# Characteristics of Sites Supporting Large Paper Birch in the 1836, 1837 and 1842 Ceded Territories

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# INTRODUCTION

Paper birch (*Betula papyrifera* Marshall; Ojibwe *wiigwaasatig*) is one of the northwoods' iconic trees (Figure 1). It is an early-successional species found most often in even-aged stands that have developed after heavy cutting or fire (Marquis et al. 1969, Safford et al. 1990). It is also found in uneven-aged stands as scattered long-lived individuals or small groups, where logging or natural disturbance such as fire or wind created a canopy opening. Paper birch tolerates a wide variety of soil conditions, though it is usually more abundant on mesic to dry sites than on wet or poorly drained soils. The best-developed stands occur on well-drained to moderately well-drained sandy loams, on cool moist sites (Safford et al. 1990, WDNR 2015). Birch exhibits relatively poor development and growth on excessively drained and poorly drained sites (WDNR 2015).

Six intergrading geographical varieties of paper birch occur in North America, two in the Upper Great Lakes region (Safford et al. 1990). Typical paper birch, *B. papyrifera var. papyrifera*, is the most common and widespread variety in the Great Lakes region. It's leaf blades are cuneate (wedge-shaped), rounded, or truncate at the base, with 9 or fewer pairs of lateral veins, the lateral lobes of the ripe catkin scales are held at nearly at right angles to axis, and the mature bark is generally creamy to chalky white or pale (Furlow 1997). Heart-leaf birch, *B. papyrifera var. cordifolia* (Regel) Fernald, has larger leaf blades with mostly cordate (heart-shaped) bases and 9–12 pairs of lateral veins, with lateral lobes of fruiting catkin scales turned toward the apex, and mature bark that is pinkish or brownish white to reddish tan or bronze. Heart-leaf birch is diploid or rarely tetraploid, while typical paper birch is usually pentaploid or hexaploid (rarely tetraploid).

***Figure 1. Paper birch is an iconic tree of North America's cold-temperate and boreal forests. (SCG photo)***

There is still disagreement as to whether heart-leaved birch should be considered a separate species (*Betula cordifolia* Regel) or a variety of *B. papyrifera*, and the range of heart-leaf birch in the Great Lakes region. Voss and Reznicek (2012, see also [http://michiganflora.net/](http://michiganflora.net/) ) consider all Michigan birch specimens examined so far to fit within typical *B. papyrifera*, while Wisflora (2016) considers heart-leaf birch to be a distinct species, widespread in Wisconsin. Furlow (1997) also treats heart-leaf birch as a distinct species, conceding that it could just as well be considered a variety of paper birch. At any rate, genetic variability is probably part of the reason for the variability seen in northwoods birch populations.

With its light, wind-blown seeds, paper birch is a good colonizer of disturbed forest, taking advantage of logging disturbance, abandoned agricultural land and blowdowns (Perala and Alm 1990b, Safford et al. 1990). The seeds generally ripen in August and September, and disperse from September through November, though some dispersal can occur throughout the year (WDNR 2015). Most seed fall within 100 to 200 feet of the parent tree, although seed can blow across the snow for long distances.

Seedlings require exposed mineral soil for establishment, and usually don't survive where there is a substantial leaf layer (Perala and Alm 1990b, Lynch 1997). Seedlings grow best where there is decaying wood in the soil (Perala and Alm 1990b, WDNR 2015). Tip-up mounds, decaying logs and stumps provide important sites for seedling establishment, especially in mixed deciduous forest (Lynch 1997). Seedlings also take advantage of road, pipeline, and power line corridors, though they generally are not allowed to mature on these sites. Fire can create ideal site conditions for the germination, early growth, and survival of paper birch seedlings (WDNR 2015).

While saplings and mature trees have relatively low shade tolerance, shade-tolerance of seedlings is fairly high (Perala and Alm 1990a). Paper birch is a weak competitor with shade-tolerant northern hardwood trees such as sugar maple, yellow birch, hemlock and balsam fir, and generally disappears from such stands after one generation (Marquis et al. 1969).

Paper birch requires fertile sites for best growth. It use relatively high amounts of nutrients and is "particularly sensitive to available soil P" (Perala and Alm 1990a). Across most of its range mature paper birch trees average 10 to 12 inches (25-30 cm) in trunk diameter (dbh) and 70 ft (21 m) in height (Safford et al. 1990). On the best sites occasional trees may reach 30 in (75 cm) in diameter and 100 ft (30 m) in height (Safford et al. 1990, Gleason and Cronquist 1991). Heart-leaf birch can grow even larger, reaching 40 in (102 cm) dbh (Safford et al. 1990). Paper birch trees often grow rapidly in height early on, but slows dramatically after 50 years and typically ends at 60-80 years (WDNR 2015).

Paper birch is relatively short-lived. Trees on good sites may live as long as 140 years (Marquis et al. 1969), though trees over 200 years old have been documented (Safford et al. 1990). Birch stands on poorer sites frequently experience dieback after 60-75 years (Jones et al. 1993). Birch decline is caused by multiple factors including drought, excessive heat, and soil compaction. Dieback of stressed trees is often aggravated by the bronze birch borer (*Agrilus anxius* Gory) (Coleoptera: Buprestidae) (Marquis et al. 1969), an endemic North American beetle that is a close relative of the emerald ash borer. The bronze birch borer generally only attacks stressed and dying trees, so while it may contribute to birch decline it is rarely the primary cause.

Changes in land use practices and forest management appear to be primarily responsible for the decrease in birch in the ceded territory. Most existing paper birch stands in the upper Great Lakes region originated after heavy, extensive logging followed by intense slash fires in the early 1900s

(Lynch 1997). It's sensitivity to severe drought and to elevated soil temperatures are likely to make paper birch increasingly vulnerable as the climate continues to warm.

Paper birch trees (Ojibwe *wiigwaasitigoog)* have been honored and used by the Ojibwe and other North American tribes for centuries, and its importance to Ojibwe culture cannot be overstated. (Densmore 1974, Geniusz 2009). *Wiigwaas* (paper birch bark) is durable and easy to work with. With a few simple folds and some *wiigobimizh* (basswood, *Tilia americana*) fiber or split *gaawaandag* (spruce, *Picea* spp.) roots for stitching, *wiigwaas* can be fashioned into quick containers of all sorts (Densmore 1974). If the container needs to hold water, *zhingob* (usually balsam fir, *Abies balsamea*) or *gaawaandag* (usually white spruce, *Picea glauca*) pitch is applied to *wiigwaas*. *Wiigwaas* is traditionally used for everything from baskets and trays to medicine to wigwam roofing, and birch bark canoes are known worldwide for their beauty and durability (Figure 2). Because of its fundamental role in Anishinaabe culture, paper birch can be considered a "cultural keystone species" (Garibaldi and Turner 2004).

There is widespread concern among tribal elders and those who use birch traditionally about the declining numbers of birch. Canoe makers are particularly concerned, as they need high-quality bark from large trees for their craft. For these traditions to continue, it is critical that healthy, reproducing populations of paper birch continue to be found across the ceded territories.

Unless otherwise noted, plant nomenclature follows Voss and Reznicek (2012).

# TRADITIONAL KNOWLEDGE

## History

A book by Adney and Chappelle (2007) represents a unique record of traditional North American canoe- and watercraft-building. Born in Ohio in 1868, Edwin Tappan Adney met a Malecite Indian man by the name of Peter Joe while on vacation in New Brunswick. Adney became interested in Peter Joe's traditional way of life. In 1889 Peter Joe and he each built a birch bark canoe together, with Adney following his mentor's every step. Adney spent the rest of his life documenting the construction of canoes and other watercraft by tribes across North America, recording detailed information from the people who

***Figure 2. Birch bark canoes from St. Croix complete their maiden voyage across Big Sandy Lake, Minnesota. July 31, 2013. (SCG photo)***

built and used them. After his death in 1950, Howard Chappelle of the Smithsonian Institution went through Adney's "hills of paper" and wrote the only detailed record of the many types of birch bark and other watercraft that once traveled the streams, rivers, lakes and coastlines of North America.

Adney's view of what constitutes high-quality bark for birch bark canoes is summarized as follows: "The thickness of the bark cannot be judged from the size of the tree and may vary markedly among trees of the same approximate size in a single grove. The thickness varies from a little less than one-eighth to over three-sixteenths inch; bark with the thickness of one-quarter inch or more is rarely found. For canoe construction, bark must be over one-eighth inch thick, tough, and from a naturally straight trunk of sufficient diameter and length to give reasonably large pieces. The "eyes" must be small and not so closely spaced as to allow the bark to split easily in their vicinity." He notes that "...the lower part of the tree, to about the height of winter snows, has bark that is usually rough, blemished and thin", while the bark above this line up to the lowest branches "is often only slightly blemished and is thick and well formed."

Adney and Chappelle (2007) note that the bark of many other trees was once used in canoe construction, including spruce, elm (*Ulmus* spp.), chestnut (*Castanea dentata*), hickory (*Carya* spp.), basswood and cottonwood (*Populus deltoides*). These generally made inferior quality canoes though, and were only used for temporary or emergency use.

# Conversations with Tribal Members

To start my search for "big" birch I visited several tribal reservations of Ojibwe member tribes and met with elders and craftspeople knowledgeable about gathering canoe bark and constructing canoes. On June 21, 2016 I met with tribal elders and skilled traditional craftsmen Boycee (Leon Valliere) and Biskakone (Greg Johnson) at the Lac du Flambeau reservation in Lac du Flambeau, Wisconsin. On July 6, 2016. I visited two sites with Lac Vieux Desert, Michigan tribal elder Roger LaBine. On August 3-4, 2016 I visited the Sokaogon reservation at Mole Lake, Wisconsin, and talked with Sokaogon elder Robert Van Zile and expert canoe-maker Marvin DeFoe of Red Cliff. DeFoe was making a traditional birch bark canoe for the Sokaogon tribe. I also talked on the phone with Bad River tribal member April Stone-Dahl and her husband and canoe-maker Jarrod.

## *What is canoe-quality bark?*

Jarrod Stone-Dahl looks for bark that doesn't delaminate, and that has the smallest lenticels (or "eyes") possible. The most important characteristic is that it doesn't delaminate. Trees with curly outer bark will readily delaminate, causing the layers to split from each other in the canoe. Jarrod prefers a little thinner bark than most people – from ⅛ to ¼ inch thick. If it's any thicker the canoe will be too inflexible.

According to Jarrod, the overall quality of birch bark in Maine and Quebec is much better than here [in the Lake Superior region]. In Quebec there are records of harvesting 25 feet of clear bark, and making canoes from 1 piece of bark ("1-piece canoes"). Here 3-5 panels were historically used.

There never were big trees with that quality of bark here, or at least they were never commonplace. That could be due to climate, genetic factors, or something else.

## *Where trees with canoe-quality bark grow*

Robert Van Zile said that a few people at Mole Lake harvest birch, mostly on the Chequamegon-Nicolet National Forest (CNNF). He said that there are a few big trees around the area, but not a lot. He said that people keep their gathering sites kind of quiet, adding that “If you tell people where you’re harvesting you’ll have lots of people around.”

Boycee said that he looks for canoe-quality birch in ravines, on steep slopes, or other “places where they couldn't get their logging equipment in.” He said that for half the year there are no leaves on the trees. They look for birch in fall, winter and early spring, when you can see through woods.

