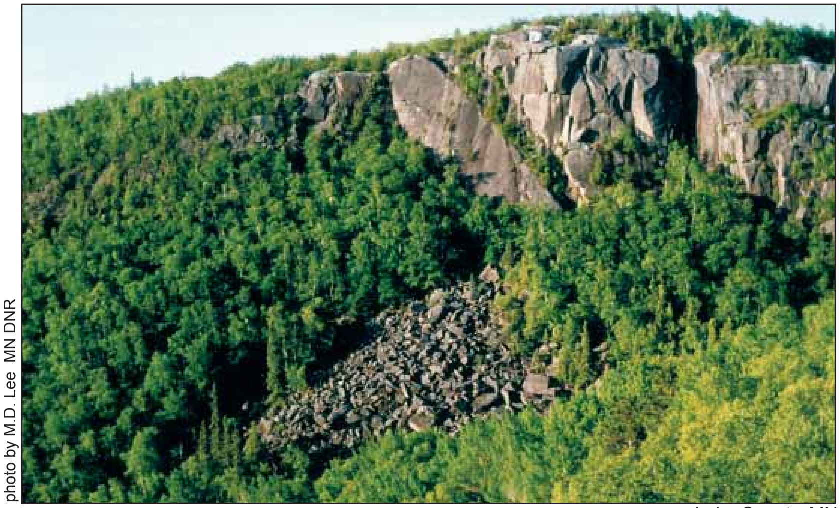


photo by M.D. Lee MN DNR

Lake County, MN

General Description
Communities in the Cliff/Talus (CT) System are present on cliffs or talus slopes on steep-sided knobs, in river gorges, along lakeshores, and in other settings with sheer bedrock exposures. Often, cliffs and talus slopes are associated with one another because talus slopes are composed of rock fractured either from cliffs or from exposed bedrock on steep hillsides. The vegetation of CT communities is generally open. Lichens and mosses are the dominant life forms, with vascular plants sparse or patchy because of scarcity of soil. In this classification, cliff communities are grouped by moisture and light regimes and by bedrock type, which are the major determinants of species composition. Cliff habitats range from warm and dry to cool and wet depending on cliff aspect, proximity to streams or lake shores, and presence of groundwater seepage on the cliff face. In the Laurentian Mixed Forest (LMF) Province, cliffs are formed most commonly of igneous bedrock, although cliffs on metamorphic rock are also common. Talus communities are classified according to amount of woody plant cover and moisture regime.

In the LMF Province, CT communities are restricted mostly to the North Shore Highlands and Border Lakes subsections in NSU, where Precambrian bedrock is frequently at or just below the surface and topography is often rugged. Scattered cliffs are present in WSU and are likely in the Laurentian Uplands Subsection in NSU and the Littlefork-Vermilion Uplands Subsection in Northern Minnesota & Ontario Peatlands MOP, primarily along lakes and streams where water has exposed the underlying bedrock.

In the landscape as a whole, CT communities are small features, rarely covering more than 10 acres (4ha). In the LMF Province, they are commonly surrounded by expansive upland forests, especially Fire-Dependent Forest/Woodland (FD) and Mesic Hardwood Forest (MH) communities. The disturbance regimes that shape these forest communities often affect CT communities. Major fires that originate in forests or woodlands may scorch cliff vegetation. Removal of forest canopies by fire often leaves cliffs or talus slopes more exposed to sunlight, causing warmer and drier conditions. Major windstorms or logging in forests adjacent to CT communities can have similar warming and drying effects.

Vegetation Structure and Composition
Typically, lichens or mosses cover rock surfaces in CT communities and colonize areas exposed by erosion. On cliffs, vascular plants are generally limited to crevices and ledg-

Vascular plant species that occur in bog Native Plant Community Classes.

Because only those species listed below can persist in the ombrotrophic conditions of bogs, the occurrence of any other species can be considered an indicator of minerotrophic conditions. However, some seedlings, particularly tree species, can germinate in bogs but are short-lived and should not be considered as minerotrophic indicators.

	Common Name	Scientific Name	Northern Spruce Bog APn80	Northern Open Bog APn90
			Frequency(%)	
Tree	Tamarack	*Larix laricina*	51	62
	Black spruce	*Picea mariana*	100	82
	Jack pine	*Pinus banksiana*	4	6
Low Shrub	Bog rosemary	*Andromeda glaucophylla*	49	74
	Leatherleaf	*Chamaedaphne calyculata*	87	94
	Creeping snowberry	*Gaultheria hispidula*	44	–
	Bog laurel	*Kalmia polifolia*	91	94
	Labrador tea	*Ledum groenlandicum*	99	74
	Lowbush blueberry	*Vaccinium angustifolium*	45	12
	Velvet-leaved blueberry	*Vaccinium myrtilloides*	29	9
	Small cranberry	*Vaccinium oxycoccus*	95	94
	Lingonberry	*Vaccinium vitis-idaea*	31	–
	Dwarf misletoe	*Arceuthobium pusillum*	1	–
Forb	Stemless lady's slipper	*Cypripedium acaule*	19	–
	Round-leaved sundew	*Drosera rotundifolia*	38	35
	Heart-leaved twayblade	*Listera cordata*	3	–
	Indian pipe	*Monotropa uniflora*	28	–
	Pitcher plant	*Sarracenia purpurea*	29	59
	Three-leaved false Solomon's seal	*Smilacina trifolia*	86	18
Graminoid	Bog wiregrass sedge	*Carex oligosperma*	17	76
	Few-flowered sedge	*Carex pauciflora*	33	41
	Poor sedge	*Carex paupercula*	22	–
	Three-seeded bog sedge	*Carex trisperma*	79	9
	Tussock cottongrass	*Eriophorum spissum*	72	88
	Tawny cottongrass	*Eriophorum virginicum*	14	3

depth and conductivity of regional aquifers, and groundwater temperature and chemistry. The influence of groundwater hydrology on variation in species composition among WF communities is especially evident in responses of plants to patterns of water flow, mineral content, and temperature.

