United States Department of Agriculture

Ecological Site Description

Major Land Resource Area 93A

Superior Stony and Rocky Loamy Plains and Hills, Western Part

Bedrock Controlled Upland Hardwood Forests

Northern Red Oak – Sugar Maple / Hophornbeam – Beaked Hazelnut / Pennsylvania Sedge – Cream Pea

Contact for Lead Authors: Kyle Steele (Kyle.Steele@usda.gov), Ecological Site Specialist, United States Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS), Albert Lea, MN; and Roger Risley (Roger.Risely@usda.gov), USDA-NRCS Soil Survey Office Leader, Duluth, MN.

Front cover: Top photo is of a Bedrock Controlled Upland Hardwood Forest reference state, taken in Lake County, Minnesota (by Kyle Steele, USDA-NRCS). Bottom left photo is of northern red oak (*Quercus rubra*) foliage and acorns (by Peter Dziuk, http://www.minnesotawildflowers.info). Bottom right photo is of a typical bedrock controlled landscape on the north shore of Lake Superior, taken at Tettegouche State Park, Lake County, Minnesota (by Kyle Steele, USDA-NRCS).

Table of Contents

General Information 5
MLRA Notes 5
Ecological Site Concept 6
Physiographic Features 8
Climatic Features 9
Influencing Water Features 11
Representative Soil Features 12
States and Community Phases 14
Ecological Dynamics 14
STATE 1 – REFERENCE STATE 18
Community Phase 1.1 21
Community Phase 1.2 21
STATE 2 – SIMPLIFIED FOREST STATE 22
Community Phase 2.1 23
Community Phase 2.2 24
STATE 3 – EVEN-AGED STATE 25
Community Phase 3.1 26
Community Phase 3.2 27
STATE 4 – INVADED STATE 28
Community Phase 4.1 31
Community Phase 4.2 33
Community Phase 4.3 33
Relationship to Other Established Classifications 34
Associated Ecological Sites 34
Similar Ecological Sites 35
Inventory Data References 35
Other References 36
Acknowledgements 39

This page was intentionally left blank.

General Information

Ecological Site Name:

Abiotic: Bedrock Controlled Upland Hardwood Forests

Biotic: Northern Red Oak – Sugar Maple / Hophornbeam – Beaked Hazelnut / Pennsylvania Sedge – Cream Pea

Quercus rubra – Acer saccharum / Ostrya virginiana – Corylus cornuta / Carex pensylvanica – Lathyrus ochroleucus

Ecological Site ID: 093AY002

Hierarchical Framework Relationships

Major Land Resource Area (MLRA): Superior Stony and Rocky Loamy Plains and Hills, Western Part (93A)

USFS Subregions: Northern Superior Uplands Section (212L); North Shore Highlands Subsection (212Lb)

MLRA Notes

The Superior Stony and Rocky Loamy Plains and Hills, Western Part is located and completely contained in northeastern Minnesota (Figure 1). This area has both the highest and lowest elevations in the state, as well as some of the state's most rugged topography (Ojakangas and Matsch, 1982). The MLRA was glaciated by numerous advances of the Superior, Rainy, and Des Moines glacial lobes during the Wisconsin glaciation as well as pre-Wisconsin glacial periods. The geomorphic surfaces in this MLRA are geologically very young (i.e., 10,000 to 20,000 years) and dominated by drumlin fields, moraines, small lake plains, outwash plains, and bedrock-controlled uplands (USDA-NRCS, 2006). There are thousands of lakes

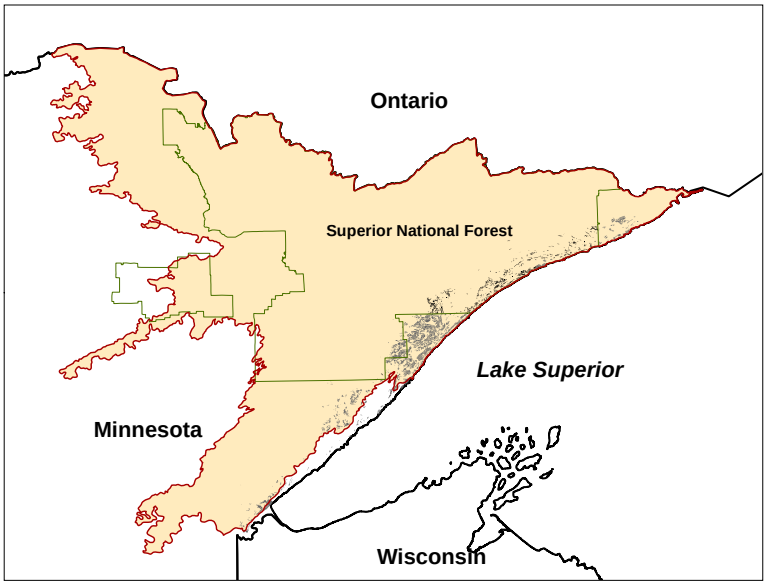


Figure 1. Potential distribution of Bedrock Controlled Upland Hardwood Forests within MLRA 93A. Light colored polygons show USDA-NRCS Soil Survey mapping and dark colored polygons show Superior National Forest Landtype Phase mapping.

scattered throughout the region that were created by these glacial events. Most of these lakes are bedrock-controlled in comparison to adjacent glaciated regions where glacial drift deposits are much thicker and the lakes occur in depressions atop the glacial drift (Ojakangas and Matsch, 1982). In contrast to adjacent MLRAs, the depth to the predominantly crystalline or sandstone bedrock in MLRA 93A is relatively shallow because the most recent glacial events were more erosional than depositional (Ojakangas and Matsch, 1982).

Ecological Site Concept

Bedrock Controlled Upland Hardwood Forest ecological sites are limited to high elevation landforms adjacent to Lake Superior, and have the benefit of a lake-moderated climate. They are associated with areas of bedrock protrusion within the extent of the Automba phase of the Superior glaciation, the first of several main advances of the Superior Lobe along the north shore of Lake Superior (Wright and Watts, 1969). Soils are moderately deep (20-40 inches to bedrock), coarse-loamy (<18 percent clay), well drained, and have low available water capacity. Parent material above the bedrock is best classified as glacial drift, and is a mix of water-worked and ice contact features associated with the retreating glacier.

Effective free air drainage limits early fall and late spring frosts, thus allowing mesic hardwood species to occur in an otherwise frigid climate (Albert, 1994; Anderson and Fischer, 2015). Limited rooting depth and lower available water capacity produces low to moderate site quality, often resulting in more open conditions. Within a given stand, variation in available water capacity related to differences in rooting depth produce a complex of dry-mesic and mesic hardwood forest. Historically, light surface fires and small extent windthrow were the main disturbances (MN DNR, 2014). Site conditions allow a mix of hardwood species to dominate the overstory, such as northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), paper birch (*Betula papyrifera*), and aspen (*Populus* spp.). Hophornbeam (*Ostrya virginiana*) is a frequent subcanopy tree. Shade-tolerant conifers like white spruce (Picea glauca) and balsam fir (*Abies balsamea*) may also be present in older stands. Historically, eastern white pine (*Pinus strobus*) was an important component of this ecosystem, due to its ability to compete with hardwoods on these landforms with low available water capacity soils, but it has been largely extirpated due to extensive logging during the early 1900s. Spring flowering, sub-boreal species dominate the herbaceous layer. Examples include: bigleaf aster (*Eurybia macrophylla*), bluebead (*Clintonia borealis*), Canada mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia*

nudicaulis), twistedstalk (*Streptopus lanceolatus*), and bunchberry dogwood (*Cornus canadensis*), (Jim Drake, NatureServe ecologist, personal communication). Some species indicative of drier sites are also common, such as cream pea (*Lathyrus ochroleucus*) and brackenfern (*Pteridium aquilinum*). There is often substantial grass and sedge cover, including species like Pennsylvania sedge (*Carex pensylvanica*), longstalk sedge (*C. pedunculata*), and roughleaf ricegrass (*Oryzopsis asperifolia*).

In MLRA 93A, northern hardwoods are on the northwestern extent of their range. Lake Superior has a significant effect on the climate and thus growing conditions of this ecological site; including a moderation of both summer and winter high and low daily temperatures, increased insulation of the soil surface due to lake effect snowfall, and a longer frost-free period (Albert, 1994; Anderson and Fischer, 2015; Butters and Abbe, 1953; Rosendahl and Butters, 1928). Although soils and environmental conditions are suitable for this forest type, this ecological site produces comparatively low quality timber. Average site index at base age 50 for northern red oak is generally less than 45 feet, which is considered poor for this species (Carmean, 1989 and 1978). In comparison, a good site index for northern red oak is 75, or possibly higher, elsewhere in its range (Carmean, 1979).