Biskakone showed me an area with good-quality birch in a mixed, moist northern mesic forest dominated by *aninaatig* or sugar maple (*Acer saccharum*) and *gaagaagiwanzh* or eastern hemlock (*Tsuga canadensis*). He pointed out that it was about 6 degrees cooler in the woods than on the edge of the road corridor, even in the shade. He said the birch bark is ready when the strawberries are ripe. He also showed me an area with scattered, nice-quality trees. These trees were in northern mesic forest stands as well, and some were “elder-approved birch” areas (see below).

Jarrod Stone-Dahl said that when looking for large birch in the CNNF, he prefers mixed mesic forest with rich soil. He looks for places with water nearby, such as around wetlands and lakes. He usually finds himself in maple-basswood (or northern mesic) forest. There may be a couple of giant white pine around. His impression is that there tends to be birch around areas where there are groves of balsam fir up to ⅛ acre or so. He said there isn’t much big birch in the area, and most is less than 12 in (30 cm) diameter. April said that they take maps along, do a fair amount of walking, and mark stuff with a GPS receiver.

April Stone-Dahl mentioned a site in the Moquah sand plains that the CNNF recommended to them, as the site was slated to be clearcut. But the quality wasn’t good so they didn’t take any bark. Another sand plains site had only a couple of trees worth harvesting, so they just left them. She said that it seems like the trees in the sand plains sites are “too exposed to a lot of sun” and develop low quality (rough) bark. She said birch in mixed forest tend to have nice bark.

## *Lac du Flambeau’s inventory system*

Boycee mentioned that the Lac du Flambeau Reservation has 1100 tribal people living on only 12 square miles of land. He said that at LDF, the users of canoe-quality bark have an inventory system to keep track of paper birch trees. He said that “birch trees are like people – nobody has perfect skin.” He added that some trees are more dominant, just like people. “We want to know where these big trees are”, he said. “We may not need them now, but we'd like to know where they are for the future.” He said that “without an inventory, we could hope they're there, but could test 150 trees and not find a good one." He explained that "at Lac du Flambeau the Anishinaabe continue to assess and inventory their surroundings. We use physical location and memory. We know where there is a huge tree. You could get a 16 ft (4.9 m) long by 54 in (137 cm) piece of bark that is ¼ in (0.6 cm) thick." Boycee ended with the point that if you use poor-quality bark, you'll get a poor-quality canoe.

### *Size and age of canoe bark trees*

According to Jarrod Stone-Dahl, not any big birch tree will do. Sixteen inches (41 cm) dbh is minimum for canoe bark, including bottom panels. Sixteen to 22 in (56 cm) is perfect. Bigger bark tends to be scabby. Robert Van Zile mentioned that birch trees have to be at least 80 years old before they produce good canoe bark.

Emery et al. (2014) found that smooth bark (defined as 0-25% rough bark) is significantly more common on birch trees in stands where other trees species dominate.

# METHODS

## Site selection

I attempted to locate sites with large paper birch in several ways. The first few sites were shown to me by tribal members, and are designated with acronyms for their tribe. Many of the subsequent sites were ones approved by tribal elders from GLIFWC member tribes in 2001, as part of an Anishinaabe Wild Plant Traditional Environmental Knowledge project (GLIFWC 2000-2002). (While these sites were considered acceptable for birch bark harvest, they didn't necessarily have trees with canoe-quality bark.) These sites are designated by "EB" and a number in this report. I located two of the eastern UP sites based on advice from Bay Mills tribal elder Dan Tadgerson, while two more were sites that I encountered along the way. These last sites are designated "NS" for "new site". One site was designated with an acronym for its location (AINL).

All but a few of the sites I surveyed had significant amounts of overstory paper birch.  Within these sites I chose areas that seemed to have the largest birch, and that appeared to have at least a moderate degree of internal homogeneity with respect to environmental factors such as light, soil moisture, maturity of the forest and distance from the shoreline and patch edges. I recorded presence and abundance of birch seedlings and saplings, and general topography. I also tried to compile a comprehensive plant list for each site. It was generally too late in the season to detect spring ephemerals and other early-season species, except for the few cases where bulbs (presumably yellow trout lily, *Erythronium americanum*) or dried seed stalks (presumably *Allium tricoccum*) could be found.

The first few sites I surveyed generally did not support trees with canoe-quality bark, but as I gained experience with what exactly constitutes a "good birch site" and a "big" birch, I became better at recognizing these sites and selecting them for surveying. Over 40 sites were visited, of which 23 were surveyed. Sites surveyed for this project are listed in Table 1.

# Data collection and analysis

## *Overview of site surveys*

An intuitive sampling approach was used, based on the judgment of the sampler (see Burt et al. 2014, p. 2). The strategy at first was to simply take notes of the vegetation, soil characteristics, slope, aspect, and other features of each site. As time went on this evolved into a semi-quantitative sampling procedure. I recorded the data for the first several sites in a notebook, before designing a 4-page data form.

After choosing an area to survey, I recorded the GPS coordinates at the approximate middle of the site, using a Garmin 62sc receiver. Then I took 6-7 photos to form a 360º panorama of the site. A soil sample was then taken at this location. For details on soil sampling see below.

After taking the photos and first soil sample, I began working my way out from the point in a roughly spiral pattern, recording all the vascular plants in the area, along with my impressions of their abundances (rare, uncommon, fairly common, common and abundant). I recorded notes on the apparent abundances of paper birch and other trees in the overstory, understory and ground layer. I continued to record new plants while gathering the other data.

Whenever possible all the vascular plants on the site were recorded to species. I collected samples of taxa whose identity was uncertain and verified them later. An exception was made for most Juneberries (*Amelanchier* spp.), which are notoriously difficult to identify without flowers and/or fruit. Juneberries that seemed to have a tree-like form (e.g., one main stem) with closely serrate, glabrous or very sparsely pubescent leaves and distally anastomosing, indistinct veins were assumed to be smooth Juneberry (*A. laevis*), while those with the same characteristics but with moderately pubescent leaves were assumed to be downy Juneberry (*A. arborea*). The “pidgeonholing” of these two Juneberries may have resulted in the omission of *A. interior* from some sites. Roadside and forest edge vegetation often included weedier plant species (native and introduced) that were not present within the stand, and these were not included in the surveys.

While walking through the sites I briefly noted whether earthworms were present. Earthworms are not native to the Ceded Territories or to the glaciated north in general. I also took notes on whether large, old, decayed white pine stumps from the first cut (in the late 1800s and early 1900s) were present, whether the site had been recently logged, whether the forest was fairly young, mature, or approaching old-growth, the rough percentage of overstory birch that were alive or dead, the presence and abundance of birch seedlings and saplings, and other ecological information as appropriate. I also measured the largest birch on each site (see below).

**Table 1. Paper birch sites surveyed for this project. Elder-approved stands were visited by Ojibwe tribal elders in 2001. Stand type and year of origin for US Forest Service stands was obtained from USDA-FS-HNF (2016), USDA-FS-ONF (2015), and USDA-FS-CNNF (2017) as applicable. Notes for elder-approved sites (denoted by "EB") are from GLIFWC (2000-2002).**

| Site | County, state | Date sampled | Land ownership | USFS Stand type | Year of origin | Notes |
|---|---|---|---|---|---|---|
| **AINL** | Bayfield, WI | 2016-09-23 | National Park Service | | — | New site, based on discussion with Marvin DeFoe, Red Cliff. |
| **EB01** | Price, WI | 2016-09-28 | Chequamegon-Nicolet National Forest | Paper birch | 1958 | Approved by Joe Chosa, Lac du Flambeau |
| **EB05** | Sawyer, WI | 2016-09-14 | Chequamegon-Nicolet National Forest | Mixed upland hardwoods | 1920 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB06** | Ashland, WI | 2016-09-09 | Chequamegon-Nicolet National Forest | Mixed upland hardwoods | 1953 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB08** | Bayfield, WI | 2016-08-24 | Chequamegon-Nicolet National Forest | Northern red oak | 1934 | Approved by Leo LeFernier and Dick Gurnoe, Red Cliff |
| **EB15** | Chippewa, MI | 2016-10-03 | Hiawatha National Forest | Paper birch, northern red oak | 1930, 1948 | Approved by Audrey Lyons, William LeBlanc, and Keith Cameron, Bay Mills |
| **EB17** | Chippewa, MI | 2016-10-04 | Hiawatha National Forest | Aspen-white spruce/balsam fir | 1947 | Approved by Audrey Lyons, William LeBlanc, and Keith Cameron, Bay Mills |
| **EB23** | Houghton, MI | 2016-09-19 | Ottawa National Forest | Quaking aspen | 1928 | Approved by Virgil Loonsfoot, Keweenaw Bay |
| **EB26** | Bayfield, WI | 2016-09-08 | Chequamegon-Nicolet National Forest | Paper birch | 1948 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB27** | Bayfield, WI | 2016-09-07 | Chequamegon-Nicolet National Forest | Quaking aspen, oak-hardwoods | 2012, 1947 | Approved by Art Tainter, Lac Courte Oreilles, with concern that hillside access might be difficult for elders |
| **EB28** | Bayfield, WI | 2016-08-23 | Chequamegon-Nicolet National Forest | Mixed upland hardwoods | 1923 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB30** | Bayfield, WI | 2016-09-02 | Chequamegon-Nicolet National Forest | Mixed upland hardwoods | 1918 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB31** | Bayfield, WI | 2016-08-25 | Chequamegon-Nicolet National Forest | Paper birch | 1920 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB34** | Bayfield, WI | 2016-08-31 | Chequamegon-Nicolet National Forest | Paper birch | 1920 | Approved by Art Tainter, Lac Courte Oreilles |
| **EB39** | Forest, WI | 2016-10-10 | Chequamegon-Nicolet National Forest | Paper birch | 1930 | Approved by Peter McGeshick, Jr. and Roger McGeshick, Sokaogon |
| **EB44** | Sawyer, WI | 2016-09-14 | Chequamegon-Nicolet National Forest | Paper birch, hemlock | 1925, 1887 | Approved by Clarence Crowe, Bad River |
| **KBIC** | Baraga, MI | 2016-06-28 | US Bureau of Land Management | | — | Visited with DeAnna Hadden, Keweenaw Bay Indian Community |
| **LDF** | Vilas, WI | 2016-06-21 | Lac du Flambeau Reservation | | — | Visited with Greg Johnson, Lac du Flambeau |

| | | | | | | |
|---|---|---|---|---|---|---|
| **LVD** | Ontonagon, MI | 2016-07-06 | Ottawa National Forest | Sugar maple | 1938 | Visited with Roger LaBine, Lac Vieux Desert |
| **NS01** | Bayfield, WI | 2016-08-24 | Chequamegon-Nicolet National Forest | Paper birch | 1939 | New site. |
| **NS02** | Vilas, WI | 2016-09-29 | Chequamegon- Nicolet National Forest | Paper birch | 1925, 1930 | New site. |
| **NS03** | Chippewa, MI | 2016-10-05 | Hiawatha National Forest | Sugar maple-beech/yellow birch | — | New site, based on tip from Dan Tadgerson, Bay Mills. |
| **NS04** | Florence, WI | 2016-10-11 | Chequamegon- Nicolet National Forest | Mixed upland hardwoods | 1920 | New site, based on discussion with Larry Van Zile, Sokaogon. |

Site surveys were generally completed in 4-6 hours. After completing the surveys I attempted to classify the Wisconsin and Michigan sites into habitat types following Kotar et al. (2002) and Burger and Kotar (2003), respectively. Within climatic regions, soil characteristics and topography are the primary factors determining the composition of the plant community on a given site (Kotar et al. 2002).