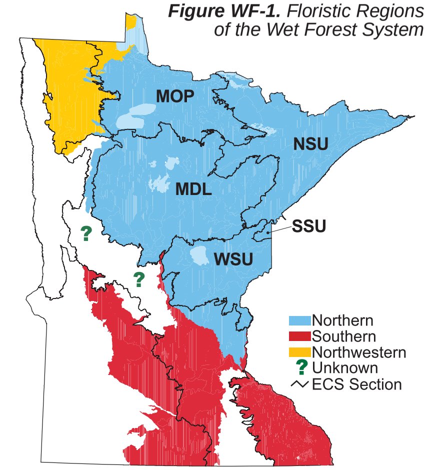


Figure WF-1. *Floristic Regions of the Wet Forest System*

Groundwater Hydrology and Plant Indicators of WFn Communities

Communities of the WFn Region exhibit greater variation in vegetation and in landscape setting than WFs or WFw communities. WFn communities occur most often in settings that are transitional between upland forests (MH and FD communities) and northern peatlands (AP, FP, OP, and WM communities) and have many plants that are characteristic of these adjacent, more extensive communities. WFn communities are hydrologically very distinct from WFw and WFs communities. The WFn Region lies in an area that receives more precipitation (especially as snow) and has more runoff than either the WFs or WFw Regions. WFn communities are highly influenced by the groundwater component of this runoff, which moves annually through shallow, local aquifers into streams, lakes, and peatlands. In comparison with groundwater in the WFw and WFs Regions, this groundwater is substantially more dilute, nearly neutral in pH, warmer, and more seasonal in its abundance. WFs and WFw communities occur in regions that are dry compared to the LMF Province, and for that reason are dependent on deep aquifers that deliver steady supplies of groundwater through the growing season, independently of the annual hydrologic cycle.

Selected plants with high fidelity for the WFn Region in comparison with the WFs and WFw Regions are presented in Table WF-1. The only plant species with high affinity for WFn communities that also have higher affinity for the WF System than any other System are balsam fir, common oak fern *(Gymnocarpium dryopteris)*, bladder sedge *(Carex intumescens)*, long beech fern *(Phegopteris connectilis)*, and shining firmoss *(Huperzia lucidula)*. These species all have affinity for WF communities that are transitional to MH forests. Many of the plants with high fidelity for the WFn Region are equally at home in mossy habitats in communities in the FD, FP, and AP Systems. Among these species are evergreens such as balsam fir, white cedar, goldthread (Coptis trifolia), and twinflower (Linnaea borealis) and deciduous species such as bristle-stalked sedge (Carex *leptalea)* and northern marsh fern *(Thelypteris palustris)*. There are no evergreen plants that have highest fidelity in the WF System for WFs communities, and only one evergreen plant (pink shinleaf *[Pyrola asarifolia])* that has highest fidelity within the System for WFw communities. Mosses themselves are rather diagnostic of WFn communities. The most important high-affinity moss species in WFn communities are *Plagiomnium ellipticum, Calliergon cordifolium, Hypnum lindbergii, Climacium dendroides, Thuidium delicatulum*, and *Thuidium recognitum.*

Groundwater Hydrology and Plant Indicators of WFs Communities

Communities in the WFs Region are represented in the LMF Province by the Southern Wet Ash Swamp (WFs57) Class. These communities occur mostly at the contact between steep, high, bedrock walls and alluvial bottomlands of the St. Croix, Minnesota,

Table WF-1. *Plants useful for differentiating the Northern from the Southern and Northwestern Floristic Regions of the Wet Forest System*

Region	Group	Subgroup	Common Name	Scientific Name	Frequency (%) WFn	WFs	WFw
Northern Floristic Region	Moss Substrate Affinity	Deciduous	Bristle-stalked sedge	*Carex leptalea*	36	4	–
			Northern marsh fern	*Thelypteris palustris*	23	4	–
			Three-fruited bog sedge	*Carex trisperma*	22	–	–
			Lowbush blueberry	*Vaccinium angustifolium*	12	–	–
			Bog goldenrod	*Solidago uliginosa*	10	–	–
		Evergreen	Balsam fir (U)	*Abies balsamea*	61	–	13
			White cedar (U)	*Thuja occidentalis*	45	–	–
			Goldthread	*Coptis trifolia*	44	–	–
			Twinflower	*Linnaea borealis*	22	–	–
			Black spruce (U)	*Picea mariana*	16	–	–
			Three-leaved false Solomon's seal	*Smilacina trifolia*	15	–	–
			Creeping snowberry	*Gaultheria hispidula*	13	–	–
			Shining firmoss	*Huperzia lucidula*	13	–	–
			One-sided pyrola	*Pyrola secunda*	13	–	–
			One-flowered pyrola	*Moneses uniflora*	11	–	–
			Labrador tea	*Ledum groenlandicum*	10	–	–
	Other		Common oak fern	*Gymnocarpium dryopteris*	54	4	–
			Bladder sedge	*Carex intumescens*	50	12	–
			Bluebead lily	*Clintonia borealis*	48	4	–
			Fly honeysuckle	*Lonicera canadensis*	38	–	6
			Large-leaved aster	*Aster macrophyllus*	33	4	–
			Long beech fern	*Phegopteris connectilis*	21	–	–
			Mountain ashes (U)	*Sorbus* spp.	18	–	–
			Hairy honeysuckle	*Lonicera hirsuta*	12	–	–
			Drooping wood sedge	*Carex arctata*	10	–	–
			Fine-nerved sedge	*Carex leptonervia*	10	–	–

(U) = understory tree

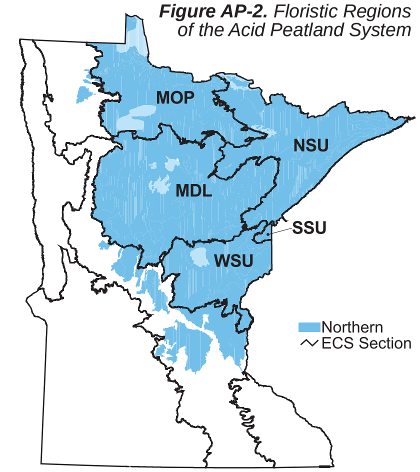
and Mississippi Rivers and their tributaries. Such sites are areas of transition between southern upland hardwood forests (MHs) and bottomland forests (FF) and contain plants common in both of these Systems but uncommon in WFn or WFw communities. Local relief is high within these river valleys, resulting in substantial vertical head in aquifers and the presence of active springs and spring runs in WFs communities. The primary aquifers are relatively conductive bedrock layers or basal layers of till over bedrock. The groundwater is cold and its chemistry somewhat alkaline, reflecting the composition of the sedimentary bedrock.