Physiographic Features

These sites are located in glacially scoured landscapes associated with the Automba phase of the Superior Lobe glacial advance (Table 1). They occur on high elevation, bedrock-controlled moraines close to Lake Superior, primarily in the Sawtooth Mountains Bedrock Complex and Tettegouche Till Plain Landtype Associations (LTAs). Hillslope positions are mostly shoulder slopes and backslopes, ranging from 15 to 45 percent slope. They can also occur on summits and narrow ridges. Slopes often are complex and occur in a stair-stepping pattern, with rock outcrops frequently occurring at major slope breaks. Slope shape is convex or linear upslope, and linear across slope, thereby effectively shedding water to adjacent, downslope ecological sites. Aspect does not appear to be important for this ecological site, although MN DNR (2005) has previously stated that these native plant communities may be more prominent on south and east facing aspects. Elevation is mainly between 1,100 and 1,600 feet above sea level. These sites do not flood or pond.

Table 1. Physiographic features.
(Data and information presented here were obtained from the National Soil Information System (NASIS) and USDA-NRCS integrated plot data.)

	Minimum	Maximum
Elevation (ft.)	1,100	1,600
Slope (percent)	15	45
Aspect (degrees)	0	360
Water Table Depth (in.)	none	none
Flooding	none	none
Ponding	none	none

Landforms: bedrock controlled moraine, uplands
Hillslope Positions: shoulder slopes, backslopes, summits
Slope Shape: convex to linear (up slope), linear (across slope)

Climatic Features

The average freeze-free period of this ecological site is about 140 days, and ranges from 131 to 149 days (Table 2). Effective drainage of cold air to lower elevation landforms (i.e., free air drainage) prevents the likelihood of late spring frosts and is an important component of this ecological site. Average annual precipitation is 32 inches, which includes rainfall plus the water equivalent from snowfall. About 65 percent of the precipitation falls as rain during the growing season (from May through September), and about 21 percent falls as snow (Table 3). Most of the spring snowmelt runs off the steeply sloping or high relief surfaces into high gradient drainageways and then into wetlands, streams or lakes. Most of the rainfall during the growing season is transpired by plants, which leaves a small proportion of the total precipitation for deep aquifer recharge. The high ridges above Lake Superior which support this ecological site receive the most snowfall in Minnesota, averaging over 70 inches annually (Flaccus and Ohmann, 1964; MN DNR, 2013a). This lake effect snow is the result of warm, moist air rising and moving inland from the lake, ultimately cooling to produce localized snowfall (Anderson and Fischer, 2015; MN DNR, 2013a). The average annual low and high temperatures are 28 and 48 degrees Fahrenheit, respectively (Table 3). These data are derived from 30-year averages gathered from four National Oceanic and Atmospheric Administration (NOAA) weather stations contained within the range of this ecological site and located on correlated map units (Table 4).

Table 2. Frost-free and freeze-free days.
(Data were obtained from NOAA weather stations within the range of this ecological site, using 30-year averages.)

	Minimum days	Maximum days
Frost-free period (32.5°F or greater, 90% probability)	97	124
Freeze-free period (Less than 28.5 °F, 90% probability)	131	149

Table 3. Monthly and annual precipitation and Temperature.
(Data were obtained from NOAA weather stations within the range of this ecological site, using 30-year averages.)

Monthly Moisture (Inches) and Temperature (°F) Distribution			
		----------Temperature----------	
	Average Precipitation	**Average Low**	**Average High**
January	1.21	-0.3	19.0
February	0.86	3.5	24.3
March	1.59	14.8	34.5
April	2.63	28.2	48.6
May	3.25	39.0	61.4
June	4.03	48.6	70.2
July	3.64	53.9	75.6
August	3.70	53.1	73.5
September	3.78	44.7	64.0
October	3.35	33.2	50.8
November	2.50	20.7	35.2
December	1.56	6.1	22.6
Annual	32.10	28.8	48.3

Table 4. NOAA climate stations used for data analysis, located within the range of this ecological site.

Station ID	Location	From	To
MN4918	LUTSEN 3NNE	1981	2010
MN8421	TWO HARBORS 7NW	1981	2010
MN9134	WOLF RIDGE ELC	1981	2010
MN4913	DULUTH INTL AP	1981	2010

Influencing Water Features

This ecological site is not influenced by wetland or riparian water features.

Representative Soil Features

These soils were formed in coarse loamy glacial drift, deposited during the first and most extensive advance of the Superior Lobe of the Wisconsin Glaciation. Depth to bedrock is moderately deep (20 to 40 inches to bedrock; Table 5). Drainage class is well drained. Soil family is characterized as coarse-loamy, having less than 18 percent clay within the majority of the rooting zone. Soil textures include sandy loam, loam, silt loam or their gravelly analogues. Coarse fragments are mostly between five and 30 percent, becoming more abundant with depth. Depending on depth to bedrock, available water capacity can range from 1.7 to 6.9 inches (in 40 inches), in stark contrast to the related, and more productive Till Upland Mesic Hardwood Forests ecological sites, which can range from 4.0 to 8.5 inches of available water. Soil pH ranges from very strongly acid to moderately acid (4.5 to 6.0). Small-scale windthrow is an important tree regenerating disturbance on this ecological site. Characteristic pit and mound micro-topography (also known as cradle-knolls) can be scattered throughout a stand and provide microenvironments for certain plants and wildlife. For example, the mounds produce microsites for tree recruitment (Kabrick et al., 1997) and the pits can temporarily hold water, thus allowing species characteristic of wetter environments to persist. The relatively constant supply of downed woody debris is an important characteristic of properly functioning natural communities within this ecological site. Downed woody debris helps the soil retain moisture, provides refuge and habitat for wildlife (particularly amphibians), and act as nurse-logs that are essential for some tree species to regenerate (Table 6; Erdmann, 1990; Great Lakes Worm Watch, 2013; Johnston 1990). The Mesaba series, an Inceptisol, is primarily associated with this site.

Table 5. Representative soil features.
(Data and information presented here were obtained from the National Soil Information System (NASIS) and USDA-NRCS integrated plot data.)

	Minimum	Maximum
Surface Fragments less than 3" (percent cover)	0	1
Surface Fragments greater than 3" (percent cover)	0	1
Subsurface Fragments less than 3" (percent volume)	5	30
Subsurface Fragments greater than 3" (percent volume)	0	7
Soil Depth (in.)	20	40
Soil Reaction/pH (1:1 water)	4.5	6.0
Available Water Capacity (inches in 40")	1.7	6.9