## *Large birch tree measurement*

At the suggestion of GLIFWC Wildlife Section Leader Jon Gilbert, I began recording the diameter (dbh) of the 12 largest paper birch trees that I could find on each site. If large birch were fairly abundant and scattered I usually recorded a few extra trees to try and get the 12 largest in the area. I recorded the locations and diameters of these trees with the Garmin 62sc. I later revisited the first several sites and obtained birch dbh measurements for those.

The dbh values for the 12 largest paper birch trees measured at each site were included in this analysis. For trees with two or more trunks, all trunks were measured but only the trunk with the largest diameter was included in the analysis.

## *Floristic Quality Assessments*

I calculated Floristic Quality Index for each of the sites using the Universal Floristic Quality Assessment (FQA) Calculator, at www.universalfqa.org (see also Freyman et al. 2015). For purposes of comparison across sites I ran all the sites through both the Michigan FQA database (Reznicek et al. 2014) and the Wisconsin north-central and northeastern database (Parker et al. 2014).

The Floristic Quality Assessment method was designed to measure the natural quality or environmental integrity of a site, as compared to conditions before European settlement. It is based upon a coefficient of conservativism (C) value assigned to each native vascular plant species. C-values range from 1 to 10, representing the affinity of each plant for natural, unaltered communities (that is, its fidelity to a pre-settlement community). Plants with little or no affinity to natural communities (such as *Pteridium aquilinum*, bracken fern) are given low values (0 in the Michigan database), while those which are almost always restricted to specific natural communities (e.g., *Poa interior*, interior bluegrass) are given high values (in this case, 10 in the Michigan database). Intermediate values are given to those found to one degree or another in degraded communities. Non-native species by definition do not have an affinity to native plant communities, so species that are not native to their respective state are given C-values of 0.

The floristic quality index (FQI) for a site is calculated by first finding the mean C-value ($\overline{C}$), where $\overline{C} = \Sigma Ci / n$, i =1...number of native taxa and n = the total number of plant taxa. $\overline{C}$ is then multiplied by $n^{½}$ to give the site's FQI. (Equivalently, FQI = $\Sigma C_i / n^{½}$.) Multiplication by $n^{½}$ corrects to some extent for the tendency of larger sites to contain more species.

The Wisconsin database has a higher total mean C-value (4.2) than the Michigan database (4.1), even though the mean C for Michigan native species (6.5) is higher than for Wisconsin (6.4).

Both FQA databases also include coefficients of wetness for each species, giving the estimated probability of each species occurring in wetlands. These values were based on US Army Corps of Engineers National Wetland Plant List for the Northcentral and Northeast Region (Lichvar 2012, cited in Slaughter et al. 2014; see also Lichvar et al. 2016). Plants fall into five possible wetness categories: upland, facultative upland, facultative, facultative wetland, and obligate wetland. These categories are assigned coefficients of wetness (W-values) of +5, +3, 0, -3, and −5, respectively. Thus a plant that almost never occurs in wetlands would have a W-value of +5, a plant that is primarily upland but occasionally occurs in wetlands would rate a +3, etc., on down to zero (equally likely to occur in wetlands as in uplands), and continuing to -3 and −5 (occurs almost exclusively in wetlands). This wetness index ($\hat{W}$) for a site simply equals the mean of the individual W-values of all its constituent species (or $\hat{W} = \Sigma W_j / n$, with j = 1...n).

While the FQA method is admittedly somewhat subjective, it is based on decades of experience by seasoned field botanists and is standardized and repeatable. A rule-of-thumb for Michigan is that areas with values of > 35 "possess sufficient conservatism and richness that they are floristically important from a statewide perspective", while areas with values of >50 are now rare and represent significant native biodiversity and natural landscapes (Herman et al. 2001). FQI scores are sensitive to area, landscape patterns, and physiognomy though, limiting their usefulness in assessing the relative conservation value of different sites (Slaughter et al. 2015). Therefore FQI and $\overline{C}$ scores should be used as but one component of an ecological integrity assessment (Slaughter et al. 2015).

Before running the FQA calculations I modified the Parker et al. (2014) FQA database for Wisconsin to include *Poa interior*, a native bluegrass that was tentatively identified from one Wisconsin site but not previously recorded from the state. Values for *P. interior* (C = 10, W = 0) follow the Michigan database (Reznicek et al. 2014).

## *Community similarity*

Sørensen coefficients of community similarity were calculated for each pair of sites following Magurran (2004). Coefficients for the presence/absence version of this index are calculated as SS = 2a/(2a + b + c), where

> SS= Sørensen similarity coefficient,
> a = number of species common to both sites,
> b = number of species unique to the first site, and
> c = number of species unique to the second site.

An alternative formula is SS = $2a/(N_b + N_c)$, where a = the number of species common to both sites, and $N_b$ and $N_c$ = the number of species found in the first and second site respectively. As is standard practice, the Sørensen coefficients were multiplied by 100 to give percentages.

The theoretical maximum for the Sørensen qualitative index is 1.0 or 100% (Wolda 1981). When sample sizes are unequal however, the expected maximum is somewhat less than 1.0. Presence-absence similarity coefficients are relatively low-resolution measures for judging similarity between communities because they weight rare species the same as common species, and do not take commonness and scarcity into consideration (Krebs 2014).

## *Soil sampling and analysis*

### *Sample collection*

I collected the soil samples using a garden trowel. The first sample was taken after the photos, at the middle of the site. For all but three sites, I took two additional soil samples at representative locations towards opposite ends of the site. Samples were usually taken in the vicinity of large paper birch. Sampling locations were recorded with the Garmin 62sc.

At each point, I scraped aside the duff layer and other loose organic material before excavating a cylindrical hole to the depth of the 6 inch long trowel blade. I placed the soil from the middle and bottom of the sample into a 90 mL snap-top plastic vial.

At each soil sampling location I did a soil “feel test”, following the flow chart given by USDA-NRCS (2016). With experience this test can be as accurate as most other field soil texture determination methods (USDA-NRCS 2016). Soil from middle of each hole was used for this test as well.

As with birch dbh measurements, I revisited several of the early sites and collected soil samples. I obtained three “representative” soil samples from all the sites (four for NS03) except for EB05 (one sample) and LVD, EB23 and EB44 (two samples).

### *Sample preparation*

I air-dried soil samples on a sheet of 8.5 x 11 inch (21.6 x 27.9 cm) white office paper in the GLIFWC offices. Samples collected while working from home were placed into the refrigerator until they could be dried. After drying, samples were placed back into their respective vials.

After removing any rootlets, pebbles and other non-soil material from each sample, I mixed each sample with a spoon, crushing any aggregates. The air-dried soil was then placed back into the snap-top vial until needed.

### *Soil pH*

Soil pH was measured using a slightly modified version of the 1:1 water pH and 1:2, 0.01 M calcium chloride pH determinations, as outlined in Burt (2014, p. 276-279). I used a Hanna HI98128 pH meter with temperature correction (Hanna Instruments Inc., Woonsocket, RI) to measure soil pH.

For each sample I poured 20 g of dry soil into a cylindrical 2.125 inch diameter by 5.0 inch tall (5.4 cm by 12.7 cm) glass olive jar, and mixed it with 20 mL of distilled water. [While Burt (2014) recommends deionized water for this test, the dissolved $CO_2$ in distilled water has “practically no effect” on the results, except for soils well above pH 7 (McLean 1982, p. 203).]  I allowed the sample to stand for 1 hour, stirring occasionally with a glass stirring rod. At the 1-hour mark I stirred the sample for about 30 seconds, waited 1 minute and then measured the pH ($pH_w$) with the meter, holding the sensor just above the soil sediment. I then added 20 mL of 0.02 M $CaCl_2$ to the soil suspension, resulting in a final soil-solution ratio of 1:2, 0.01 M $CaCl_2$. After stirring the solution for 1 minute and waiting for 1 minute I took the second reading ($pH_s$). The sensor was rinsed with tap water and then distilled water before testing the next sample. Use of $CaCl_2$ is recommended to mask differences in salt concentration that can displace $H^+$ and $Al^{3+}$ ions, resulting in artificially low pH readings (McLean 1982).

The pH values for each sample were converted to hydrogen ion concentrations ($[H^+]$, in mol/L) before calculating the mean and 90% confidence interval for each site using the t-distribution. Values were then converted back to pH values ($-\log[H^+]$). The 90% confidence intervals were also calculated using the t-distribution.

### *Soil particle size*

Soil texture was measured using a simple soil settling technique outlined by Whiting et al. (2002-2011). After testing the pH I poured the rest of the soil sample being tested into the olive jar. (This was done in order to have enough soil for an accurate test.) Then 100 ml of tap water was added until the jar was about three-quarters full. I added one-half teaspoon of powdered, non-foaming dishwasher detergent to the sample, screwed the lid on and shook the sample hard for 10 minutes. This shaking breaks apart the soil aggregates and separates the soil into individual mineral particles. I then set the jar where it will not be disturbed.

After 1 minute I marked the depth of the sand on side of the jar. I measured the silt depth after 2 hours, and the clay level after the water had mostly cleared, typically several days to a week. The thickness of each layer was used to calculate the percent sand, silt and clay in each sample. Soil texture class was calculated from percent sand, silt and clay using an online spreadsheet calculator (Van Lear 2008).

# RESULTS

## Habitat types

The surveyed birch sites spanned all five of Kotar et al.'s (2002) broad habitat type groups, based on soil moisture and nutrient levels (Table 2). Twelve of the sites fell into group 4 (mesic, medium to very rich nutrient level) with four falling under group 3 (dry mesic, poor to rich) and four under group 2 dry to dry-mesic, poor to medium). The only group 1 site (very dry to dry, poor) was EB08, in the Moquah sand plains. This site supported relatively small birch with relatively low-quality bark.

The single most common habitat type was ATM, or sugar maple-eastern hemlock/wild lily-of-the-valley (Table 2). This group 4 habitat type is found on "well to moderately well-drained soils on moraines and water-worked till" (Kotar et al. 2002). Three sites appeared to be the very similar, group 4 ATD habitat type - sugar maple-eastern hemlock/spinulose shield fern. Four sites were variants of the group 2 PArVAa (white pine-red maple/blueberry-wild sarsaparilla) habitat type, found on sandy, poor to medium-nutrient soils.

## Large diameter birch trees

The diameters of the 12 largest birch trees varied substantially between sites (Figure 3, see also Table 3 for summary statistics). The site with the largest median paper birch diameter was AINL (for Apostle Islands National Lakeshore), an old-growth ATM site on a north-facing hill near Lake Superior (Table 2). This was followed by NS03, classified as AFPo (defined as mesic, medium-nutrient). This site occupied a steep northwest-facing hillside about 0.1 mile from Lake Superior. Third was EB05, a mesic, inland ATD site with "medium to rich" nutrient levels and "well-drained loamy till and loess". Fourth was NS04, an inland site approaching old-growth on fairly level ground. NS04 is a mesic site on "well-drained loamy till and loess" with "medium to rich" soils.