Selected plants with high fidelity for WFs communities in comparison with WFn and WFw communities are listed in Table WF-2. Plants with high affinity for WFs communities that are also more frequent in the WF System than any other System include Michigan lily *(Lilium michiganense)*, bulblet fern *(Cystopteris bulbifera)*, hairy-leaved sedge *(Carex hirtifolia)*, skunk cabbage *(Symplocarpus foetidus)*, agrimonies *(Agrimonia* spp.), Pennsylvania bitter cress *(Cardamine pensylvanica)*, Wood's sedge *(Carex woodii)*, Goldie's fern *(Dryopteris goldiana)*, true forget-me-not *(Myosotis scorpioides)*, small-leaved water cress *(Rorippa nasturtium-aquaticum)*, bog bluegrass *(Poa paludigena)*, and drooping trillium *(Trillium flexipes)*. A few WFs plants, including bulblet fern, Virginia spring beauty *(Claytonia virginica)*, cut-leaved toothwort *(Cardamine concatenata)*, false rue anemone *(Enemion biternatum)*, Pennsylvania bitter cress, and Goldie's fern, have disjunct populations in riparian habitats along the Mississippi River and around large lakes such as Mille Lacs, Winnibigoshish, Leech, and Lake Superior.

Variation Among Acid Peatland Classes

The four plant community Classes in the AP System are divided into two moisture groups that also correspond to amount of tree cover. The drier group includes the wooded Classes, Northern Spruce Bog (APn80) and Northern Poor Conifer Swamp (APn81). The wetter group includes the more open Classes, Northern Open Bog (APn90) and Northern Poor Fen (APn91). These two groups are further divided by pH and mineral concentration. Spruce Bogs and Open Bogs have pH <4.2 and are dependent on precipitation for minerals. Poor Conifer Swamps and Poor Fens have pH >4.2 and receive some minerotrophic groundwater or surface water.

Figure AP-2. *Floristic Regions of the Acid Peatland System*



Succession

In the absence of external influences, such as flooding by beaver activity or changes in hydrology, the succession of peatlands in the LMF Province moves in the direction of conversion of rich peatlands (OP or FP) to acid peatlands (AP) because of accumulation of *Sphagnum* peat. Within the AP System, the trend is also from less acidic to more acidic communities, in this case from Northern Poor Fen, to Northern Poor Conifer Swamp, to Northern Spruce Bog. Succession to more acidic conditions, however, can be stopped (or even reversed) by mineral inputs from outside sources that offset depletion of calcium by *Sphagnum*. Even groundwater inputs of less than 5% of the total water budget (i.e., relative to inputs from precipitation) can neutralize the acids produced by *Sphagnum* and raise pH above 5.0.

In Minnesota, Northern Open Bogs develop only in special circumstances. In large (>250,000 acres [100,000ha]) peatlands with well-developed Northern Spruce Bogs, the peat surface can become raised over time and develop incipient drains. The drains channel surface water with increased concentrations or fluxes of cations downslope and in the process can convert Northern Spruce Bogs to Northern Open Bogs (and ultimately to Northern Poor Fens or even Northern Rich Fens [OPn91]). In basins and possibly in large raised bogs, fire can convert Northern Spruce Bogs into Northern Open Bogs by destroying the tree canopy, resulting in reduced evapotranspiration and increasingly water-logged conditions. This causes a shift toward greater presence of carpet-forming *Sphagnum* species (relative to hummock-forming *Sphagnum* species) and the development of wet hollows.

In addition, species in AP communities are adapted to survive in environments with very low concentrations of minerals such as calcium and magnesium. Most woody plants in AP communities are evergreen, an adaptation that enables plants to retain scarce nutrients. Deciduous woody plants, which lose nutrients every year when leaves are shed, are uncommon in AP communities. Many plants in AP communities have thickened outer leaf membranes and alkaloids in leaf tissues that help to reduce herbivory. The low palatability of leaves also retards breakdown of litter by decomposing organisms and contributes to peat accumulation. Graminoids, which are the most abundant herbaceous plants in AP communities, are limited to short, fine-leaved sedges and cottongrasses. Although most species in AP communities are physiologically adapted to extract nutrients from substrates with very low nutrient concentrations, a few characteristic peatland species, such as pitcher plant *(Sarracenia purpurea),* sundews *(Drosera* spp.), and intermediate bladderwort *(Utricularia intermedia)* have developed means of supplementing their intake of nitrogen and phosphorus by capturing and digesting insects.

In addition to physiological adaptations for obtaining or conserving scarce nutrients and minerals, it appears that vascular plant survival in AP communities is strongly linked to associations with mycorrhizal fungi. As a result, AP communities are among the most diverse communities in Minnesota in species of ectomycorrhizal fungi. Many of the plants in AP communities, including ericads, conifers, and orchids, depend on mycorrhizal associations to obtain minerals and nutrients and even to prevent uptake of toxic heavy metals that are soluble in waters with extremely low pH. It is possible that most, if not all, vascular plants in the AP System have symbiotic associations with mycorrhizal fungi.

Even with the adaptations mentioned above, the effect of nutrient-poor conditions is evident in reduced growth of woody plants. Trees are usually stunted and have small crowns. They are often only a few feet tall and rarely more than 33 feet (10m) tall, even when over 100 years old. The predominant shrub species are low ericaceous shrubs, such as bog rosemary *(Andromeda glaucophylla),* Labrador tea *(Ledum groenlandicum),* and bog laurel *(Kalmia polifolia).* When characteristically tall shrubs such as speckled alder *(Alnus incana)* or willows *(Salix* spp.) are present in AP communities, they are sparse and diminished in size.

Like most wetland species, plants in the AP system have adaptations that allow them to survive waterlogged, anoxic conditions. Many plants in AP communities are also adapted to survive desiccation because acid peatlands are highly dependent on precipitation and summer drought can cause drastic lowering of local water tables. Some species, such as *Sphagnum angustifolium,* have xerophytic structural and physiological adaptations that enable them to regenerate from dried tissue after desiccation. Other species, such as the ericaceous shrubs, have thick, hirsute leaves with thick cuticles that retard moisture loss. The extremes of summer drawdown are also modified in peatland environments by the wicking capability of *Sphagnum*, which draws water from the water table by capillary action and can hold up to 25 times its weight in water. Because of the characteristically rapid growth of *Sphagnum*, other acid peatland plants have adaptations to prevent being over-topped by accumulating peat. Black spruce, for example, is able to layer or reproduce vegetatively from branches that become covered by moss.