Drainage Class: well drained

Permeability Class (most limiting layer): very slow

Parent Material – Kind: gravelly drift

Parent Material – Origin: various igneous and sedimentary bedrock types

Surface Texture: sandy loam, loam, silt loam

Surface Texture Modifier: gravelly, or none

Subsurface Group: coarse-loamy

Soil Series: Mesaba

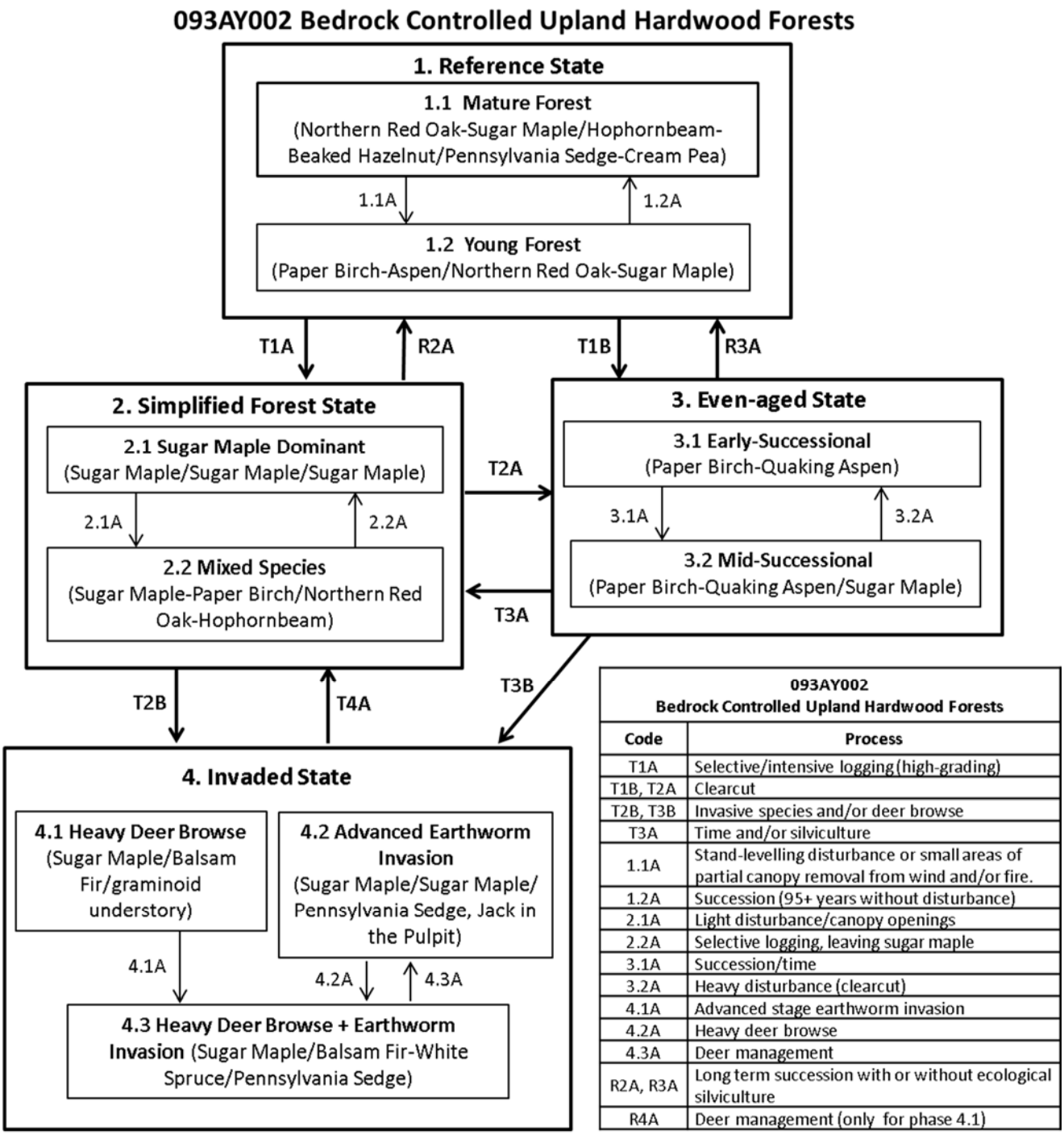
States and Community Phases

Ecological Dynamics

On a multi-regional scale, northern hardwoods forest types are transitional between the oak-hickory types to the south and the boreal forest types to the north (Johnson et al., 2009; Tubbs, 1997). The distribution of this ecological site abuts the southern edge of the boreal forest biome. The climate-moderating effect of Lake Superior allows this forest type to persist (Albert, 1994; Anderson and Fischer, 2015). In addition to Lake Superior's overall temperature moderation, the insulating effect of the elevated snowfall on the rooting zone and the near absence of late spring frosts due to high elevation, free air drainage, provide the opportunity for this forest type to exist in an otherwise inhospitable climate (Albert, 1994; Anderson and Fischer, 2015; Houston, 1999). Even so, this forest type is on the limit of its botanic range and faces a myriad of disturbance factors such as frost cracking, ice damage, and fungal pathogens, as well as herbivory from insects and mammals; and as a result produces comparatively poor quality timber.

Bedrock Controlled Upland Hardwood Forests were historically uneven-aged forests with canopies dominated by a mix of hardwood and coniferous species, ranging in their ability to tolerate shade (Tables 6, 7, and 8). Highly variable available water capacity, due to variable depths to bedrock, allow a diversity of tree species to proliferate on this site. This prevents domination of sugar maple in the canopy, which is common in the related Till Upland Mesic Hardwood Forests ecological site (Figure 2). Hardwood species included: northern red oak, sugar maple, American basswood, and sometimes yellow birch (*Betula alleghanienis*). Shade-tolerant conifers like white spruce and balsam fir were common in older forests. Although rarely encountered today, eastern white pine would theoretically be well suited to compete on these sites. Along with white spruce, they typically occurred as super canopy trees, and regenerated in a variety of settings (MN DNR, 2014). Small to moderate sized canopy openings, produced by light surface fire and wind, allowed paper birch, bigtooth aspen (*Populus grandidentata*) and quaking aspen (*Populus tremuloides*) to be common. These periodic disturbances kept most forests from reaching an old growth stage (i.e., >120 years).

Broad-scale, stand-regenerating disturbances were uncommon, and likely occurred only once in 1,000+ years (MN DNR, 2014; MN DNR, 2005). Nutrient cycling in the forest floor is high, producing enrichment of the soil and resulting in comparatively little accumulation of leaf litter in organic surface horizons (Nyland, 1999). Altogether, these attributes provided little opportunity for



093AY002
Bedrock Controlled Upland Hardwood Forests

Code	Process
T1A	Selective/intensive logging (high-grading)
T1B, T2A	Clearcut
T2B, T3B	Invasive species and/or deer browse
T3A	Time and/or silviculture
1.1A	Stand-levelling disturbance or small areas of partial canopy removal from wind and/or fire.
1.2A	Succession (95+ years without disturbance)
2.1A	Light disturbance/canopy openings
2.2A	Selective logging, leaving sugar maple
3.1A	Succession/time
3.2A	Heavy disturbance (clearcut)
4.1A	Advanced stage earthworm invasion
4.2A	Heavy deer browse
4.3A	Deer management
R2A, R3A	Long term succession with or without ecological silviculture
R4A	Deer management (only for phase 4.1)

Figure 2. State-and-transition model for Bedrock Controlled Upland Hardwood Forests.

large fires to spread. The main regenerating disturbances were light surface fires and light to moderate windthrow (i.e., one too many trees), particularly in areas with shallower soils. This disturbance pattern occurred in an estimated 130 year rotation (MN DNR, 2014; MN DNR, 2005); which is at a higher rate on this ecological site than on other northern hardwoods sites (e.g., Till Upland Mesic Hardwood Forests). Resulting stands allowed all of the aforementioned tree species to perpetuate themselves, and formed were a complex of young and mature forests.

Table 6. Reference State community phase 1.1 ground surface cover, downed wood, and tree snags.
(Data presented are based on ground cover transects at three USDA-NRCS type locations.)

	Type	**Cover (%)**
Ground Surface Cover	Grass/Grasslike	15-25
	Forb	20-35
	Shrub/Vine	5-15
	Tree	3-10
	Non-Vascular Plants	0-1
	Biological Crust	0-1
	Litter	18-30
	Surface Fragments (.25-3”)	1-3
	Surface Fragments (>3”)	1-3
	Bedrock	0-1
	Water	0
	Bare Ground	1-3
Downed Wood	Fine/Small (1-hour)	1-5
	Fine/Medium (10-hour)	1-5
	Fine/Large (100-hour)	3-8
	Coarse/Small (1,000-hour)	1-5
	Coarse/Large (10,000-hour)	0-2
Tree Snags (No./acre)	Hard Snags	10-30
	Soft Snags	10-20

Table 7. Reference State community phase 1.1 canopy cover by height Class.
(Data presented are based on relevè data from three USDA-NRCS type locations.)

	Percent Cover			
Height Above Ground (ft.)	Grass/ Grasslike	Forb	Shrub/ Vine	Tree
0.5	5-25	5-15	1-5	1-5
0.5-1	5-15	15-50	1-5	1-5
1-2	-	5-15	5-15	1-5
2-4.5	-	1-5	25-65	5-25
4.5-13	-	-	5-25	40-75
13-40	-	-	-	50-75
40-80	-	-	-	25-75
80-120	-	-	-	0-20*

*hypothetical estimate to portray historic super canopy

Table 8. Reference State community phase 1.1 overstory.
(Data presented are adapted from USDA-NRCS plot data.)

Species	**USDA Symbol**	**DBH (in)**	**Basal Area (ft^2/ac)**	**Trees Per Acre**
NORTHERN RED OAK (*Quercus rubra)*	QURU	2-15	40-60	30-50
SUGAR MAPLE (*Acer saccharum)*	ACSA3	2-10	5-15	30-50
PAPER BIRCH (*Betula papyrifera)*	BEPA	2-10	5-15	10-20
ASPEN (*Populus tremuloides* or *P. grandidentata*)	POTR5/ POGR4	2-10	5-15	10-20
AMERICAN BASSWOOD (*Tilia americana*)	TIAM	2-10	5-15	10-20
HOPHORNBEAM (*Ostrya virginiana*)	OSVI	2-6	1-2	10-20
WHITE SPRUCE* (*Picea glauca)*	PIGL	20-30	0-10	0-5
EASTERN WHITE PINE* (*Pinus strobus)*	PIST	20-30	0-10	0-5
STAND TOTAL	-	2-30	60-100	100-140

*hypothetical estimate to portray historic super canopy

Due to the dominance of undesirable hardwood tree species, these forests were not clearcut like other forests in the Great Lakes states during settlement times. Instead, they were selectively logged (i.e., high-graded) in multiple pulses during the early part of the Twentieth Century, leaving behind stands of inferior quality and composition (Johnson et al., 2009). Very few old-growth stands exist today. As a result of these selective logging practices, some formerly common overstory species were essentially extirpated, such as eastern white pine. Past logging practices and subsequent slash fires are largely responsible for the forest we see today. Most areas are second- or third-growth, and vary in composition depending on extent and timing of past disturbance and management. Many areas have been significantly affected by exotic earthworms and historically high white-tailed deer (*Odocoileus virginianus*) densities. Earthworms, which were introduced post-settlement, significantly alter soil surface horizons and disrupt nutrient cycling dynamics, and thus directly affect habitat conditions for native flora (Great Lakes Worm Watch, 2013). Increased herbivory resulting from high deer densities has caused decline in many genera and an overall loss of species diversity. Deer and earthworm damage is most prevalent near developed areas.