Fifth was EB23, a "dry to dry-mesic", "poor to medium" nutrient site on "sand to sandy loam on glacial outwash and moraines". This inland site occupied a low ridge bordered by open, boggy sedge meadows to the north and sandy, well-drained woods to the south. Sixth was EB01, classified as a wet- to wet-mesic, poor nutrient inland site on nearly level ground. All of these sites supported

**Table 2. Kotar habitat types and characteristics of paper birch sites surveyed for this project. Habitat types indicate the types of mature plant communities an area or site will support, based primarily on understory "indicator" species present on the site (Kotar et al. 2002). Wisconsin and Michigan habitat types were assigned following Kotar et al. (2002) and Burger and Kotar (2003), respectively. * = Michigan habitat.**

| Site | Habitat Group | Group Description | Habitat Type | Type Description | Landforms and Soils | Moisture Regime | Nutrient Regime |
|---|---|---|---|---|---|---|---|
| **AINL** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **EB01** | G5 | Mesic to wet-mesic, poor to rich | ArAbVC | Red maple-Balsam fir/ Blueberry-Goldthread | Somewhat poorly drained sands. Occurs on most landforms, but most common on pitted outwash. | Mesic to wet-mesic | Poor |
| **EB05** | G4 | Mesic, medium to very rich | ATD | Sugar maple-Eastern hemlock/ Spinulose shield fern | Well-drained loamy till and loess. | Mesic | Medium to rich |
| **EB06** | G4 | Mesic, medium to very rich | ATD | Sugar maple-Eastern hemlock/ Spinulose shield fern | Well-drained loamy till and loess. | Mesic | Medium to rich |
| **EB08** | G1 | Very dry to dry, poor | PArV-U | White pine-Red maple/ Blueberry and Sessile bellwort variant | Deep, excessively drained outwash sands. | Dry | Poor |
| **EB15** | G3* | Dry mesic, poor to rich | AFPo | Sugar maple-American beech/ Hairy Solomon's seal | Well to somewhat excessively drained deep sands and loamy sands on a variety of landforms. Gravely, cemented and mottled layers are common. | Mesic | Medium |
| **EB17** | G2 | Dry to dry-mesic, poor to medium | PArVAa | White pine-Red maple/ Blueberry-Wild sarsaparilla | Excessively to well drained sandy soils on deep lacustrine deposits of sand and gravel. | Dry to dry-mesic | Poor |
| **EB23** | G2 | Dry to dry-mesic, poor to medium | PArVAa[w] | White pine-Red maple/ Blueberry-Wild sarsaparilla [Wisconsin variant] | Sand to sandy loam on glacial outwash and moraines. | Dry to dry-mesic | Poor to medium |
| **EB26** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **EB27** | G3 | Dry mesic, poor to rich | AVVb* | Sugar maple/Blueberry-Maple-leaved viburnum | Well drained sandy loams and loamy sands on rolling moraines and pitted outwash. | Dry-mesic | Medium |
| **EB28** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **EB30** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **EB31** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **EB34** | G2 | Dry to dry-mesic, poor to medium | PArVAa-Po | White pine-Red maple/ Blueberry-Wild sarsaparilla habitat type, Hairy Solomon's seal variant | Sandy outwash soils, but also water worked sands on moraines and lake plains. | Dry to dry-mesic | Poor to medium |
| **EB39** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **EB44** | G5 | Mesic to wet-mesic, poor to rich | TMC | Eastern hemlock/Wild lily-of-the-valley-Goldthread | Somewhat poorly drained soils on most landforms. Most common on sandy loams on moraines. | Mesic to wet-mesic | Medium |
| **KBIC** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Loamy sand and sandy loam soils on end moraines and outwash covered moraines. | Dry-mesic to mesic | Medium |
| **LDF** | G4 | Mesic, medium to very rich | ATM | Sugar maple-Eastern hemlock/ Wild lily-of-the-valley | Well to moderately well-drained loamy soils on moraines and water-worked till. | Dry-mesic to mesic | Medium |
| **LVD** | G4 | Mesic, medium to very rich | ATM-O | Sugar maple-Red maple/Stiff club-moss | Sandy loam soils over clay on clay and lacustrine deposits. | Mesic | Medium |
| **NS01** | G2 | Dry to dry-mesic, poor to medium | PArVAa-Po | White pine-Red maple/ Blueberry-Wild sarsaparilla habitat type, Hairy Solomon's seal variant | Sandy outwash soils, but also water worked sands on moraines and lake plains. | Dry to dry-mesic | Poor to medium |
| **NS02** | G3 | Dry mesic, poor to rich | AVVb | Sugar maple/Blueberry-Maple-leaved viburnum | Well drained sandy loams and loamy sands on rolling moraines and pitted outwash. | Dry-mesic | Medium |
| **NS03** | G3* | Dry mesic, poor to rich | AFPo | Sugar maple-American beech/ Hairy Solomon's seal | Well to somewhat excessively drained deep sands and loamy sands on a variety of landforms. Gravely, cemented and mottled layers are common. | Mesic | Medium |
| **NS04** | G4 | Mesic, medium to very rich | ATD | Sugar maple-Eastern hemlock/ Spinulose shield fern | Well-drained loamy till and loess. | Mesic | Medium to rich |

mature to old-growth forest, with tall paper birch that generally lacked branches below their canopy-level crowns.

The site that had the smallest median and maximum dbh for the 12 largest trees was EB08. This Moquah sand plains site was classified as habitat type PArV-U, defined as “dry” and “poor” nutrient, on “deep, excessively drained outwash sands.” Next lowest was EB30, an ATM site defined as being dry-mesic to mesic, with medium nutrient levels and “moderately-drained loamy soils” or “well-drained sandy loams”, followed by EB27, an AVVb site defined as having “well-drained sandy loams and loamy sands on rolling moraines and pitted outwash.”

The site with the two largest trees (25.2 and 23.7 in, or 63.9 and 60.3 cm dbh) was EB39, an inland site classified as ATM. Both these trees were relatively short for their diameter, with low branches and low-quality bark. [The largest-diameter birch I saw in 2016 was a 107 in (271 cm) dbh tree on the edge of the woods next to the lawn of the Peter White camp in Alger County, Michigan. This tree was also branchy and relatively short, with rough, cracked bark.] The largest birch at site EB23 (22.9 in or 58.1 cm dbh) grew on the edge of the woods and a sandy opening, while the second and third largest trees at NS03 (22.1 and 22.0 in, or 56.1 and 55.8 cm dbh) grew on the edge of a power line corridor. Figure 4 shows the median and maximum diameter paper birch for the sites, labeled by habitat type. Figure 5 shows the same sites, labeled by nutrient regime.