Floristic Regions

Only one Floristic Region is recognized in the AP system in Minnesota, the Northern Floristic (APn) Region (Fig. AP-2). APn communities are similar to the continental bogs north of Minnesota in Ontario. They differ from the maritime bogs characteristic of Maine and eastern Canada, which receive significantly more precipitation and are not subjected to severe drought and low water tables during the summer. In comparison with maritime bogs, continental bogs have developed more recently, have rapidly accumulating peat, are wooded, lack surface pools, and have a crested profile in cross section rather than a convex or plateau shape.

Table WF-2. *Plants useful for differentiating the Southern from the Northern and Northwestern Floristic Regions of the Wet Forest System*

Region	Group	Common Name	Scientific Name	Frequency (%) WFn	WFs	WFw
Southern Floristic Region	Disjunct Populations	Bulblet fern	*Cystopteris bulbifera*	–	41	–
		Virginia spring beauty	*Claytonia virginica*	–	29	–
		Cut-leaved toothwort	*Cardamine concatenata*	–	29	–
		False rue anemone	*Enemion biternatum*	–	25	–
		Goldie's fern	*Dryopteris goldiana*	–	16	–
	Associated with Springs	Skunk cabbage	*Symplocarpus foetidus*	2	33	–
		Pennsylvania bitter cress	*Cardamine pensylvanica*	1	20	–
		Spring cress	*Cardamine bulbosa*	–	20	–
		Small-leaved water cress	*Rorippa nasturtium-aquaticum*	–	12	–
		True forget-me-not	*Myosotis scorpioides*	–	12	–
		Bog bluegrass	*Poa paludigena*	1	12	–
	FF Affinity	Wood nettle	*Laportea canadensis*	13	87	–
		Tall coneflower	*Rudbeckia laciniata*	5	66	6
		White avens	*Geum canadense*	9	54	–
		Cleavers	*Galium aparine*	–	54	–
		Honewort	*Cryptotaenia canadensis*	1	41	6
		Bland sedge	*Carex blanda*	3	37	–
		Virginia waterleaf	*Hydrophyllum virginianum*	–	37	–
		Virginia wild rye	*Elymus virginicus*	5	33	–
		Brome-like sedge	*Carex bromoides*	3	29	–
		Tall scouring rush	*Equisetum hyemale*	–	29	–
		Hawthorns	*Crataegus* spp.	1	25	–
		Missouri gooseberry	*Ribes missouriense*	–	25	–
		Blue phlox	*Phlox divaricata*	–	25	–
		Gregarious black snakeroot	*Sanicula gregaria*	–	20	–
		Virginia knotweed	*Polygonum virginianum*	–	20	–
		Virgin's bower	*Clematis virginiana*	–	16	–
		Ambiguous sedge	*Carex amphibola*	–	12	–
		Creeping Charlie	*Glechoma hederacea*	–	12	–
		Yellow wood sorrels	*Oxalis* spp.	1	12	–
		Downy wild rye	*Elymus villosus*	–	12	–
		Cow parsnip	*Heracleum lanatum*	1	12	–
		Narrow-leaved hedge nettle	*Stachys tenuifolia*	2	12	–
	MH Affinity	Wild geranium	*Geranium maculatum*	–	70	–
		Common enchanter's nightshade	*Circaea lutetiana*	6	58	6
		Two-leaved miterwort	*Mitella diphylla*	7	58	–
		Blue beech (U)	*Carpinus caroliniana*	–	37	–
		Zigzag goldenrod	*Solidago flexicaulis*	5	37	–
		Common false Solomon's seal	*Smilacina racemosa*	–	33	6
		Maidenhair fern	*Adiantum pedatum*	–	33	–
		Ironwood (U)	*Ostrya virginiana*	4	29	–
		Blue cohosh	*Caulophyllum thalictroides*	1	25	–
		Bloodroot	*Sanguinaria canadensis*	2	25	–
		Shining bedstraw	*Galium concinnum*	–	20	–
		White bear sedge	*Carex albursina*	–	16	–
		Giant Solomon's seal	*Polygonatum commutatum*	–	16	–
		Red-berried elder	*Sambucus racemosa*	3	16	–
		White oak (U)	*Quercus alba*	–	12	–
		Sharp-lobed hepatica	*Anemone acutiloba*	–	12	–
		Drooping trillium	*Trillium flexipes*	–	12	–
		Large-flowered trillium	*Trillium grandiflorum*	1	12	–
	Other	Michigan lily	*Lilium michiganense*	2	50	–
		Hairy-leaved sedge	*Carex hirtifolia*	–	33	–
		Golden ragwort	*Senecio aureus*	4	33	–
		Agrimonies	*Agrimonia* spp.	4	25	–
		Wood's sedge	*Carex woodii*	–	20	–
		Reed canary grass	*Phalaris arundinacea*	1	20	–
		Porcupine sedge	*Carex hystericina*	2	16	–
		Eastern panicled aster	*Aster lanceolatus*	2	12	–

(U) = understory tree

Presumably, large water bodies and river valleys have an ameliorating effect on local climate that allows plants typical of WFs communities to occur well into the WFn Region. Several plants with highest affinity for WFs communities are intimately associated with spring-heads and cold-water runs. These plants include skunk-cabbage, Pennsylvania bitter cress, and true forget-me-not. The majority of the plants with high fidelity for WFs relative to WFn and WFw communities are actually more frequent in MH forests and FF forests, most likely because WFs communities usually occur at bases of steep valley walls, with MH forests above and FF forests below.

Groundwater Hydrology and Plant Indicators of WFw Communities

Communities in the WFw Region are represented in the LMF Province by the Northwestern Wet Aspen Forest (WFw54) Class. They are present at the toes of sandy beach ridges traversing the Glacial Lake Agassiz Basin in settings that are natural transitions between OP and WP, UP, or FD communities. As a result, WFw forests typically contain open peatland, prairie, and fire-dependent woodland plants not common in WFn or WFs communities. The groundwater supplying WFw forests emanates from aquifers associated with the sandy beach ridges and is rich in bicarbonate, which precipitates in the upper soil horizons. The landscape of the Lake Agassiz Basin is extremely flat. Therefore, the groundwater has low vertical head, and springs or other evidence of groundwater discharge are not often obvious in WFw forests.