STATE 1 – REFERENCE STATE

Community phases within the Reference State follow classic successional trajectories. However, stands rarely became old growth because of periodic low severity disturbances, such as light surface fires and small to moderate windthrow events. An estimated rotation of such events is 130 years (MN DNR, 2014 and 2005). This produced a patchwork of young and mature forests of mixed hardwood composition. Sugar maple and northern red oak are the most influential species and can even be co-dominant with paper birch and aspen in the young forest community phase due to their ability to accumulate as advance regeneration. However, if blowdown events are followed by a combination of drought and fire, quaking aspen and paper birch will be favored (Frelich, 1999; Landfire, 2007). As stands age, old paper birch and aspen are still present, but mostly give way to more shade tolerant species, such as younger generations of sugar maple. Historically, older forests had higher cover of coniferous species, including eastern white pine, white spruce, and balsam fir. Forests rarely grew older than 130 years before small to moderate scale regeneration disturbance occurred (MN DNR, 2014), but scattered super canopy trees of eastern white pine and white spruce may have persisted through these events and lived to old age.

Table 9. Reference State community phase 1.1 composition.
(Adapted from MN DNR, 2005 and USDA USDA-NRCS integrated plot data. Not all species are assumed to be present in one location.)

Layer	Common Name	Scientific Name	USDA Symbol	Type	Cover (%)	Height (ft.)
Canopy	NORTHERN RED OAK	*Quercus rubra*	QURU	tree	10-75	40-70
	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	10-50	40-70
	AMERICAN BASSWOOD	*Tilia americana*	TIAM	tree	5-25	40-70
	PAPER BIRCH	*Betula papyrifera*	BEPA	tree	5-25	40-70
	QUAKING ASPEN	*Populus tremuloides*	POTR5	tree	0-25	40-70
	BIGTOOTH ASPEN	*Populus grandidentata*	POGR4	tree	0-25	40-70
	WHITE SPRUCE	*Picea glauca*	PIGL	tree	0-15	80-120
	EASTERN WHITE PINE	*Pinus strobus*	PIST	tree	0-15	80-120
Sub Canopy	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	5-25	16-30
	HOPHORNBEAM	*Ostrya virginiana*	OSVI	tree	5-25	16-30
	NORTHERN RED OAK	*Quercus rubra*	QURU	tree	0-25	16-30
	RED MAPLE	*Acer rubrum*	ACRU	tree	0-25	16-30
Shrub/ Seedling	SERVICEBERRIES	*Amelanchier spp.*	AMELA	tree	5-15	1-10
	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	5-15	1-10
	WHITE SPRUCE	*Picea glauca*	PIGL	tree	0-5	1-10
	BEAKED HAZELNUT	*Corylus cornuta*	COCO6	shrub	15-50	1-10
	ROUNDLEAF DOGWOOD	*Cornus rugosa*	CORU	shrub	5-15	1-10
	AMERICAN FLY HONEYSUCKLE	*Lonicera canadensis*	LOCA7	shrub	5-15	1-5
	BUSH HONEYSUCKLE	*Diervilla lonicera*	DILO	shrub	5-15	1-5
	HAIRY HONEYSUCKLE	*Lonicera hirsuta*	LOHI	shrub	0-5	1-5
	LEATHERWOOD	*Dirca palustris*	DIPA9	shrub	0-5	1-5
Herbaceous	PENNSYLVANIA SEDGE	*Carex pensylvanica*	CAPE6	graminoid	10-50	0.1-1
	WILD SARSAPARILLA	*Aralia nudicaulis*	ARNU2	forb	10-50	0.1-2
	BIGLEAF ASTER	*Eurybia macrophylla*	EUMA2	forb	10-50	0.1-1
	TWISTEDSTALK	*Streptopus lanceolatus*	STLAL3	forb	5-25	0.1-1
	CANADA MAYFLOWER	*Maianthemum canadense*	MACA4	forb	5-25	0.1-1
	WOOD ANEMONE	*Anemone quinquefolia*	ANQU	forb	5-25	0.1-1
	FRAGRANT BEDSTRAW	*Galium triflorum*	GATR3	forb	5-25	0.1-1
	BLUEBEAD	*Clintonia borealis*	CLBO3	forb	5-25	0.1-1
	ROUGHLEAF RICEGRASS	*Oryzopsis asperifolia*	ORAS	graminoid	5-25	0.1-1
	HAIRY SOLOMON'S SEAL	*Polygonatum pubescens*	POPU4	forb	5-25	0.1-1
	STARFLOWER	*Trientalis borealis*	TRBO2	forb	5-25	0.1-1
	COMMON LADY FERN	*Athyrium felix-femina*	ATFI	fern	5-25	0.1-2
	BRACKENFERN	*Pteridium aquilinum*	PTAQ	fern	1-15	0.1-3
	DOWNY YELLOW VIOLET	*Viola pubescens*	VIPU3	forb	1-15	0.1-1

Species list continued

Layer	Common Name	*Scientific Name*	USDA Symbol	Type	Cover (%)	Height (ft.)
	ZIGZAG GOLDENROD	*Solidago flexicaulis*	SOFL2	forb	1-15	0.1-2
	CREAM PEA	*Lathyrus ochroleucus*	LAOC2	forb	1-15	0.1-1
	VIRGINIA STRAWBERRY	*Fragaria virginiana*	FRVI	forb	1-15	0.1-1
	LONGSTALK SEDGE	*Carex pedunculata*	CAPE4	graminoid	1-15	0.1-1
	BANEBERRIES	*Actaea rubra / A. pachypoda*	ACRU2/ ACPA	forb	1-5	0.1-1
	WHIP-POOR-WILL FLOWER	*Trillium cernuum*	TRCE	forb	1-5	0.1-1
	SPREADING DOGBANE	*Apocynum androsaemifolium*	APAN2	forb	1-5	0.1-2
	WAXFLOWER SHINLEAF	*Pyrola elliptica*	PYEL	forb	1-5	0.1-1
	ROUNDLOBE HEPATICA	*Hepatica nobilis* var. *obtusa*	HENOO	forb	1-5	0.1-1
	BEARDED SHORTHUSK	*Brachyelytrum erectum*	BRER2	graminoid	1-5	0.1-1
	LARGEFLOWER BELLWORT	*Uvularia grandiflora*	UVGR	forb	1-5	0.1-1
	BLACK SNAKEROOT	*Sanicula marilandica*	SAMA2	forb	1-5	0.1-1
	GROUNDPINES	*Lycopodium dendroideum / L. hickeyi*	LYDE/ LYHI2	forb	1-5	0.1-1
	DWARF RED BLACKBERRY	*Rubus pubescens*	RUPU	forb	1-5	0.1-1

Small to medium scale windthrow events would have provided habitat for forest interior wildlife, microsites for tree regeneration, and opportunity for some disturbance-adapted species to maintain themselves (such as beaked hazelnut: Kabrick et al., 1997; Landfire, 2007). Coupled with this is the accumulation of coarse woody debris in the way of snags and downed wood in various sizes and levels of decomposition (Table 6; Hale et al., 1999).

Today, good examples of the Reference State are uncommon. However, some do exist in a few state parks or natural areas, mostly limited to northern populations within large intact landscapes having high biological significance. Post-settlement logging and contemporary forest management in part mimic early- and mid-successional dynamics, and are more common today.

Community Phase 1.1 Mature Forest By stand age 95, quaking aspen, paper birch and early-successional shrubs and ground flora have largely subsided (Figure 3). Forest interior, shade-tolerant ground flora take over, particularly spring-flowering species (Table 9). The dominance of sugar maple and yellow birch may begin to subside while the extremely shade-tolerant white spruce and northern white cedar become more prominent in the overstory (MN DNR, 2013b). At this stage the forest is essentially self-sustaining, with small to medium scale wind throw events providing opportunities for gap and patch regeneration (Kabrick et al., 1997). The resulting pit and mound micro-topography adds to habitat and structural complexity, providing unique niches for certain plant and wildlife species. Beyond age 95, the stand continues to develop structural complexity through structural layering as well as build-up of coarse woody debris (Hale et al., 1999). Old stumps, downed logs, and the mounds created from fallen trees provide regeneration sites for species like northern white cedar, yellow birch, and even the sun-loving paper birch (Erdman, 1990; Johnston, 1990; and Safford, 1990). These structural dynamics result in habitat diversity essential to support many species of birds, amphibians, and other forest interior species. Historically, this was a common community phase on the landscape.

Pathway 1.1A - Stand-levelling disturbance or small areas of partial canopy removal from wind and/or fire.