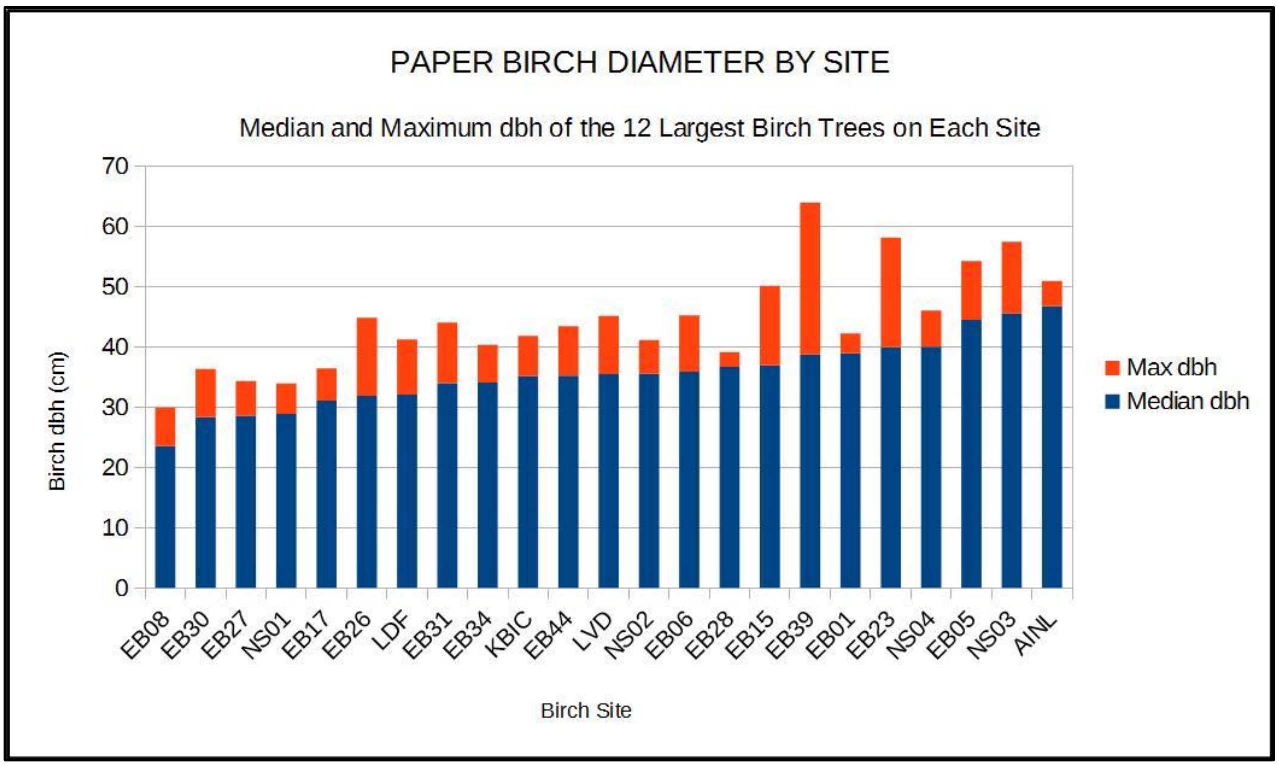


**Figure 3. Sites ranked from low to high, based on median diameter of the 12 largest paper birch trees on each site.**

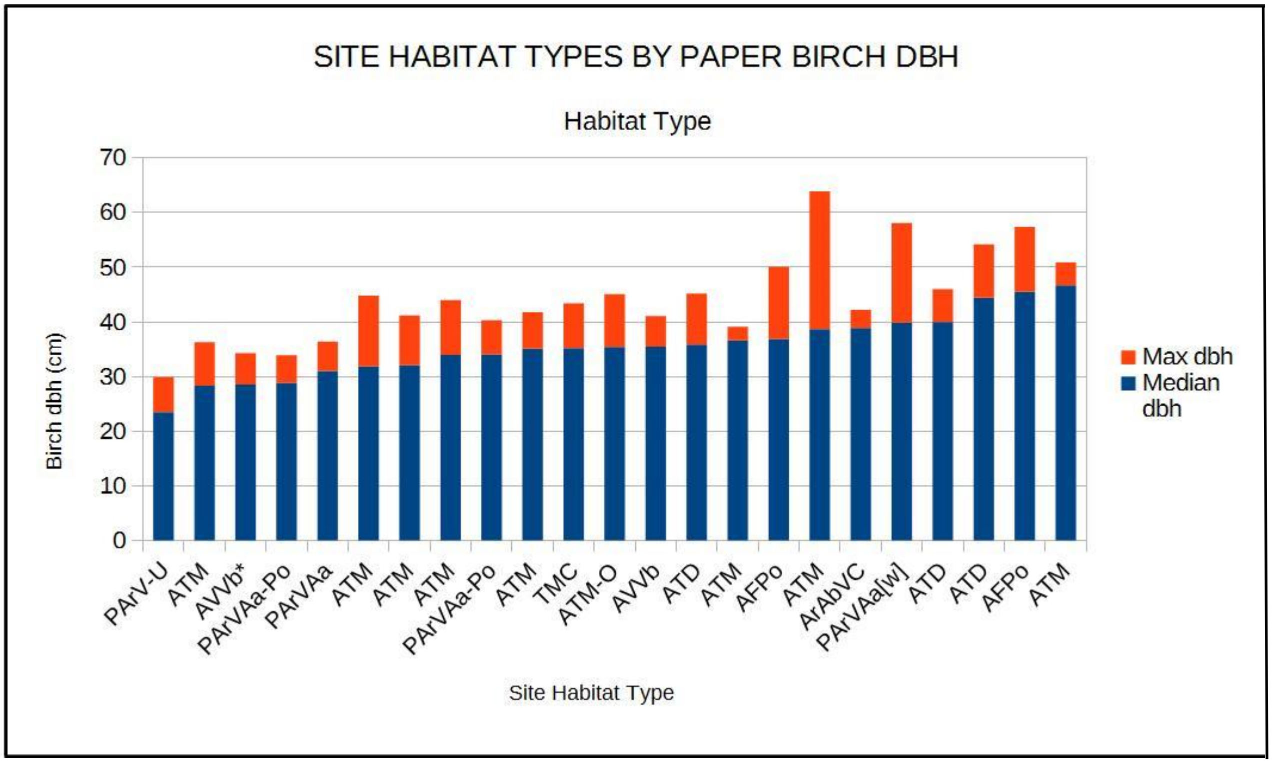


**Figure 4. Paper birch sites ranked as in Figure 1, labeled by habitat type (Kotar et al. 2002, Burger and Kotar 2003).**

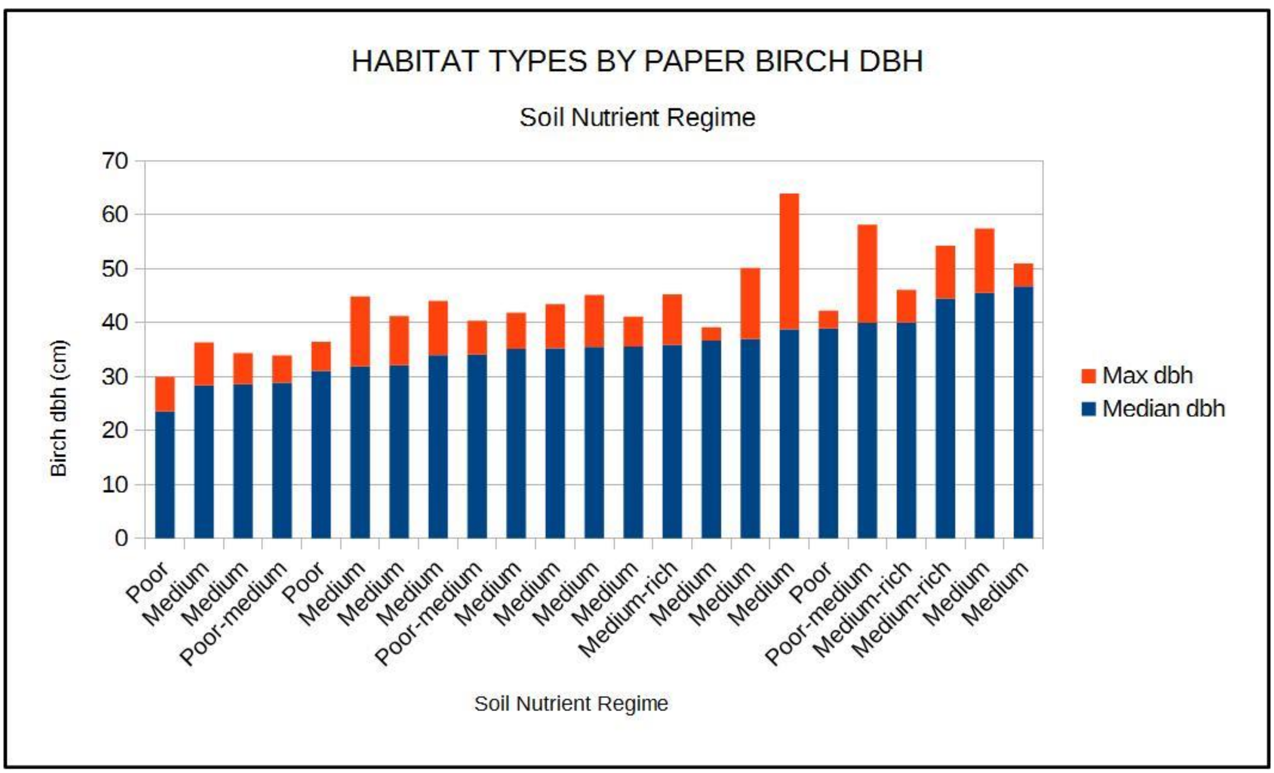


**Figure 5. Paper birch sites ranked as in Figure 1, labeled by habitat nutrient regime (Kotar et al. 2002, Burger and Kotar 2003).**

A power regression between median birch dbh and the nutrient regime of each site (reclassified as poor = 1 to rich = 4) accounted for only a small portion of the variability between the two variables ($r^2$ = 0.17). Nutrient regime was somewhat positively correlation with median birch dbh (r = 0.41).

# Floristic Quality Assessment

## *Floristic quality indices*

The Wisconsin database ranked EB44 highest in terms of floristic quality. EB44 was the only site classified as TMC. Next highest was the ATD site EB05, followed the ATM site EB39. The Michigan database switched the rankings of first two sites, giving EB05 the highest ranking, followed by EB44 and EB39. While none of the sites scored a Michigan FQI value of >50, considered by Herman et al. (2001) to be areas that are "rare and represent significant native biodiversity and natural landscapes", 16 had values of >35, and so "possess sufficient conservatism and richness that they are floristically important from a statewide perspective".

Site EB08 ranked last using the Wisconsin database and third from last using the Michigan database. This site was a PArV-U habitat on excessively-drained, low-nutrient sands (Table 2). Next lowest for the Wisconsin database and lowest in Michigan was EB17, an eastern UP site with habitat type PArVAa, also dry- to dry-mesic with low nutrient levels. Third lowest in Wisconsin and second lowest in Michigan was EB30, an ATM site in south central Bayfield County.

The average floristic quality was lower for the sites using the Michigan database than the Wisconsin database. Summary statistics for floristic quality are listed in Table 3.

A power regression provided a slightly better fit between median birch dbh and Wisconsin or Michigan FQI values than linear regression did, but still accounted for well under half of the variability ($r^2$ = 0.35 and $r^2$ = 0.25, respectively). Floristic quality was positively correlated with median dbh (r = 0.59 and r = 0.50, respectively).

## *Wetness indices*

A power regression accounted for only a small portion of the variability Wisconsin or Michigan wetness values and median birch dbh ($r^2$ = 0.05 and $r^2$ = 0.07, respectively). Correlation between wetness and dbh was low, with median birch dbh decreasing slightly with increasing dryness (r = -0.23 and r = -0.26, respectively). If the dry site EB08 is removed, correlation was even lower (r = -0.07 and r = -0.09, respectively).

Figure 6 shows the distribution of FQI and wetness values across paper birch dbh values for both databases. Summary statistics for site wetness are listed in Table 3.

**Table 3. Summary statistics for Floristic Quality Assessments paper birch sites. Michigan and Wisconsin values were calculated for all sites, using the Michigan (Reznicek et al. 2014) and the Wisconsin north-central and northeastern databases (Parker et al. 2014).**

| Birch Site | Habitat Type | | Birch DBH (cm) | | FQA: | Wisconsin | | Michigan | | Wisconsin | | Michigan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Habitat type | Description | Median | Max | Species (N) | Mean C-val | FQI | Mean C-val | FQI | W-val | 95% CI | W-val | 95% CI |
| AINL | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 46.7 | 50.9 | 56 | 5.6 | 42.2 | 4.4 | 32.9 | 1.8 | 0.7 | 1.8 | 0.7 |
| EB01 | ArAbVC | Red maple-Balsam fir/Blueberry-Goldthread | 38.9 | 42.2 | 69 | 4.9 | 41.1 | 3.8 | 31.8 | 1.9 | 0.6 | 2.0 | 0.6 |
| EB05 | ATD | Sugar maple-Eastern hemlock/Spinulose shield fern | 44.5 | 54.2 | 63 | 5.7 | 45.1 | 4.6 | 36.5 | 2.1 | 0.6 | 2.1 | 0.6 |
| EB06 | ATD | Sugar maple-Eastern hemlock/Spinulose shield fern | 35.9 | 45.2 | 59 | 5.6 | 42.8 | 4.5 | 34.4 | 2.0 | 0.6 | 2.0 | 0.6 |
| EB08 | PArV-U | White pine-Red maple/Blueberry and Sessile bellwort variant | 23.5 | 29.9 | 36 | 4.9 | 29.5 | 4.3 | 25.8 | 2.9 | 0.6 | 3.0 | 0.5 |
| EB15 | AFPo | Sugar maple-American beech/Hairy Solomon's seal | 36.9 | 50.1 | 44 | 5.7 | 37.7 | 4.5 | 29.8 | 2.4 | 0.6 | 2.3 | 0.6 |
| EB17 | PArVAa | White pine-Red maple/Blueberry-Wild sarsaparilla | 31.1 | 36.4 | 29 | 5.6 | 30.3 | 4.4 | 24.0 | 2.3 | 0.8 | 2.3 | 0.8 |
| EB23 | PArVAa[w] | White pine-Red maple/Blueberry-Wild sarsaparilla [Wisconsin variant] | 39.9 | 58.1 | 52 | 4.9 | 35.2 | 4.1 | 29.4 | 2.8 | 0.6 | 2.9 | 0.6 |
| EB26 | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 31.9 | 44.8 | 50 | 5.5 | 38.6 | 4.5 | 31.5 | 1.9 | 0.7 | 1.9 | 0.7 |
| EB27 | AVVb | Sugar maple/Blueberry-Maple-leaved viburnum | 28.6 | 34.3 | 74 | 4.6 | 40.0 | 3.9 | 33.2 | 2.1 | 0.6 | 2.0 | 0.6 |
| EB28 | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 36.7 | 39.1 | 62 | 5.1 | 40.4 | 4.1 | 32.4 | 1.9 | 0.6 | 1.9 | 0.6 |
| EB30 | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 28.3 | 36.3 | 44 | 4.7 | 31.4 | 3.7 | 24.4 | 2.3 | 0.6 | 2.4 | 0.7 |
| EB31 | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 34.0 | 44.0 | 70 | 4.9 | 41.0 | 4.0 | 33.8 | 1.5 | 0.7 | 1.4 | 0.7 |
| EB34 | PArVAa-Po | White pine-Red maple/Blueberry-Wild sarsaparilla habitat type, Hairy Solomon's seal variant | 34.1 | 40.3 | 36 | 5.6 | 33.3 | 4.4 | 26.5 | 2.3 | 0.7 | 2.4 | 0.7 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EB39 | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 38.7 | 63.9 | 69 | 5.3 | 44.2 | 4.2 | 34.7 | 1.2 | 0.7 | 1.3 | 0.7 |
| EB44 | TMC | Eastern hemlock/Wild lily-of-the-valley-Goldthread | 35.2 | 43.4 | 61 | 5.9 | 46.1 | 4.6 | 35.9 | 1.9 | 0.6 | 1.8 | 0.6 |
| KBIC | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 35.1 | 41.8 | 64 | 5.0 | 39.6 | 3.9 | 31.3 | 2.3 | 0.6 | 2.2 | 0.6 |
| LDF | ATM | Sugar maple-Eastern hemlock/Wild lily-of-the-valley | 32.1 | 41.2 | 39 | 5.8 | 36.5 | 4.4 | 27.7 | 1.8 | 0.7 | 1.9 | 0.7 |
| LVD | ATM-O | Sugar maple-Red maple/Stiff club-moss | 35.5 | 45.1 | 42 | 5.3 | 34.1 | 3.9 | 25.3 | 2.5 | 0.6 | 2.6 | 0.6 |
| NS01 | PArVAa-Po | White pine-Red maple/Blueberry-Wild sarsaparilla habitat type, Hairy Solomon’s seal variant | 28.9 | 33.9 | 38 | 5.1 | 31.5 | 4.3 | 26.3 | 2.6 | 0.7 | 2.6 | 0.7 |
| NS02 | AVVb | Sugar maple/Blueberry-Maple-leaved viburnum | 35.5 | 41.1 | 36 | 5.4 | 32.5 | 4.5 | 26.8 | 2.4 | 0.7 | 2.3 | 0.7 |
| NS03 | AFPo | Sugar maple-American beech/Hairy Solomon’s seal | 45.5 | 57.4 | 33 | 6.4 | 36.6 | 4.9 | 28.4 | 2.7 | 0.6 | 2.6 | 0.6 |
| NS04 | ATD | Sugar maple-Eastern hemlock/Spinulose shield fern | 40.0 | 46.0 | 49 | 5.5 | 38.3 | 4.5 | 31.7 | 2.3 | 0.7 | 2.2 | 0.7 |

