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,

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.

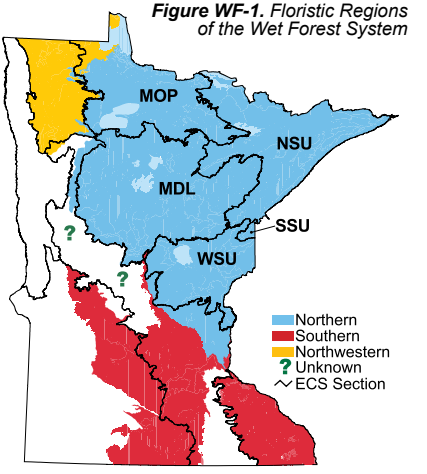

Figure WF-1. *Floristic Regions of the Wet Forest System*

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*

Northern Floristic Region	Moss Substrate Affinity		Common Name	Scientific Name	Frequency (%) WFn	WFs	WFw
		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.

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

		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*

			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

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.