Community Phase 1.2 Young Forest The initiation of the stand development follows windthrow events. Increased light and heat on the forest floor favor ruderal trees and shrubs such as quaking aspen, paper birch, beaked hazelnut, and *Rubus* species. However, dominance can be shared with sugar maple and northern red oak advance regeneration already in place. An estimated 40 percent of these sites burned in the years following the blowdown due to extreme fuel buildup and dry conditions (Landfire, 2007). In these cases, the fire-intolerant suite of overstory dominants (such as sugar maple) would have been further set back, favoring complete dominance of quaking aspen and paper birch.

Pathway 1.2A - Succession (>95 years without disturbance).

Transition 1A - Selective/intensive logging (high-grading) of healthy, large-diameter conifers and subsequently, large-diameter hardwoods.

Transition 1B - Clearcut: mechanical removal of all or nearly all trees.

Figure 3. Reference State (community phase 1.1) for Bedrock Controlled Upland Hardwood Forest ecological site; Mesaba soils. Photo by Kyle Steele, Lake County forest land, Lake County, Minnesota, in September of 2014.

STATE 2 – SIMPLIFIED FOREST STATE

The simplified forest state was a common state that followed the pre-settlement forests, and may be the most common state existing today. In general, forests on this ecological site were not completely cleared like other forests in the Great Lakes states (as in many coniferous forest types). This was largely due to the abundance of less desirable hardwoods, and partially because maple (and other hardwoods) could not be easily transported along waterways (Johnson et al., 2009). Instead, destruction of reference communities came in the way of selective logging of sought after species of adequate size (i.e., high-grading). This occurred in numerous pulses, with large eastern white pine and white spruce removed initially, which likely accounts for the limited occurrence

and/or decline of these species today. In many cases, overstory vegetation turned into monotypic sugar maple stands; however, in other cases some level of diversity in the overstory was secured, although probably less than before. These two situations represent each of the community phases within this state. Like the reference state, these forests tend to be uneven-aged and, with natural succession or careful silviculture (e.g., retention of snags, removal of poor quality trees, etc.), it may be possible to restore some sites to reference conditions (Hale et al., 1999).

Communities in this state are a common occurrence on the modern landscape, particularly in private landholdings, which tend to be unmanaged. Today, depending upon the specific location, there may be early stages of earthworm invasion (e.g., *Dendrobaena octaedra*) as well as some elevated deer browse, but not enough to push it into the Invaded State.

Community Phase 2.1 Sugar Maple Dominant In this phase, sugar maple accumulates to an extreme extent, dominating all structural layers in the overstory, subcanopy, and understory (Figure 4). Presumably all or nearly all other overstory species have been selectively cut, leaving sugar maple to dominate. This is essentially a high-graded condition. By removal of the sub-dominants (e.g., northern red oak and scattered conifers), there is a high potential for near-extirpation of these species from the site, partly because a legacy seed source is no longer present and partly because of the overwhelming competitive nature of sugar maple. Small sugar maple seedlings may also carpet the forest floor, outcompeting forb species and further simplifying the diversity of the ecosystem. Due to the lack of high quality browse and mast, these monotypic stands produce limited habitat for most wildlife species (MN Division of Forestry, 2008), but are often an important local source for maple syrup and probably are under-utilized in this regard.

> Pathway 2.1A - Light disturbance providing canopy openings, possibly coupled with underplanting of appropriate tree species, such as northern red oak, American basswood, yellow birch, white spruce, and eastern white pine. The size of the gap will affect light levels, and thus affect the tree seedlings ability to compete.

Figure 4. Photo of Sugar Maple Dominant community within the Simplified Forest State (community phase 2.1) of Bedrock Controlled Upland Hardwood Forests; Mesaba soils. Photo by Kyle Steele at Magney-Snively Natural Area, City of Duluth, St. Louis County, Minnesota in July of 2014.

Community Phase 2.2 Mixed Species This community phase is very similar to 2.1 but has higher species diversity in the overstory and understory (Figure 5). It is not well-understood why some sites retain more diversity than others. It is likely these communities may have benefited from legacy trees not removed during post-settlement logging activities. In some cases paper birch, beaked hazelnut, and other sun-loving species are more common, possibly resulting from light to moderate disturbances. This could also be related to inherent site factors affecting drainage and available water capacity. While still within the aforementioned range of correlated soils, these communities are sometimes found on soils containing higher amounts of sand and rock fragments than is typical. This could be enough to allow a greater diversity of vegetation to compete with the sugar maple. It is presumed that the higher diversity in composition and structure characterized by

this community produces better wildlife habitat; however, more investigation is needed to understand these dynamics. Similar management recommendations as described in 2.1 should be considered here. Given time and appropriate silvicultural prescription to improve diversity and structural development, this community phase could be restored to a reference condition.

Pathway 2.2A - Selective/intensive logging (high-grading), leaving sugar maple to dominate. This community may succeed to 2.1 without management in locations where sugar maple is particularly competitive.

Transition 2A - Clearcut, mechanical removal of all or nearly all trees.

Transition 2B - Introduction of exotic earthworms (particularly *Aporrectodea* spp. and *Lumbricus* spp.) or heavy deer browse.

Restoration Pathway 2A - Long term succession (>95 years without disturbance), including a diversity of canopy species (e.g., northern red oak, yellow birch, American basswood, white spruce, eastern white pine, etc.) from natural or artificial regeneration, along with recovery of relevant herbaceous species indicative of the reference state.

STATE 3 – EVEN-AGED STATE

Clearcutting in state 1, or more typically in state 2, will convert the community to an even-aged stand, which is an uncharacteristic age structure for this ecological site. However, community phases within this state can be similar to community phase 1.2 from the reference state, particularly in terms of stand structure. Communities in this state are most common in managed forest settings where forest managers often have goals of improving the sugar maple quality as well as providing better wildlife habitat for various game species, such as white-tailed deer and ruffed grouse (*Bonasa umbellus*: Tubbs, 1977). As the stand matures, opportunities develop for management and restoration to states 1 or 2.

There may be early stages of earthworm invasion (e.g., *Dendrobaena octaedra*) as well as some elevated deer browse in this state, but not enough to significantly alter vegetation or dynamic soil properties.

Figure 5. Photo of Mixed Species community within the Simplified Forest State (community phase 2.2) of Bedrock Controlled Upland Hardwood Forests; Mesaba soils. Photo by Kyle Steele at Magney-Snively Natural Area, City of Duluth, St. Louis County, Minnesota in July of 2014.

Community Phase 3.1 Early-Successional Clearcut management produces the potential for more tree diversity in the future canopy (Figure 6). Due to heavy seedling accumulation and advance regeneration, sugar maple may continue to be a dominant woody species, even in the early years following overstory removal. Due to its ability to stump sprout, northern red oak can be a co-dominant, depending on stand history. Sun-loving species such as quaking aspen and paper birch will be co-dominant, along with other early-successional species. Without fuel management, these areas will be prone to wildfire, particularly if a period of drought follows the clearcut.

Pathway 3.1A - Succession (>40 years without disturbance).

Figure 6. Photo of Early-Successional community within the Even-aged State (community phase 3.1) of Bedrock Controlled Upland Hardwood Forests; Mesaba soils. Photo by Kyle Steele on Lake County forest land, Lake County, Minnesota, in September of 2014.

Community Phase 3.2 Mid-Successional Shade-tolerant species (particularly sugar maple) will begin to accumulate in the understory. Quaking aspen and paper birch begin to die out, while sugar maple, northern red oak, and possibly yellow birch begin to dominate the young forest. Similar transitions are occurring in the herbaceous layer, with shade-tolerant mesophytes becoming more prevalent. After about age 75, a more complex canopy structure develops and dominant and co-dominant trees become more susceptible to windthrow, providing the first opportunities for gap regeneration. During this phase, shade-tolerant coniferous species, such as white spruce, also begin to accumulate in the understory and midstory.

Pathway 3.2A - Clearcut, mechanical removal of all or nearly all trees.

Transition 3A - Succession (>95 years without disturbance), monotypic maple stands.

Transition 3B - Introduction of exotic earthworms (particularly *Aporrectodea* spp. and *Lumbricus* spp.) or heavy deer browse.

Restoration Pathway 3A - Succession (>75 years without disturbance), diversity of canopy species (e.g., northern red oak, yellow birch, American basswood, white spruce, eastern white pine, etc.) from natural or artificial regeneration, along with recovery of relevant herbaceous species indicative of the reference state.

STATE 4 – INVADED STATE

The Invaded State is the furthest removed from the Reference State and can transition here from either state 2 or state 3 following long-term heavy deer browse or advanced stage earthworm invasion from *Aporrectodea* spp. and/or *Lumbricus* spp. This state is more common throughout the southwestern part of this ecological site's distribution, where habitat fragmentation and human development are prevalent. Stands in this state can be either even-aged following clearcutting, or uneven-aged following selective logging.