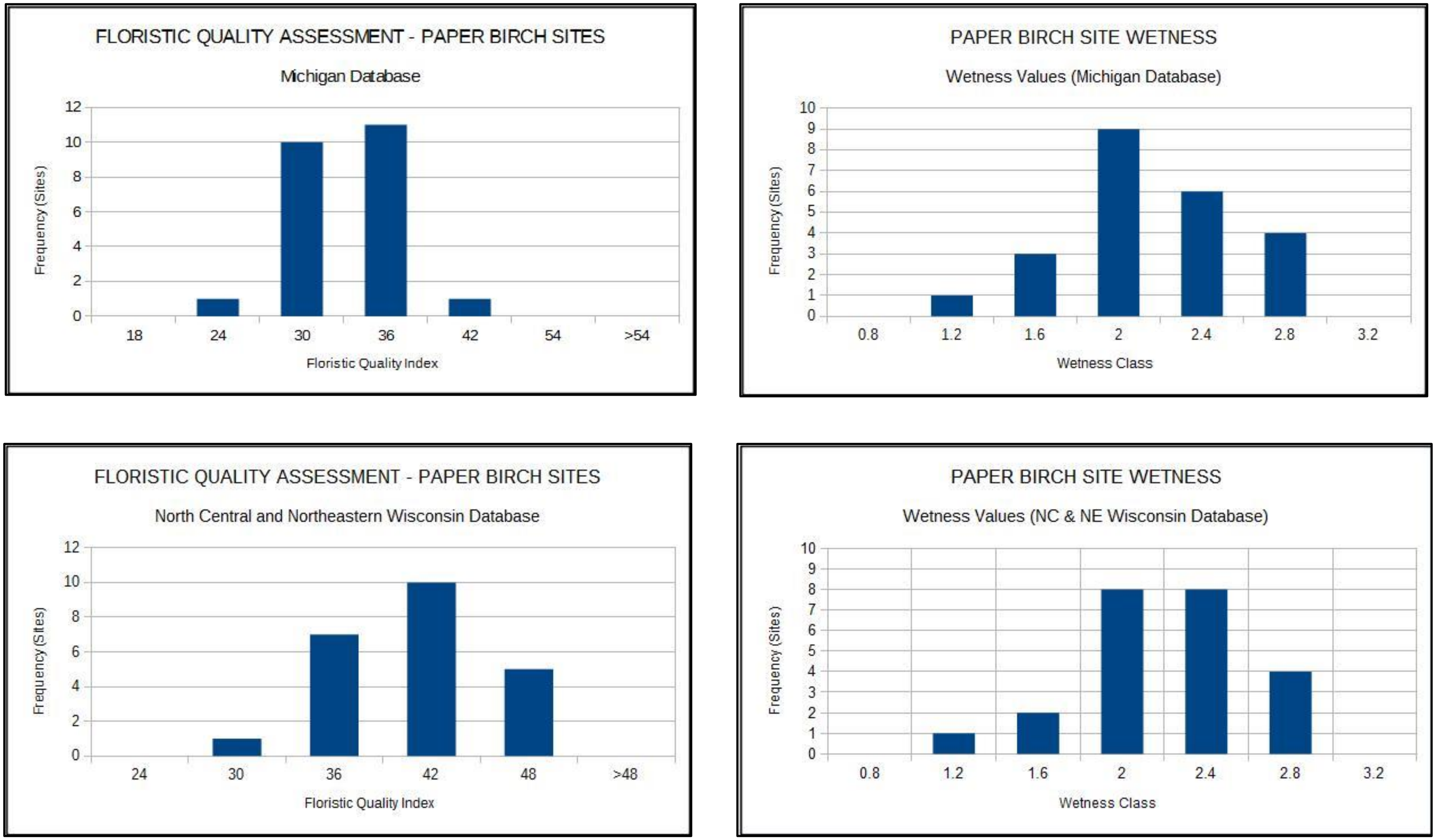


**Figure 6. Distribution of Floristic Quality Index (FQI) and wetness value classes across sites. The Michigan values were calculated using the Michigan Floristic Quality Assessment Database (Reznicek et al. 2014), while the Wisconsin values were calculated using the Northcentral-Northeast Regions database (Parker et al. 2014).**

# Community similarity

Sørensen similarity coefficients for each pair of sites are shown in Table 4. Perhaps not surprisingly, some of the highest coefficients of similarity occur between sites that were fairly close to each other. These include EB05 and EB06 south of Clam Lake (71% floristically similar), EB30 and EB34 south of Delta (70% similar), and EB05 and EB44 south and southwest of Delta (60% similar).

As for the sites with the largest median birch dbhs, the AINL site ranked most floristically similar to the LDF site (63% similar), followed by EB01, EB15 and EB39 (all 56% similar). The site with the second highest median dbh, NS03, was most similar to EB15 (65%), followed by LDF (53%) and AINL and EB39 (both 52%). The third-highest dbh site, EB05, was most similar to nearby site EB06, followed by LVD and EB30 (both 63%) and EB39 (61%). NS04 was most similar to EB05 (59%), followed by EB28 (58%), EB06 (57%) and EB39 (53%). EB23 ranked closest to NS01 (53%), followed by EB15 (52%) and EB08 (50%). EB01 was most similar to EB27 (60%), followed by AINL, EB05, LDF and LVD (all 56%) and EB39 (55%).

# Soil Analysis

## *pH*

While the number of samples from each site (typically 3) was not adequate to reliably characterize the soil pH of each site, it is reasonably clear from the data as a whole that these paper birch sites had consistently acid soil (Table 5). Mean $pH_w$ values for the 23 sites ranged from 4.1 to 5.3, with nearly half of the sites having a mean soil pH of less than 5.0. Seven of the sites had $pH_w$ values less than 4.5, with the rest having pH values between 4.5 and 5.8.

When pH was tested in a solution of dilute $CaCl_2$, $pH_s$ values ranged from 3.6 to 4.6. As expected, the means for $pH_w$ and $pH_s$ were highly correlated ($r = 0.97$). Coefficients of variation (CV) for $pH_w$ and $pH_s$ varied widely, with $pH_w$ CVs for four sites and $pH_s$ CVs for three sites exceeding 100%. Except for the LDF site, the difference between mean $pH_w$ and $pH_s$ was greater than 0.5 pH unit (Table 5).

There appeared to be little if any correlation between birch diameter and pH (Figure 7).

## *Particle size*

Based on the soil settling test, soil samples from all of the sites consisted of more than 50% sand. Average percent sand ranged from just over 50% for NS04 to 85% for KBIC and NS03. Mean silt percentages ranged from 10.3% for AINL to 45.8% for NS04, while clay ranged from 1.6% for EB05 to 6.3% for EB01 (These four sites all ranked in the top six for large paper birch). All of the birch sites would be classed as “loamy sand” or “sandy loam” according to the USDA soil texture triangle, except for NS03, which would be classified as “sand” (Van Lear 2008).

**Table 4. Sørensen coefficients for community similarity between paper birch sites, based on vascular plant species presence. Sites are ordered based on smallest to largest median diameter of the 12 largest paper birch on each site. Values are percents. Similarity values of greater than 50% are in bold.**