Selected plants with high fidelity for WFw communities in comparison with other WF communities are presented in Table WF-3. Just a few plants with high fidelity for WFw communities are also more frequent in the WF System than any other System in this classification. These species are balsam poplar, arrow-leaved sweet coltsfoot *(Petasites sagittatus),* and golden fruited sedge *(Carex aurea).* The other plants with high fidelity for WFw relative to other WF communities are species tolerant of occasional

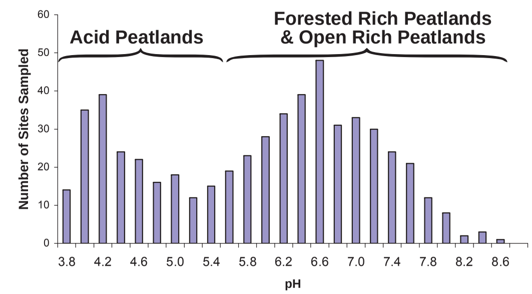
Table WF-3. *Plants useful for differentiating the Northwestern from the Northern and Southern Floristic Regions of the Wet Forest System*

Region	Group	Affinity	Common Name	Scientific Name	Frequency (%) WFn	WFs	WFw
Northwestern Floristic Region	Tolerant of Fire	FD Affinity	Lindley's aster	*Aster ciliolatus*	8	–	66
			Wild roses	*Rosa* spp.	9	–	66
			Spreading dogbane	*Apocynum androsaemifolium*	–	–	40
			Columbine	*Aquilegia canadensis*	2	–	40
			Mountain rice grass	*Oryzopsis asperifolia*	6	–	40
			Wild honeysuckle	*Lonicera dioica*	8	–	40
			American vetch	*Vicia americana*	1	–	26
			Fireweed	*Epilobium angustifolium*	2	–	20
			Virginia thimbleweed	*Anemone virginiana*	–	–	20
		WP, UP, OP, or WM Affinity	Bebb's willow	*Salix bebbiana*	1	–	46
			Showy lady's slipper	*Cypripedium reginae*	5	–	33
			Pink shinleaf	*Pyrola asarifolia*	4	–	26
			Sow thistle	*Sonchus* spp.	–	–	26
			Marsh vetchling	*Lathyrus palustris*	–	4	20
			Bebb's sedge	*Carex bebbii*	3	–	20
			Canada anemone	*Anemone canadensis*	–	–	13
			Aquatic sedge	*Carex aquatilis*	–	–	13
			Autumn willow	*Salix serissima*	–	–	13
			Golden alexanders	*Zizia aurea*	–	–	13
			Shrubby cinquefoil	*Potentilla fruticosa*	–	–	13
	Other		Arrow-leaved sweet coltsfoot	*Petasites sagittatus*	3	–	53
			Golden fruited sedge	*Carex aurea*	1	–	13
			Balsam popular (U)	*Populus balsamifera*	10	–	80

(U) = understory tree

peatlands are transitional and relatively short-lived, quickly succeeding to poor fens or poor swamp forests, and therefore are uncommon. This results in a natural bimodal distribution of pH in peatland communities (Fig. AP-1) that coincides with floristic differences in vascular plants and changes in dominance in the moss layer from brown mosses to *Sphagnum*. These distinctions among peatlands are the basis for differentiating the AP System from the rich peatland (FP and OP) Systems. At pH of 5.0, the acidification process slows, but the peat surface continues to build up until it is no longer in contact with groundwater and becomes dependent solely on precipitation. At this point, the pH of surface water is generally about 4.2. In the best-developed examples of raised peatlands, a crest with a radiating pattern of black spruce forms that is visible on aerial photos.

Figure AP-1. *Histogram of surface water pH from wetland sites in the Laurentian Mixed Forest Province. The natural bimodal distribution corresponds to separation of Acid Peatlands from Rich Peatlands.*



It is possible to have features of AP and OP or FP communities within the same peatland because of the differing water chemistry characteristic of hummocks and hollows. In OP and FP communities, hummocks and hollows have similar water chemistry. If peat accumulates, however, and the peat surface becomes isolated from mineral-rich water, the hummocks change more quickly to acidic conditions than hollows. The peatland then becomes a mosaic of patches of AP communities within larger areas of OP or FP communities until acidic species of *Sphagnum* invade the hollows. Even when the hollows have acidified to the point where the water chemistry is characteristic of AP communities (i.e., pH < 5.5), deeply rooted minerotrophic plants such as aquatic sedge *(Carex aquatilis)* and beaked sedge *(C. utriculata)* can persist in the hollows for some time. Mosaics of AP with OP or FP communities occur most commonly in peatland Systems where woody plants (shrubs and trees) are abundant, creating varied microtopography with hummocks developing initially over woody debris or around tree bases. These peatlands are most likely to develop in settings with water-table drawdowns large enough to provide the aerated microhabitats necessary for establishment of trees. Where the water table does not fluctuate significantly and woody plants are not common, more uniform peatlands develop that are dominated by OP or FP communities and lack small inclusions of AP communities.

Plant Adaptations

With decline in pH and nutrients, the number of vascular plant species that can survive in peatland communities drops significantly. The vascular plants in AP communities consist mainly of a subset of the species present in FP and OP communities; only tussock cottongrass *(Eriophorum vaginatum),* tawny cottongrass *(E. virginicum),* few-fruited sedge *(Carex pauciflora),* and bog wiregrass sedge *(C. oligosperma)* are unique to the AP System. Within the AP System, bogs, which have the most acidic and nutrient-poor conditions, are inhabited only by a set of 25 species (see page LMF-AP5).

Species in AP communities have many of the physiological and structural adaptations to low pH and low-nutrient environments present in plants in rich peatland communities.

photo by N.E. Aaseng MN DNR

St. Louis County, MN

General Description

The Acid Peatland (AP) System is characterized by conifer-, low-shrub, or graminoid-dominated communities that develop in association with peat-forming *Sphagnum*. AP communities are acidic (pH < 5.5), extremely low in nutrients, and have hydrological inputs dominated by precipitation rather than groundwater. These communities are floristically depauperate, with the flora composed primarily of a small subset of species characteristic of rich peatland Systems that are able to survive in the harsh, low-nutrient environments typical in AP communities. The floristic differences between forested and open AP communities are subtle because of low species diversity in the AP System as a whole and because trees, when present, are usually sparse, making the boundary between forested and open AP communities diffuse. Therefore, this classification places all acid peatland communities into one System, unlike the rich peatland communities, which are divided into forested and open Systems.