Herbivory by deer affects both woody and herbaceous vegetation by direct consumption of plant material. In areas of high deer densities sugar maple may become even more favored due to preferential browsing of other woody species, such as yellow birch (Rooney and Waller, 2003). Deer herbivory by itself has the potential to cause extirpation of the most preferred, palatable forb species, such as those in the lily family (Augustine and Frelich, 1998). In extreme cases, vegetation can become so sparse it is possible that changes in soil moisture, soil temperature, and dynamic soil properties may occur; for example, a reduction in soil organic carbon, which may result in a decline in soil moisture or an increase in soil temperature. Overall, elevated herbivory can result in distorted vegetation composition and structure in the forest understory (Alverson et al., 1988; Augustine and Frelich, 1998) and indirectly alter the trajectory of the entire forest ecosystem, thus creating novel, deer-induced natural communities affecting vegetation as well as wildlife patterns (Rooney and Waller, 2003; White, 2012).

This ecological site (and mesic hardwood forests in general) is particularly susceptible to earthworm degradation (Frelich et al., 2006). The type of leaf litter (e.g., sugar maple, American basswood, etc.) these forests produce has high nutritional value for earthworms compared to drier and less nutrient-rich pine and spruce-fir forests (Frelich et al., 2006; Godman et al., 1990). In previous states, the organic surface horizons may or may not have been affected by the epigeic (i.e., above the soil surface) *Dendrobaena octaedra* species of earthworm. This species does not by itself cause transition to the invaded state because it only affects the organic surface horizons, which happens by mixing the Oa (i.e., well decomposed) and Oe (i.e., partly decomposed) horizons, but leaving the Oi (i.e., recent litter) intact (Frelich et al., 2006). The advanced stages of earthworm invasion include the presence of *D. octaedra* as well as the deeper burrowing endogeic (i.e., beneath the soil surface) species in the *Aporrectodea* and *Lumbricus* genera, which cause the most significant dynamic soil property changes (Hale et al., 2006; Loss et al., 2013). *Aporrectodea* and *Lumbricus* species completely consume the organic surface horizons and incorporate that material into the upper mineral soil horizons (Frelich et al., 2006), producing an uncharacteristic bloated A horizon, along with mixing of any existing E horizons (Figure 7).

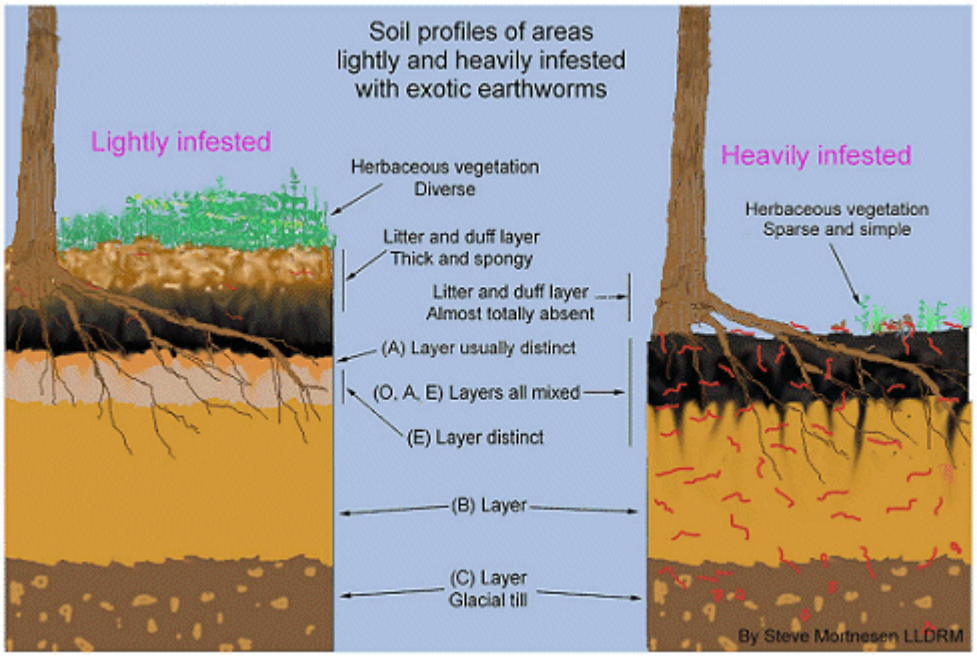


Figure 7. Diagram showing changes in soil and vegetation properties resulting from advanced stages of earthworm invasion. Reproduced with approval by Great Lakes Worm Watch (www.nrri.umn.edu/worms).

In earthworm-free forest soils, there tends to be a net increase in organic material on the soil surface (Great Lakes Worm Watch, 2013). By comparison, in the advanced stages of earthworm invasion, all of this organic material can be completely removed within 3-5 years, making the only input of organic material from new leaf litter each fall, which is quickly consumed, leaving bare soil at the surface by the next fall (Great Lakes Worm Watch, 2013). This process completely alters the nitrogen cycle (in which nitrogen is depleted by leaching) and produces a dense, pan-like layer similar to plowed agricultural soils (Frelich et al., 2006). Changes in dynamic soil properties, such as loss of the organic surface, along with higher bulk densities in the subsoil, produce drier growing conditions for plants, affecting the ability for characteristic native species to persist. The loss of the organic surface also can expose tree roots, potentially causing long-term effects on the life and/or health of trees. However, immature trees (i.e., saplings and seedlings) are likely to be the most at risk to root exposure. Sugar maple seedlings in particular decrease dramatically as a result of earthworm invasion (Hale et al., 2006). Forb seeds also are affected, as the duff layer provides insulation from hot and cold weather extremes and protection from predation by small mammals and birds (Great Lakes Worm Watch, 2013). Another negative consequence of advanced earthworm invasion is the alteration of important soil bacterial and fungal networks, especially symbiotic mycorrhizae, which facilitate essential water and nutrient uptake to many native plant species (Great Lakes Worm Watch, 2013).

Advanced earthworm invasion results in a physically and chemically altered plant rooting environment. Some species are able to handle these changes, while others are not. Pennsylvania sedge (*Carex pensylvanica*), one of the few non-mycorrhizal species, along with wild leeks (*Allium tricoccum*) and jack in the pulpit (*Arisaema triphyllum*), which produce toxic secondary chemicals hazardous to herbivores (and may also be avoided by earthworms), have been shown to increase in these situations (Table 10; Frelich et al., 2006; Holdsworth et al., 2007). In contrast, other species like bigleaf aster, twisted stalk, and wild sarsaparilla tend to decrease (Holdsworth et al., 2007; Great Lakes Worm Watch, 2013). Although earthworms do not kill canopy trees, it is expected that long-term recruitment will be affected, particularly in the sapling stage. This may cause elevated sunlight to the forest floor, increasing the likelihood for dry-mesic, mid-tolerant species to establish (Frelich et al., 2006).

Overall, the combined effects of invasion by deer and earthworms can initiate an ecosystem decline syndrome that can negatively affect all parts of the ecosystem, from overstory structure, to

forb diversity, soil properties, bacteria, fungi, insects, birds, reptiles, amphibians, and mammals. Sites near larger cities, heavily-used lakes, or other developed areas are particularly susceptible to the combination of deer and earthworm problems. Currently, we do not believe any community phases with advanced earthworm invasion can be restored. More research on this topic is needed.

Table 10. List of common plant species documented to increase or decrease following earthworm invasion Reproduced with approval by Great Lakes Worm Watch (www.nrri.umn.edu/worms).

	Decreasers		Increasers	
Life Form	**Scientific Name**	**Common Name**	**Scientific Name**	**Common Name**
Forbs and Sedges	*Aralia nudicaulis*	Wild sarsaparilla	*Arisaema triphyllum*	Jack in the pulpit
	Polygonatum pubescens	Hairy Solomon's seal	*Maianthemum racemosum* subsp. *racemosum*	False Solomon's seal
	Uvularia grandiflora	Largeflower bellwort		
	Uvularia sessilifolia	Sessileleaf bellwort	*Carex pensylvanica*	Pennsylvania sedge
	Streptopus roseus	Twistedstalk		
	Aster macrophyllus	Bigleaf aster		
	Hepatica nobilis var. *obtusa*	Roundlobe hepatica		
	Trientalis borealis	Starflower		
Ferns	*Dryopteris* spp.	Woodferns	None	
Tree Seedlings	*Acer saccharum*	Sugar maple	*Fraxinus* spp.	Ash
	Acer rubrum	Red maple		
	Tilia americana	American basswood		
	Amelanchier spp.	Serviceberry		

Community Phase 4.1 Heavy Deer Browse This community phase can be variable depending on the type, amount, and timing of deer browse. If browse occurs in both summer and winter, all vegetation types are affected. If browse is more common in the winter months, woody vegetation will be affected. In these cases no species are spared, however, balsam fir and white spruce are less preferred (Anderson et al., 2002; White, 2012). If browse occurs in the summer, mostly forb species are affected, often increasing the importance of grasses, sedges (*Carex* spp.), and less palatable forb species, such as jack in the pulpit and wild leeks (Frelich et al., 2006; Rooney and Waller, 2003).