| Site | EB08 | EB30 | EB27 | NS01 | EB15 | EB17 | EB26 | LDF | EB31 | EB34 | KBIC | EB44 | LVD | NS02 | EB06 | EB28 | EB39 | EB01 | EB23 | NS04 | EB05 | NS03 | AINL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EB08** | | | | | | | | | | | | | | | | | | | | | | | |
| **EB30** | 43 | | | | | | | | | | | | | | | | | | | | | | |
| **EB27** | 35 | **51** | | | | | | | | | | | | | | | | | | | | | |
| **NS01** | **73** | 44 | 39 | | | | | | | | | | | | | | | | | | | | |
| **EB15** | 48 | 41 | 36 | **51** | | | | | | | | | | | | | | | | | | | |
| **EB17** | **55** | 36 | 27 | **51** | **55** | | | | | | | | | | | | | | | | | | |
| **EB26** | 40 | **60** | **55** | 43 | 45 | 35 | | | | | | | | | | | | | | | | | |
| **LDF** | 35 | 48 | 50 | 44 | **55** | 35 | **54** | | | | | | | | | | | | | | | | |
| **EB31** | 32 | **53** | 49 | 35 | 39 | 28 | 47 | 44 | | | | | | | | | | | | | | | |
| **EB34** | 50 | **70** | **51** | 49 | 45 | 40 | **67** | **53** | **55** | | | | | | | | | | | | | | |
| **KBIC** | 40 | 46 | **55** | 41 | **52** | 32 | 49 | **52** | 49 | 46 | | | | | | | | | | | | | |
| **EB44** | 37 | 48 | 50 | 40 | **51** | 31 | **59** | **58** | 41 | **52** | **53** | | | | | | | | | | | | |
| **LVD** | 44 | **63** | **53** | 45 | 44 | 39 | **59** | **54** | 45 | **67** | **53** | **52** | | | | | | | | | | | |
| **NS02** | 44 | **50** | **51** | **51** | 43 | 37 | **58** | **51** | **51** | **64** | **52** | 47 | **62** | | | | | | | | | | |
| **EB06** | 34 | **54** | **53** | 39 | 37 | 23 | **55** | 47 | **53** | **63** | 50 | **53** | **57** | **51** | | | | | | | | | |
| **EB28** | 37 | **62** | **53** | 40 | 36 | 29 | **57** | 48 | **52** | **57** | 46 | **54** | **58** | **53** | **60** | | | | | | | | |
| **EB39** | 25 | 50 | **52** | 32 | 41 | 20 | **52** | **54** | **56** | 50 | **51** | 49 | **54** | 44 | **61** | **55** | | | | | | | |
| **EB01** | 34 | 42 | **60** | 41 | 44 | 33 | **54** | **56** | 46 | 48 | **54** | **52** | **56** | 48 | **50** | 47 | **55** | | | | | | |
| **EB23** | 50 | 40 | 40 | **53** | **52** | 49 | 45 | 40 | 39 | 41 | 45 | 44 | 45 | 41 | 36 | 37 | 36 | 43 | | | | | |
| **NS04** | 26 | **52** | 46 | 25 | 30 | 23 | 48 | 39 | 49 | 49 | 46 | 45 | 48 | 45 | **57** | **58** | **53** | 41 | 32 | | | | |
| **EB05** | 41 | **57** | **59** | 46 | 43 | 33 | **61** | 50 | **56** | **63** | **54** | **60** | **63** | **57** | **71** | **60** | **61** | **56** | 47 | **59** | | | |
| **NS03** | 29 | 34 | 26 | 34 | **65** | 39 | 39 | **53** | 29 | 46 | 41 | 40 | 40 | 35 | 35 | 36 | **52** | 33 | 31 | 34 | 38 | | |
| **AINL** | 35 | 46 | 45 | 45 | **56** | 31 | 43 | **63** | 48 | **54** | **53** | **56** | **51** | 39 | 50 | 42 | **56** | **56** | 39 | 40 | **51** | **52** | |

**Table 5. Soil sample pH and particle size distribution for the 23 paper birch sites. N = the number of soil samples taken. $pH_w$ was measured in a solution 1:1 (by volume) soil and distilled water, while $pH_s$ was obtained in a soil-solution ratio of one part soil to two parts 0.01 M $CaCl_2$.**

| Site | N | $pH_w$ | | | | $pH_s$ | | | | $pH_w$-$pH_s$ | Average Soil Fraction (%) | | | | USDA Soil Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | 90% CI | Range | CV | Mean | 90% CI | Range | CV | | Sand | Silt | Clay | CV (Sand) | |
| EB08 | 3 | 4.2 | (3.9, ----) | (4.0, 4.7) | 60.7 | 3.6 | (3.2, ----) | (3.4, 4.1) | 63.1 | 0.8 | 83.4 | 12.6 | 4.0 | 6.7 | Loamy sand |
| EB30 | 3 | 4.8 | (4.4, ----) | (4.5, 6.0) | 94.7 | 4.1 | (3.7, ----) | (3.8, 5.5) | 84.7 | 0.7 | 71.2 | 24.9 | 3.9 | 10.7 | Sandy loam |
| EB27 | 3 | 5.1 | (4.7, 5.7) | (4.9, 5.3) | 45.8 | 4.4 | (4.1, 5.2) | (4.2, 4.6) | 50.8 | 0.7 | 69.5 | 27.9 | 2.6 | 15.9 | Sandy loam |
| NS01 | 3 | 4.6 | (4.2, ----) | (4.3, 5.0) | 87.8 | 3.9 | (3.6, ----) | (3.7, 4.3) | 73.2 | 0.7 | 72.1 | 21.1 | 6.8 | 3.8 | Sandy loam |
| EB17 | 3 | 4.4 | (4.1, ----) | (4.2, 4.8) | 61.6 | 3.8 | (3.5, ----) | (3.6, 4.3) | 66.6 | 0.6 | 82.3 | 15.1 | 2.6 | 6.7 | Loamy sand |
| EB26 | 3 | 5.1 | (4.8, 5.7) | (5.0, 5.1) | 13.0 | 4.3 | (4.2, 4.5) | (4.3, 4.4) | 20.3 | 0.7 | 58.4 | 36.8 | 4.8 | 26.2 | Sandy loam |
| LDF | 3 | 4.4 | (4.0, ----) | (4.1, 5.3) | 115.5 | 3.9 | (3.6, ----) | (3.7, 4.6) | 87.0 | 0.4 | 74.8 | 21.0 | 4.2 | 2.3 | Loamy sand |
| EB31 | 3 | 5.1 | (5.0, 5.3) | (5.0, 5.2) | 18.5 | 4.5 | (4.4, 4.6) | (4.4, 4.6) | 17.6 | 0.6 | 71.3 | 26.6 | 2.1 | 8.4 | Sandy loam |
| EB34 | 3 | 4.7 | (4.3, ----) | (4.4, 5.0) | 72.2 | 4.0 | (3.7, ----) | (3.7, 4.3) | 63.2 | 0.8 | 77.0 | 18.2 | 4.8 | 4.8 | Loamy sand |
| KBIC | 3 | 4.3 | (4.2, 4.6) | (4.2, 4.5) | 26.0 | 3.6 | (3.5, 3.9) | (3.6, 3.8) | 27.0 | 0.7 | 85.0 | 12.4 | 2.6 | 7.8 | Loamy sand |
| EB44 | 3 | 4.4 | (4.0, ----) | (4.3, 4.5) | 28.9 | 3.7 | (3.6, 4.0) | (3.7, 3.8) | 11.4 | 0.6 | 60.6 | 33.6 | 5.8 | 3.2 | Sandy loam |
| LVD | 2 | 4.8 | (4.0, ----) | (4.5, 5.4) | 108.5 | 4.1 | (3.4, ----) | (3.9, 4.9) | 117.8 | 0.7 | 71.6 | 25.7 | 2.7 | 26.7 | Sandy loam |
| NS02 | 3 | 5.2 | (4.7, ----) | (4.8, 6.0) | 104.9 | 4.5 | (4.1, ----) | (4.2, 5.5) | 110.7 | 0.6 | 72.6 | 24.1 | 3.3 | 4.4 | Sandy loam |
| EB06 | 1 | 4.7 | ---- | ---- | ---- | 4.2 | ---- | ---- | ---- | 0.6 | 57.1 | 37.5 | 5.4 | ---- | Sandy loam |
| EB28 | 3 | 4.6 | (4.3, ----) | (4.4, 5.1) | 59.5 | 4.0 | (3.7, ----) | (3.8, 4.3) | 61.8 | 0.8 | 76.6 | 19.7 | 3.8 | 4.3 | Loamy sand |
| EB15 | 3 | 4.2 | (3.8, ----) | (3.9, 4.6) | 68.9 | 3.5 | (3.1, ----) | (3.2, 3.9) | 74.8 | 0.6 | 81.7 | 15.6 | 2.8 | 2.3 | Loamy sand |
| EB39 | 3 | 4.6 | (4.3, 5.3) | (4.4, 4.8) | 48.8 | 4.0 | (3.8, 4.6) | (3.9, 4.3) | 44.9 | 0.5 | 62.7 | 33.8 | 3.5 | 7 | Sandy loam |
| EB01 | 3 | 4.9 | (4.5, ----) | (4.6, 5.3) | 102.0 | 4.3 | (3.8, ----) | (3.9, 4.8) | 105.1 | 0.7 | 73.6 | 20.2 | 6.1 | 8.5 | Sandy loam |
| EB23 | 3 | 4.8 | (4.6, 5.2) | (4.7, 5.0) | 34.7 | 4.1 | (3.9, 4.6) | (4.1, 4.4) | 36.9 | 0.6 | 82.3 | 12.3 | 5.4 | 5.3 | Loamy sand |
| NS04 | 3 | 4.9 | (4.5, ----) | (4.6, 5.5) | 89.5 | 4.6 | (4.3, 5.8) | (4.4, 5.0) | 56.0 | 0.6 | 50.7 | 45.5 | 3.8 | 20.2 | Sandy loam |
| EB05 | 1 | 5.0 | ---- | ---- | ---- | 4.3 | ---- | ---- | ---- | 0.7 | 67.7 | 30.6 | 1.6 | ---- | Sandy loam |
| NS03 | 4 | 4.3 | (4.2, 4.4) | (4.2, 4.4) | 15.5 | 3.6 | (3.5, 3.6) | (3.5, 3.7) | 15.9 | 0.8 | 85.0 | 12.7 | 2.3 | 3.9 | Sand |
| AINL | 3 | 5.1 | (5.0, 5.3) | (5.1, 5.2) | 20.4 | 4.5 | (4.3, 4.7) | (4.3, 4.5) | 26.8 | 0.6 | 83.5 | 10.3 | 6.3 | 3.3 | Loamy sand |

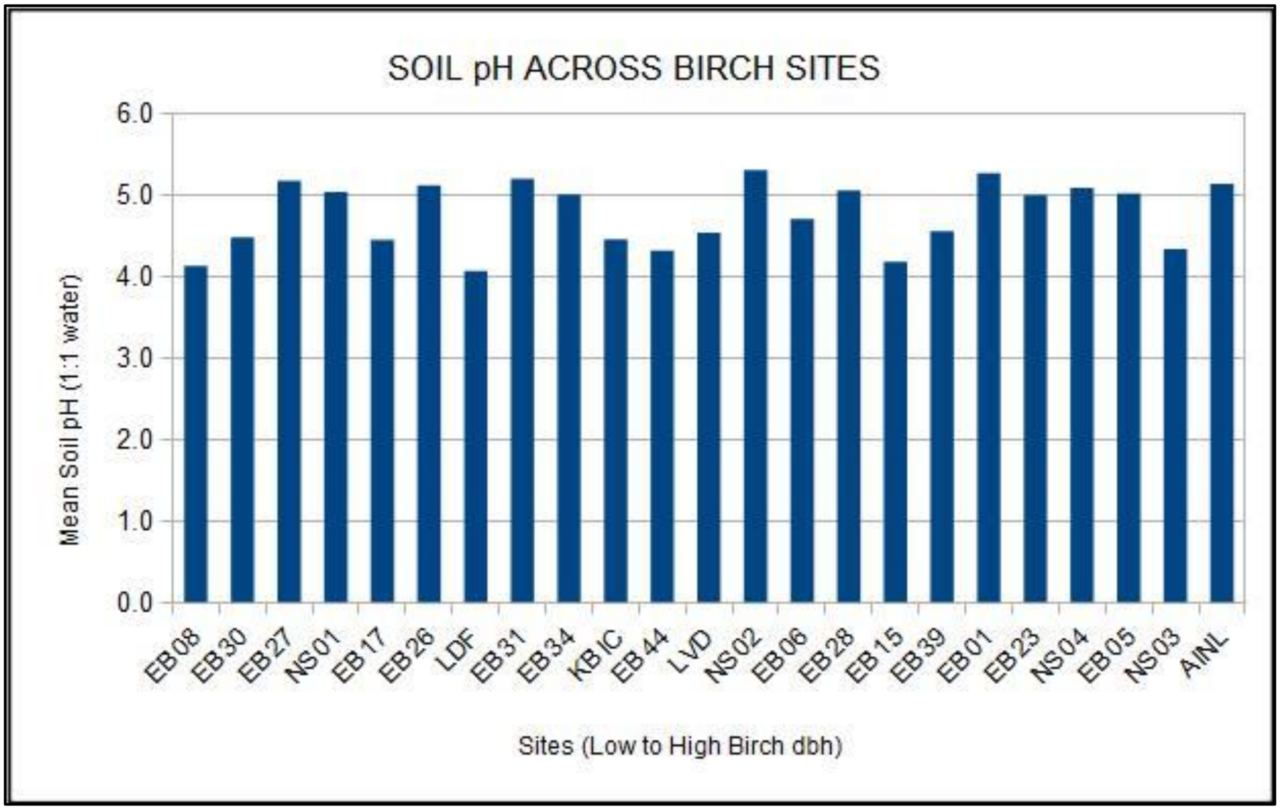


**Figure 7. Soil pH across paper birch sites, with sites ranked from low to high mean birch dbh.**

# DISCUSSION

## Characteristics of large birch sites

The AINL site had the largest 12-birch median of all the sites. It was also unique in that it supported vigorous paper birch regeneration. Birch seedlings and saplings were fairly common to common across the site. Canopy gaps were frequent, allowing more light into the understory. Paper birch appeared to be co-dominant in the overstory, along with sugar maple and red maple. Trembling and big-toothed aspen (*Populus tremuloides* and *P. grandidentata*) were frequent as well. This site was located on a gently north-sloping hill facing Lake Superior, and it seems likely that the open overstory was maintained by periodic strong winds coming off the lake.