AP communities are widespread in the Laurentian Mixed Forest (LMF) Province because of cool climate, abundant precipitation, numerous poorly drained basins, and extensive poorly drained glacial lake plains, which produce favorable conditions for peat development across much of the Province. AP communities tend to be prevalent in basins in areas with non-calcareous soils and on lake plains underlain by impermeable clayey and loamy soils, which minimize movement of groundwater through the overlying peat.

Peatland Development

AP communities develop from Forested Rich Peatland (FP) or Open Rich Peatland (OP) communities in areas where there is sufficient rainfall and low enough evapotranspiration to enable *Sphagnum* peat to accumulate to levels above the groundwater table. Once the peat surface is above the water table, surface water flows away from or around the elevated peat surface, reducing inputs of minerals and nutrients. *Sphagnum* absorbs dissolved mineral cations, particularly calcium, and exchanges them for hydrogen ions, releasing organic acids and lowering the pH of stagnant surface waters. This conversion proceeds slowly until the pH falls to 5.5, below which the water chemistry switches from a bicarbonate to a humic acid buffered system. In humic acid buffered peatlands, slight additions of acids rapidly decrease the pH to 5.0. Humic acid buffered

fire. Within the northwestern parklands, patches of WF forests are commonly surrounded by vegetation of other Systems that burn regularly, including the FD, WP, UP, OP, and WM Systems. Several species common in WFw forests relative to WFn and WFs forests, including Lindley's aster *(Aster ciliolatus)*, wild roses *(Rosa* spp.), spreading dogbane *(Apocynum androsaemifolium)*, and columbine *(Aquilegia canadensis)*, actually have their highest frequency in FD forests. Plants with an affinity for WFw and WP, UP, OP, or WM communities, include Bebb's willow *(Salix bebbiana)*, showy lady's slipper *(Cypripedium reginae)*, pink shinleaf *(Pyrola asarifolia)*, sow thistle *(Sonchus* spp.), and several other species.

Table WF-4. *Historic tree species composition & disturbance regimes in Wet Forest Classes.*

	Historic Tree Species Frequency by Class and Stand Age						Historic Disturbance Rotation Periods by Class (in years)		
	young forest age	young forest species	mature forest age	mature forest species	old forest age	old forest species	Stand-Regenerating Fire	Moderate Surface Fire + Patchy Windthrow	Catastrophic Windthrow
Northern Floristic Region						ranges →	800-1000+	110-340	365-480
WFn55	0 - 75 yrs	**black ash**	75 - 195 yrs	**black ash**	> 195 yrs	black ash *(tamarack)* *(white spruce)*	>1000	140	370
WFn64	0 - 75 yrs	**black ash**	75 - 135 yrs	**black ash**	> 135 yrs	**black ash** *(tamarack)* *(white spruce)*	>1000	110	480
WFn53	0 - 55 yrs	**balsam fir** *(white cedar)*	75 - 105 yrs	**white cedar**	> 155 yrs	white cedar *(white spruce)* *(balsam fir)* *(tamarack)*	800	340	365
Southern Floristic Region						ranges →			
WFs57	0-35 yrs	*no data*	55 - 135 yrs	*no data*	> 135 yrs	*no data*	none	140	630
Northwestern Floristic Region						ranges →			
WFw54	0 - 55 yrs	**quaking aspen** *(balsam poplar)* *(black ash)* *(tamarack)*	55 - 105 yrs	tamarack quaking aspen black ash	> 105 yrs	tamarack quaking aspen	490	20	250

bold = >50% normal = 25-50% *(italics)* = 10-25%

Disturbance Regimes of WFn, WFw, and WFs Communities

The most frequent natural disturbance in WF communities is flooding, typically resulting from periodic increases in precipitation or from beaver activity. If flooding is severe enough, it can kill the canopy trees and bring about conversion to Wet Meadow/Carr or Marsh communities. Other potential disturbances include fire and windthrow. Historically, WFn and WFs communities were affected by catastrophic fires very infrequently, with rotations of 800 to more than 1,000 years (Table WF-4). WFw communities were affected by catastrophic fires about twice as often as WFn and WFs communities, a result of being surrounded by fire-prone woodlands, prairies, and open wetlands that burned severely during drought periods. Relative to WFn and WFs communities, WFw communities had extremely short rotation periods (about 20 years) for moderate disturbances such as light surface fires and patchy windthrow of canopy trees. Again, the high frequency of moderate disturbances in WFw communities most likely results from being embedded in a landscape characterized by warmer temperatures and more frequent drought and composed mainly of fire-prone vegetation.

water, hummocks change more quickly in water chemistry than hollows. The hummocks, which are elevated above the water table, often become lower in minerals and more acidic and support species characteristic of AP communities. The hollows, which remain in contact with mineral-rich water, have water chemistry and flora typical of FP communities. The site then is characterized by a mosaic of patches of AP and FP communities until the hollows also become dominated by acidic species of *Sphagnum*. Mosaics of FP and AP communities occur most commonly in settings where woody plants (shrubs and trees) are abundant because these sites often are hummocky from presence of stumps, roots, and fallen trees. Although initially formed over woody debris or tree bases, the hummocks become amplified by growth and accumulation of moss. The settings most likely to have abundant trees and shrubs are also those with slightly larger water-table drawdowns, making the establishment of woody plants possible.

There are no species unique to the FPs Region relative to the FPn and FPw Regions, although within the FP System red maple, winterberry *(Ilex verticillata),* and Virginia creepers *(Parthenocissus* spp.) reach their highest frequency in FPs communities. The FPw Region is characterized by several species that are rare in the FPn and FPs Regions. Among these are species common in calcareous and rich fens, such as shrubby cinquefoil *(Potentilla fruticosa)* and marsh grass-of-Parnassus *(Parnassia palustris),* which are present in tamarack swamps associated with calcareous groundwater seepage zones in northwestern Minnesota.