Significant deer browse is most common near developed areas, especially around the City of Duluth. Deer browse is not common in more natural, undeveloped landscapes common in the

northeastern extent of this ecological site. In the summer months, deer use these areas as corridors and sporadically browse individual plants. During the winter months, these sites often experience heavy lake effect snow that can accumulate to several feet in depth. As a result, deer tend to migrate closer to the shore of Lake Superior where temperatures are warmer and there is less snowfall (Chel Anderson, MN DNR Ecologist, personal observation). In addition, the open nature of a hardwood-dominated canopy does not shelter snow well, as one would expect beneath a coniferous forest.

Pathway 4.1A - Advanced stage earthworm invasion by species in the *Aporrectodea* and/or *Lumbricus* genera.

Figure 8. Photo of Advance Earthworm Invasion community within Invaded State (community phase 4.2) of Bedrock Controlled Upland Hardwood Forests; Mesaba soils. Photo by Kyle Steele at Magney-Snively Natural Area, St. Louis County, Minnesota in July, 2012.

Community Phase 4.2 Advanced Earthworm Invasion Advanced stage earthworm invasion from *Aporrectodea* spp. and/or *Lumbricus* spp. (Figure 8). This community phase results in removal of organic duff layers incorporated into the mineral surface horizons, affecting rooting and nutrient availability. Pennsylvania sedge and jack in the pulpit increase while others decrease or become extirpated (Table 10). Downed woody debris decays at an accelerated rate, affecting various wildlife species such as salamanders.

Pathway 4.2A - Heavy deer browse.

Community Phase 4.3 Heavy Deer Browse + Advanced Earthworm Invasion Following the initial pulse of plant mortality by advanced stage earthworm invasion or deer herbivory, the combined effect of both of these unnatural disturbances puts plants at even greater risk of extirpation and produces a more degraded community. Species already affected in 4.1 and 4.2 are now dangerously susceptible to elimination from the site, due in large part to a higher deer-to-plant ratio.

Pathway 4.3A - Deer management.

Transition 4A - Currently there is only one community phase 4.1 believed to be a potentially restorable community, following the management of deer herbivory. At this time there is no evidence showing it is possible to remove earthworms from a forest soil.

Supporting Information

Relationship to Other Established Classifications

Superior National Forest Terrestrial Ecological Unit Inventory (SNF unpublished report a, b); mapping concepts are most similar to:

Landtype: 16 Upland Shallow Loamy Dry

Landtype Phase: 18 Unnamed (moraines on bedrock controlled ridges, well drained, 20-40" to bedrock, many parent materials)

MN DNR Native Plant Community Classification (MN DNR, 2005); the reference community of this ecological site is most similar to:

Primary: MHn35b Northern Mesic Hardwood Forest

Secondary: MHn45a, c Northern Mesic Hardwood (Cedar) Forest

Vegetation Associations (National Vegetation Classification System, NatureServe, 2013a); the reference community of this ecological site is most similar to:

Quaking Aspen – Paper Birch / Sugar Maple – Mixed Hardwoods Forest;

Paper Birch – Sugar Maple – Mixed Hardwoods Forest; or

Sugar Maple – Yellow Birch – (American Basswood) – Forest

Ecological Systems (National Vegetation Classification System, NatureServe, 2013b); the reference community of this ecological site is most similar to:

Laurentian-Acadian Northern Hardwood Forest

Associated Ecological Sites

Depending on adjacent components, this site can exist in complex with both deeper soils, containing rich forests heavily dominated by sugar maple, or with shallower soils, dominated by mixed hardwood-conifer woodlands or sparsely vegetated bedrock shrublands. To date, Till Upland Mesic Hardwood Forests (093AY001) is the only other associated ecological site description developed in the MLRA. That ecological site is commonly mapped adjacent to, and often surrounds Bedrock Controlled Upland Hardwood Forests. In contrast, the soils found on the Till Upland Mesic Hardwood Forests ecological site are very deep (>60 inches to bedrock) and have dense till substrata within 60 inches, making that site richer and floristically more productive. However, these two ecological sites can sometimes appear very similar, especially when in community phases are dominated by sugar maple.

Similar Ecological Sites

Till Upland Mesic Hardwood Forests (093AY001) is both associated and similar to Bedrock Controlled Upland Hardwood Forests. Till Upland Mesic Hardwood Forests are heavily dominated by sugar maple and other species characteristic of richer soils. This ecological site has thicker glacial drift deposit overlying the bedrock (i.e., >60 inches to bedrock, and often greater than 80 inches), and generally has a dense substrata soil horizon within 40 inches. The dense horizon is an aquitard that slows water permeability, and under saturation causes lateral flow downslope. In comparison, the bedrock in Bedrock Controlled Upland Hardwood Forests is an aquiclude. Thus, the main edaphic difference between the two ecological sites is that Till Upland Mesic Hardwood Forests have a thicker root zone which fosters a richer and more productive plant community. They are both considered to be dominated by northern hardwood species.

Bedrock Controlled Upland Hardwood Forests occur on high elevation, often convex bedrock protrusions. The primary landscapes it occurs in include two Landtype Associations: the Sawtooth Mountain Bedrock Complex, and the Tettegouche Till Plain. The same soils (i.e., Mesaba series) are mapped at lower elevations on the long, linear slopes adjacent to Lake Superior, in the North Shore Till Plain. The primary difference may be climate related, as these sites do not readily shed cold air, which produces more prevalent late spring frosts. These sites also do not receive as much snowfall. More research is needed, and it is likely that an additional ecological site will be correlated to these areas.

Inventory Data References

A total of 24 integrated plots, ranging from Tier 2 to Tier 3 intensity, were used as a basis for this ecological site. Three of these were Type Locations representing the data-supported community phase 1.1 in the state-and-transition model (Figure 2), and included all necessary data elements for a Tier 3 dataset (Table 11). No other community phases were supported with quantitative data analysis, and were composed mostly of community phases closely resembling 1.1, 2.1, 2.2 and 4.2. All 24 plots had soil pedon and site data collected by a professional soil scientist using a form equivalent to SF-232. Most pits were hand-dug using spade shovels, sharpshooters, and/or bucket augers. Of the 24 plots, 18 were located at established MN DNR relevé points, obtained and used with permission from the MN DNR County Biological Survey (see list below). List of MN DNR relevé plots used with verified soils data: 890, 914, 5110, 5187, 8274, 8277, 8287, 8288, 8289, 8290, 8300, 8409, 8448, 8482, 8851, 8852, and 8854.

Table 11. Location of Tier 3 data used for Type Locations.

State	County	Ownership	Legal Description	Easting	Northing
Minnesota	St. Louis	Magney-Snively Natural Area, City of Duluth	T49 R15 S28	0556743	5171318
Minnesota	Lake	Lake County Forest	T54 R10 S3	0606442	5227729
Minnesota	Lake	Tettegouche State Park	T56 R7 S6	0630179	5425203

Other References

Albert, D.A. 1994. Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin: A Working Map and Classification. USDA For. Serv. Gen. Tech. Rep. NC-178. St. Paul, MN.

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests Too Deer: Edge Effects in Northern Wisconsin. Conserv. Biol. 2 (4), 348-358.

Anderson, C.E. and Adelheid Fischer 2015. North Shore: A Natural History of Minnesota's Superior Coast. University of Minnesota Press. Minneapolis, MN.

Anderson, C.E., K.A. Chapman, M.A. White, and M.W. Cornett. 2002. Effects of Browsing Control on Establishment and Recruitment of Eastern White Pine (Pinus strobus L.) at Cathedral Grove, Lake Superior Highlands, Minnesota, USA. Nat. Areas J. 22, 202–210.

Augustine, D.J. and L.E. Frelich. 1998. Effects of Deer on Populations of an Understory Forb in Fragmented Deciduous Forest. Conserv. Biol. 12 (5), 995-1004.

Butters, F.K. and E.C. Abbe. 1953. A Floristic Study of Cook County, Northeastern Minnesota. Rhodora 55: 63-101.

Carmean, W.H. 1978. Site Index Curves for Northern Hardwoods in Northern Wisconsin and Upper Michigan. USDA For. Serv. Research Paper NC-160. St. Paul, MN.

Carmean, W.H. 1979. A Comparison of Site Index Curves for Northern Hardwood Species. USDA For. Serv. Research Paper NC-167. St. Paul, MN.

Carmean, W.H., J.T. Hahn, and R.D. Jacobs. 1989. Site Index Curves for Forest Tree Species in the Eastern United States. USDA For. Serv. Gen. Tech. Rep. NC-128. St. Paul, MN.

Erdmann, G.G. 1990. Yellow Birch. In: Silvics of North America, Vol. 2, Burns, R.M., and B.H. Honkala (tech cords). USDA For. Serv. Handb. 654, Washington, DC.

Flaccus, E. and L.F. Ohmann. 1964. Old-growth Northern Hardwood Forests in Northeastern Minnesota. Ecology 45:3, 448-459.

Frelich, L. 1999. Range of Natural Variability in Forest Structure for the Northern Superior Uplands. Minnesota Forest Resources Council. St. Paul, MN.

Frelich, L.E., C.M. Hale, S. Scheu, A.R. Holdsworth, L. Heneghan, P.J. Bohlen, and P.B. Reich. 2006. Earthworm Invasion Into Previously Earthworm-Free Temperate and Boreal Forests. Biol. Invasions 8:1235-1245.

Godman, R. M., H.W. Yawney, and C.H. Tubbs. 1990. Sugar Maple. In: Silvics of North America, Vol 2, Burns, R.M., and B.H. Honkala (tech cords). USDA For. Serv. Handb. 654, Washington, DC.

Great Lakes Worm Watch. 2013 Forest Ecology and Worms. Available online at http://www.nrri.umn.edu/worms/forest/index.html; last accessed December 11, 2013.

Hale, C.M., L.E. Frelich, and P.B. Reich. 2006. Changes in Hardwood Forest Understory Plant Communities in Response to European Earthworm Invasions. Ecology, 87 (7), 1637-1649.

Hale, C.M., J. Pastor, and K.A. Rusterholz. 1999. Comparison of Structural and Compositional Characteristics in Old-Growth and Mature, Managed Hardwood Forests of Minnesota, U.S.A. Can. J. For. Res. 29: 1479-1499.

Holdsworth, A.R., L.E. Frelich, and P.B. Reich. 2007. Effects of Earthworm Invasion on Plant Species Richness in Northern Hardwood Forests. Conserv. Biol. 21 (4), 997-1008.

Houston, D.R. 1999. History of Sugar Maple Decline. In Sugar Maple Ecology and Health: Proceedings of an International Symposium, Horsely S.B. and R.P. Long (eds.), USDA For. Serv. Gen. Tech. Rep., NE-261.

Johnson, P.S., S.R. Shifley and R. Rogers. 2009. The Ecology and Silviculture of Oaks. CABI Publishing, New York.

Johnston, W.F. 1990. Northern White Cedar. In: Silvics of North America, Vol 2, Burns, R.M., and B.H. Honkala (tech cords). USDA For. Serv. Handb. 654, Washington, DC.

Kabrick, J.M., M.K. Clayton, A.B. McBratney, and K. McSweeney. 1997. Cradle-Knoll Patterns and Characteristics on Drumlins in Northeastern Wisconsin. Soil Sci. Soc. Am. J. 61:595-603.

Landfire. 2007 (last updated in January). Landfire National Vegetation Dynamics Models. USDA For. Serv. and U.S. Department of Interior. Washington, DC.

Loss, S.R., R.M. Hueffmeier, C.M. Hale, G.E. Host, G. Sjerven, and L.E. Frelich. 2013. Earthworm Invasions in Northern Hardwood Forests: a Rapid Assessment Method. Nat. Area. J. 33:21-30.

Minnesota Department of Natural Resources. 2014. MHn35 – Northern Mesic Hardwood Forest: Natural Disturbance Regime, Stand Dynamics, and Tree Behavior. Available online at http://files.dnr.state.mn.us/forestry/ecssilviculture/plantcommunities/MHn35.pdf; last accessed November 11, 2014.

Minnesota Department of Natural Resources. 2013a. Climate – Frequently Asked Questions. Available online at http://www.dnr.state.mn.us/climate/faqs.html; last accessed December 11, 2013.

Minnesota Department of Natural Resources. 2013b. MHn45 – Northern Mesic Hardwood (Cedar) Forest: Natural Disturbance Regime, Stand Dynamics, and Tree Behavior. Available online at

http://www.dnr.state.mn.us/forestry/ecs_silv/interpretations.html; last accessed December 13, 2013.

Minnesota Department of Natural Resources. 2005. 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. St. Paul, Minnesota.

Minnesota Division of Forestry. 2008. Northern Hardwoods Cover Type Guidelines. In Minnesota Forest Development Manual. St. Paul, MN.

NatureServe. 2013a. Associations and Alliances of USFS Section 212L in Minnesota. NatureServe, St. Paul, Minnesota.

NatureServe. 2013b. Ecological Systems of USFS Section 212L in Minnesota. NatureServe, St. Paul, Minnesota.

Nyland, R.D. 1999. Sugar Maple: Its Characteristics and Potentials. In Sugar Maple Ecology and Health: Proceedings of an International Symposium, Horsely S.B. and R.P. Long (eds.), USDA For. Serv. Gen. Tech. Rep., NE-261.

Ojakangas, R.W. and C.L. Matsch. 1982. Minnesota's Geology. University of Minnesota Press. Minneapolis, MN.

Rooney, T.P. and D.M. Waller. 2003. Direct and Indirect Effects of Deer in Forest Ecosystems. Forest Ecol. Mgmt. 181: 165-176.

Rosendahl, C.O. and F.K. Butters. 1928. Trees and Shrubs of Minnesota. University of Minnesota Press. Minneapolis, MN.

Safford, L.O., J.C. Bjorkbom, and J.C. Zasada. 1990. Paper Birch. In: Silvics of North America, Vol 2, Burns, R.M., and B.H. Honkala (tech cords). USDA For. Serv. Handb. 654, Washington, DC.

Superior National Forest. Unpublished report (a). Superior National Forest Ecological Landtype Descriptions. USDA For. Serv. Duluth, Minnesota.

Superior National Forest. Unpublished report (b). Superior National Forest Ecological Landtype Phase Descriptions. USDA For. Serv. Duluth, Minnesota.

Tubbs, C.H. 1977. Manager's Handbook for Northern Hardwoods in the North Central States. USDA For. Serv. Gen. Tech. Rep., NC-39, St. Paul, MN.

United States Department of Agriculture (USDA), Natural Resources Conservation Service. 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. USDA Handbook 296. Washington, DC.

White, M.A. 2012. Long-term Effects of Deer Browsing: Composition, Structure and Productivity in a Northeastern Minnesota Old-growth Forest. Forest Ecol. Mgmt. 269: 222-228.

Wright, H. E., Jr., and W.A. Watts. 1969. Glacial and Vegetational History of Northeastern Minnesota. Minnesota Geol. Survey Spec. Pub. 11.

Acknowledgements

Ethan Perry and Chel Anderson (Ecologists, MN DNR - County Biological Survey) provided invaluable guidance throughout the development of this ecological site concept, and participated in development of the state-and-transition model. Jeff Kroll (Ecologist, BARR Engineering – formerly NRCS) was instrumental in the initiation of the ecological site concept. Myles Elsen, Mike Rokus and Larissa Schmitt (Soil Scientists, USDA-NRCS) collected soils point data. Peter Weikle (Soil Data Quality Specialist, NRCS) provided database support. Mark Krupinski (Ecological Site Specialist, NRCS) conducted the quality control review. Stacey Clark conducted the quality assurance review and provided guidance throughout the development of this ecological site description.

Jim Drake (Ecologist, NatureServe), Casey McQuiston and Jim Barott (Soil Scientists, USFS), Greg Nowacki (Regional Ecologist, USFS), Dave Cleland (Asst. National Vegetation Ecologist, USFS), Danielle Evans (GIS Specialist, NRCS), and Carla Green Adams (Editor, NRCS), all helped with the development and publication of this document.

Finally, we thank the MN DNR for the use of their relevè plot database and associated Native Plant Community Classification. This unparalleled work paved the way for our understanding of this ecosystem.

The U.S. Department of Agriculture (USDA) prohibits discrimination against its customers. If you believe you experienced discrimination when obtaining services from USDA, participating in a USDA program, or participating in a program that receives financial assistance from USDA, you may file a complaint with USDA. Information about how to file a discrimination complaint is available from the Office of the Assistant Secretary for Civil Rights. USDA prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex (including gender identity and expression), marital status, familial status, parental status, religion, sexual orientation, political beliefs, genetic information, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.)

To file a complaint of discrimination, complete, sign, and mail a program discrimination complaint form, available at any USDA office location or online at www.ascr.usda.gov, or write to:

USDA
Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, DC 20250-9410

Or call toll free at (866) 632-9992 (voice) to obtain additional information, the appropriate office, or to request documents. Individuals who are deaf, hard of hearing, or have speech disabilities may contact USDA through the Federal Relay service at (800) 877-8339 or (800) 845-6136 (in Spanish). USDA is an equal opportunity provider, employer, and lender.

Persons with disabilities who require alternative means for communication of program information (e.g., Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).