Variation Within the Northern Floristic Region

In plant community composition and ecosystem function, the FPn Region is the most varied of the three Floristic Regions in the FP System. It is represented by seven Native Plant Community Classes with ranges that together cover the entire LMF Province. The FPn community Classes can be divided into two groups based on differences in topography, substrate, and hydrology. Communities in the first group—Northern Rich Spruce Swamp (Basin) (FPn62), Northern Cedar Swamp (FPn63), Northern Rich Tamarack Swamp (Eastern Basin) (FPn72), and Northern Rich Tamarack Swamp (Western Basin) (FPn82)—form in basins underlain by fine-textured substrates with relatively low hydraulic conductivity. These communities are influenced primarily by stagnant groundwater and are common where irregular topography allows the development of poorly drained, isolated depressions. They typically form in peat-filled depressions and on floating mats adjacent to lakes, ponds, or rivers.

Communities in the second group—Northern Rich Spruce Swamp (Water Track) (FPn71) and Northern Rich Tamarack Swamp (Water Track) (FPn81)—form on flat or slightly sloping surfaces, such as glacial lake plains and appear to be associated with lenses of sandy substrates within otherwise clayey landscapes. The sand lenses have high hydraulic conductivity, channeling groundwater into overlying peatlands and producing flowing, mineral-influenced surface water. In these settings, FP communities are associated with water tracks that slope gently in the direction of water flow.

Succession

FP communities can develop from Wet Forest (WF) communities if conditions become suitable for accumulation of organic matter (peat) and rooting contact with mineral soil is reduced. These conditions typically occur in settings where the water table becomes elevated or stabilized so that the ground surface is continuously saturated. As peat accumulates, and the peat surface and water table rise, rates of water flow and inputs of minerals to the peat surface are gradually reduced and the community is transformed into a Forested Rich Peatland. Conditions then become suitable for invasion of the site by minerotrophic *Sphagnum* species, which absorb and retain minerals—particularly calcium—and release hydrogen ions, increasing the acidity of surface waters. As acidity increases, more acid-tolerant *Sphagnum* species become established at the site and pH gradually falls. Above pH 5.5, the water chemistry is buffered by bicarbonate. At pH 5.5, an important change occurs, with the water chamistry no longer buffered by bicarbonate, marking conversion to an Acid Peatland. As pH continues to drop, at some point below pH 5.5 the water chemistry becomes buffered by humic acids. The higher parts of hummocks quickly become more bog-like and minerotrophic *Sphagnum* species in hollows are replaced by oligotrophic species. The transformation of an FP community to an AP community can be stopped or slowed if groundwater or surface water inputs to the site increase and supply enough minerals to compensate their removal by *Sphagnum*.

When peatlands have well-developed hummock and hollow topography, it is possible to have characteristics of both AP and FP communities in the same site. Initially, both hummocks and hollows in rich peatland communities have similar water chemistry, but as peat accumulates and the surface becomes more isolated from mineral-rich

photo by N.E. Aaseng MN DNR

Roseau County, MN

General Description

Forested Rich Peatland (FP) communities are conifer- or tall shrub-dominated wetlands on deep (>15in [40cm]), actively forming peat. They are characterized by mossy ground layers, often with abundant shrubs and forbs. FP communities are widespread in the Laurentian Mixed Forest (LMF) Province. The cool climate of the region, abundant precipitation, and presence of poorly drained basins and glacial lake plains result in extensive peat development relative to other parts of Minnesota. FP communities are particularly prominent in the LMF Province in MOP and in the Tamarack Lowlands Subsection of MDL.

Peatland Formation

Most of Minnesota's peatlands began to form following climate cooling and increased precipitation about 5–6,000 years ago. Change in climate stabilized seasonal water levels in many basins and on large, flat, poorly drained landscapes such as glacial lake plains, causing saturation of soils and oxygen deficiency (anaerobic conditions). The anaerobic conditions, along with lower temperatures, inhibit plant decomposition and result in accumulation of peat. Peat accumulation rates in Minnesota are variable but generally range from 1.5 to 3 inches (4–8cm) per century. Once peat accumulates to a depth of 12–15 inches (30–40cm), the nutrients available to plants fall sharply because plants are no longer rooted in mineral soil. (In some instances, saturated soils and low-nutrient environments can develop on thinner peat deposits, either in shallow basins with small watersheds or in landscapes with nutrient-poor sandy soils.) In addition to isolating plants from mineral soil, peat adsorbs and holds nutrients, which, combined with low levels of microbial activity in anaerobic environments, limits nutrient recycling. With accumulation of peat, plants in peatlands become dependent on inputs of essential nutrients from hydrologic processes such as atmospheric deposition (especially in precipitation), surface runoff from adjacent uplands, and groundwater-derived subsurface flow. These sources usually supply very low concentrations of the essential nutrients, nitrogen and phosphorus. However, concentrations of minerals are often abundant in groundwater that has percolated through till. Therefore, peatlands influenced by inputs of groundwater (including FP and Open Rich Peatland [OP] communities) can have relatively high concentrations of minerals such as calcium and magnesium.

The peat in FP communities is moderately decomposed (hemic) and formed from woody plant debris. The water table is typically below the peat surface and drops regularly and predictably during the summer. At high water levels, pools may form on the peat surface, but undulating microtopography and low hummocks at the bases of trees provide substrates that remain dry and aerated enough to support trees and shrubs. The presence of trees and shrubs, in turn, favors herbaceous species in the ground layer that are tolerant of at least moderate levels of shade. In contrast, OP communities have water table levels that remain near the surface throughout the growing season, preventing establishment of significant tree cover and leaving the ground exposed to full sunlight. As a result, FP communities typically are richer in forb species than OP communities, because forbs tend to be more competitive than graminoids in low-light environments. Another prominent feature of FP communities is the presence of feather-mosses and brown mosses, which are adapted to high mineral content, low nutrients, and sustained moisture. Brown mosses typically dominate the moss layer, with patches of minerotrophic *Sphagnum*.

Plant Adaptations

The environment in FP communities favors dominance by herbaceous vascular plants, brown mosses, minerotrophic *Sphagnum*, and tree and shrub species that can survive periods of inundation or saturated substrates. Many of the plant species in FP communities have structures that allow them to survive water-logged conditions for short periods. For example, speckled alder *(Alnus incana)* has adventitious roots (originating from the stem or root collar) that provide access to oxygen during high water levels. Other plants grow on aerated substrates on tree bases and moss hummocks elevated above the water table. These species are often characteristic of surrounding upland forest communities and include such plants as bunchberry *(Cornus canadensis),* Canada mayflower *(Maianthemum canadense)*, starflower *(Trientalis borealis),* and bluebead lily *(Clintonia borealis).*

As in other peatland systems, plants of FP communities are adapted to low-nutrient environments. Evergreen species, which conserve nutrients by retaining their leaves from year to year, are common and include conifers such as black spruce and ericaceous shrubs such as bog rosemary *(Andromeda glaucophylla)*, Labrador tea *(Ledum groenlandicum),* and bog laurel *(Kalmia polifolia)*. Deciduous tree species, which lose nutrients when leaves are shed each year, are nearly absent from FP communities. The thickened outer leaf membranes characteristic of ericaceous shrubs and other species such as bog birch *(Betula pumila)* and the presence of chemical compounds in leaves help to reduce loss from herbivory. The low palatability of leaves also retards breakdown of litter by decomposing organisms and contributes to peat accumulation. Some species in the community, such as pitcher plant *(Sarracenia purpurea)* and sundews *(Drosera* spp.), supplement their intake of the important nutrients, nitrogen and phosphorus, with structures that trap and digest insects.

Floristic Regions

Based on general differences in species composition, FP communities in Minnesota are grouped into three "floristic" regions: the Northern Floristic (FPn) Region, the Southern Floristic (FPs) Region, and the Northwestern Floristic (FPw) Region (Fig. FP-1). All three Floristic Regions are represented in the LMF Province. However, the FPs and FPw Regions extend only into the southern and western edges of the Province. Differences in species composition among FPn, FPs, and FPw communities are presented in Table FP-1. Both FPs and FPw communities are at the edge of the range of climate suitable for peat-forming vegetation. It is likely that frequent drought, prolonged drawdown of the water table, and more frequent fire reduce the presence of characteristic FPn species in FPs and FPw communities. Notable among these are white cedar, balsam fir, and ericaceous shrubs such as creeping snowberry *(Gaultheria hispidula)* and leatherleaf *(Chamaedaphne calyculata).*

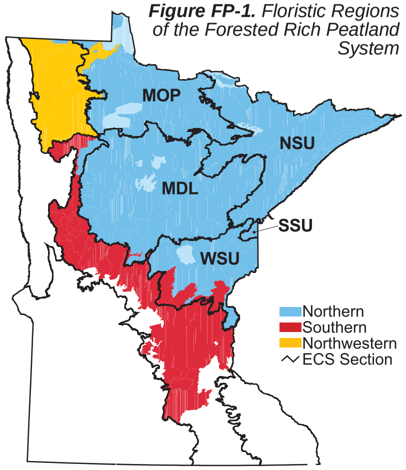


Figure FP-1. *Floristic Regions of the Forested Rich Peatland System*

Table FP-1. *Plant species useful for differentiating the Northern, Southern, and Northwestern Floristic Regions of the Forested Rich Peatland System.*

Region	Layer	Common Name	Scientific Name	Frequency (%) FPn	FPw	FPs
Northern Floristic Region	Tree	White cedar (C)	*Thuja occidentalis*	49	3	–
		Balsam fir (C)	*Abies balsamea*	30	3	–
		White cedar (U)	*Thuja occidentalis*	49	10	–
		Mountain ashes (U)	*Sorbus* spp.	14	–	–
		White pine (U)	*Pinus strobus*	6	–	–
	Tall Shrub	Fly honeysuckle	*Lonicera canadensis*	29	–	4
		Black chokeberry	*Aronia melanocarpa*	8	–	–
		Diamond-leaved willow	*Salix planifolia*	6	–	–
	Low Shrub	Creeping snowberry	*Gaultheria hispidula*	62	7	–
		Leatherleaf	*Chamaedaphne calyculata*	38	–	4
		Bog rosemary	*Andromeda glaucophylla*	35	7	–
		Bog laurel	*Kalmia polifolia*	15	–	–
	Forb	Goldthread	*Coptis trifolia*	62	14	–
		Bluebead lily	*Clintonia borealis*	34	3	4
		Pitcher plant	*Sarracenia purpurea*	24	7	–
		Round-leaved sundew	*Drosera rotundifolia*	16	–	4
		One-flowered pyrola	*Moneses uniflora*	15	–	–
		Heart-leaved twayblade	*Listera cordata*	14	–	–
		Small northern bog orchid	*Platanthera obtusata*	14	–	–
		Lesser rattlesnake plantain	*Goodyera repens*	13	–	–
		Indian pipe	*Monotropa uniflora*	11	–	–
		Early coralroot	*Corallorhiza trifida*	10	–	–
		Gaywings	*Polygala paucifolia*	9	–	–
		Palmate sweet coltsfoot	*Petasites frigidus*	7	–	–
		Small round-leaved orchis	*Orchis rotundifolia*	7	–	–
		Spurred gentian	*Halenia deflexa*	6	–	–
	Fern	Bristly clubmoss	*Lycopodium annotinum*	10	–	–
		Dwarf scouring rush	*Equisetum scirpoides*	7	–	–
Southern Region	Tree	Red maple	*Acer rubrum*	7	–	30
	Shrub	Winterberry	*Ilex verticillata*	9	–	35
	Vine	Virginia creeper	*Parthenocissus* spp.	5	10	57
Northwestern Floristic Region	Shrub	Shrubby cinquefoil	*Potentilla fruticosa*	1	34	–
	Forb	Tall meadow-rue	*Thalictrum dasycarpum*	1	28	4
		Arrow-leaved sweet coltsfoot	*Petasites sagittatus*	5	24	–
		Fireweed	*Epilobium angustifolium*	3	17	–
		Wood strawberry	*Fragaria vesca*	3	17	–
		Rough bugleweed	*Lycopus asper*	–	10	–
		Black-eyed Susan	*Rudbeckia hirta*	–	10	–
		Marsh grass-of-Parnassus	*Parnassia palustris*	2	10	–
		Clayton's sweet cicely	*Osmorhiza claytonii*	–	7	–
		Grass-leaved goldenrod	*Euthamia graminifolia*	1	7	–
		Columbine	*Aquilegia canadensis*	1	7	–
		Eastern panicled aster	*Aster lanceolatus*	1	7	–
	Graminoid	Common reed grass	*Phragmites australis*	4	17	–
		Sterile sedge	*Carex sterilis*	–	14	–
		Clustered muhly grass	*Muhlenbergia glomerata*	1	10	–
		Mexican muhly grass	*Muhlenbergia mexicana*	–	7	–
		Mat muhly grass	*Muhlenbergia richardsonis*	–	7	–

(C)=canopy tree (U)=understory tree