Conditions for birch regeneration may be nearly optimal on the AINL site. According to WDNR (2015), early height growth of paper birch may be best in about 50% full sunlight. Periodic disturbance on this site may allow paper birch to compete with the much more shade-tolerant sugar maple, which was also common on the site.

Site NS03 occupied a steep northwest-facing hillside about 0.1 mile from Lake Superior. The site has also not been logged for a long time, and supported mature mixed deciduous-conifer forest. Large birch were scattered across nearly the entire slope, including several perched along the top of the hill.

From there south the hill was basically level and supported only widely scattered, small to medium-sized birch. The hilltop forest was much younger though, and obviously had been logged much more recently than the mature forest on the slope.

Site EB05 was an inland site that occupied the upper slopes and broad, nearly level top of a large hill. It also supported mature northern mesic forest of older trees approaching old-growth. There was no evidence of recent (within the last few decades) logging, the litter layer was intact and I did not see evidence of earthworms or non-native slugs. The site is slated for select-cutting though, as many trees had “blue spot disease.” Few if any paper birch were marked for cutting.

Site NS04 was another inland site in mature northern mesic forest. The site was nearly level overall, with gently undulating topography. Many of the trees on this site were also marked for cutting, including many of the paper birch. This site was within ¼ mile of two National Forest campgrounds.

Site EB23 was an inland site occupied a low ridge bordered by open, boggy sedge meadows to the north, and sandy, well-drained woods to the south. Classified as PArVAa[w], it had an overstory mix that resembled southern boreal forest. It also included a significant amount of sugar maple, and apparently had not been logged for a long time.

Site EB01 was a basically level site that gently sloped down to wet woods on the north side. No exceptionally large birch trees were seen on this site, but the site supported a number of trees around 16 in (40 cm) dbh.

The sites with the largest paper birch were all mixed stands usually dominated by sugar maple and/or red maple, with lesser amounts of other species as well. Northern red oak (*Quercus rubra*) was fairly common to common (even co-dominant) in a number of sites including two sites with larger-diameter birch (EB39 and NS02), but also sites with smaller-diameter birch, including the Moquah Sand Plains sites. Several of the large-diameter birch sites had low to moderate amounts of red oak (EB05, EB23, NS03, NS04) or no detected red oak (AINL, EB01). Other frequent tree species in these stands included big-toothed and trembling aspen, ironwood (*Ostrya virginiana*) and balsam fir (*Abies balsamea*).

According to WDNR (2015), the growth potential for paper birch is only “fair” on the very dry to dry PArV-U habitat type, which site EB08 falls into (Table 2). It is considered “good” on the dry to dry-mesic PArVAa habitat type, which includes sites EB17 and EB23, and the dry to dry-mesic habitat type PArVAa-Po, which includes EB34 and NS01. It is also considered “good” on the mesic to wet-mesic habitat types ArAbVC (EB01) and TMC (EB44). Paper birch growth potential is considered “excellent” on the remaining habitat types, including the sites AINL, NS03, EB05, and NS04, which had the largest mean large birch diameters. WDNR (2015, Figure 12-10) considers growth potential of paper birch across northern habitats to be “good” on dry-dry mesic and dry-mesic sites, “very good” on mesic sites, and “good” on mesic-wet-mesic sites.

Stafford (1990) considers typical mature paper birch trees to average 10 to 12 inches (25-30 cm) in trunk diameter (dbh) and 70 ft (21 m) in height. All of the sites had at least a few birch trees larger than the 25 cm (10-12 inches) dbh, and all but EB08 had trees over 12 in dbh.

## Soil pH and texture

Along with an understanding of the geologic history of a site, texture, drainage and pH are the most important site-level soil characteristics to consider in forestry applications in Wisconsin (WDNR 2015, page 11-18). Soil pH is affected by many factors, including the type and amount of inorganic and organic matter, the amount and type of exchangeable cations and anions, the soil to solution ratio, and the $CO_2$ content (McLean 1982). Forest soils often have low pH (3-6) because of the high acidity of the litter (Barbour et al. 1987). Soil pH is a critical factor affecting the availability of most essential elements for plants (Burt et al. 2014), with major nutrients such as nitrogen, phosphorus, potassium, magnesium and calcium having lowered availability in acid soils (Barbour et al. 1987). Though $pH_w$ readings can vary seasonally, $pH_s$ readings tend to be uniform regardless of time of year (Burt et al. 2014).

According to Buol et al. (1989), mineral soils with $pH_w$ between 4.5 and 5.8 have sufficient exchangeable aluminum (Al) to affect plant growth significantly, with a low percentage of base saturation. Mineral soils with $pH_w$ of less than 4.5 generally have significant amounts of exchangeable hydrogen and aluminum (Buol et al. 1989), and soils with $pH_w$ values below 4.0 contain free acids generally arising from the oxidation of sulfur-based compounds (Van Lierop 1990). If soil pH is below about 6.0, and if $pH_w$ is 0.5 or more units less than $pH_s$, significant amounts of exchangeable Al or complexed slowly exchangeable Al are present (Buol et al. 1989). Soils with pH below about 5.5 may also contain toxic levels of manganese (Van Lierop 1990).

With a maximum mean pH of 5.2 (site NS02), all of these paper birch sites may have significant concentrations of exchangeable aluminum. Along with pines and oaks, paper birch tolerates fairly high levels of Al in nutrient solution (up to 80 mg/l) with no reduction of root growth (McCormick and Steiner 1978). However, increasing soil acidity caused by acid precipitation has been linked to higher Al levels and lowered soil calcium availability, and a decreased ability of paper birch to recover from injury and decline in Vermont (Halman et al. 2011).

Except for the LDF site, the difference between mean $pH_w$ and $pH_s$ was greater that 0.5 pH unit (Table 5), also suggesting that significant exchangeable Al may be present in the soil of these sites (Buol et al. 1989).

## Other factors affecting birch growth and survival

Paper birch are shade-intolerant and cannot compete with the moderately- to highly shade-tolerant trees that dominate northern mesic forests. After visiting these sites it became clear that the paper birch trees persisting in these mature mixed stands were either fortunate enough to end up in an opening, or grew fast enough to stay in the canopy after a major disturbance such as a blowdown, fire or logging event (Figure 8).

The largest birch in several sites occurred on the edge of the woods next to open area, such as a road or power line corridor. Sites where I noticed this effect included EB30 in south central Bayfield County, EB23 in southwestern Houghton County, and NS03 in Chippewa County. The site with the two largest dbh birch trees, EB39, appeared to have once held an old homestead, and the morphology of these two trees suggests that they once grew in the open. The very large-diameter tree at the Peter White Camp was also on the edge of the woods, next to a lawn (Figure 9). The larger diameter and relatively low stature of these trees is probably a result of higher light levels over their lifetime.

From their analysis of USFS Forest Inventory and Analysis (FIA) data, Moser et al. (2015) concluded that four forest types in the Great Lakes region contain the majority of paper birch: northern upland hardwoods, lowland softwoods, aspen, and paper birch. They also found that the northern upland

***Figure 8. Large paper birch must keep their crowns in the canopy to survive in mixed forest. (SCG photo)***

***Figure 9. This old, branchy paper birch has spent its life on the edge of the woods, at the long-established Peter White Camp in Alger County, Michigan. (SCG photo)***

hardwood type supported the largest proportion of trees over 11 in (28 cm) dbh. The percentage of trees over this size had increased slightly on public and private “timberland” from 1980 through 1990, then decreased to around 1980 levels by 2010. Meanwhile, the number of birch in the 5.0 to 10.9 in (12.7 to 27.8 cm) class had dropped by nearly half from 1980 through 2010. This study supports the view of many tribal elders and harvesters that paper birch populations in the Ceded Territories are declining.

# Management

## *The industrial forestry approach*

Paper birch has frequently been regenerated through clearcutting (Perala and Alm 1990b, Lynch 1997). Perala and Alm (1990b) advocate clearcutting for birch regeneration, with the qualification that sites in cool, moist climates with large seed crops might allow consistently good regeneration of clearcuts of around 160 ft (50 m) or more across, but that warm, dry climates and small or infrequent seed crops may dictate clearcuts less than half that size. They mention that clearcut size is critical - openings should be large enough to admit sufficient light but small enough to accommodate the seeding potential of birch.

Periodic select-cutting (including release, thinning, and shelterwood cuts) of birch stands might seem to mimic the processes apparently occurring at the AINL site, which has both large birch trees and fairly vigorous regeneration.  WDNR (2015) recommends the shelterwood method to regenerate paper birch stands. The goal of this method is to maintain a fully stocked stand of paper birch, rather than a diverse forest where birch is but one component. Their method typically involves two cuttings: a “seeding” cut with soil scarification, and final overstory removal 2-4 years later. The cutting interval is sometimes extended a few years to ensure adequate seedling establishment. Follow-up release of regeneration is considered necessary to maintain a fully stocked stand of paper birch. Shelterwood cuts have generally not been successful in the Ottawa National Forest or the CNNF though (Lynch 1997).

Soil scarification is considered critical to the successful regeneration of paper birch (WDNR 2015). Mineral soil provides the best moisture and temperature conditions for germination and initial survival of birch. For establishment and early growth of the seedlings, it is important for woody debris to be preserved in the seedbed, to provide  nutrients and moderate water-holding capacity. WDNR (2015) also states that logging with heavy equipment during seasons with no snow and unfrozen soil, along with whole-tree skidding of trees with branches, may provide adequate scarification.

WDNR (2015) recommends a 50 to 80 year rotation period for birch stand management, depending on site characteristics. Fifty years is recommended for dry, poorer nutrient sites and up to 80 years for exceptional, nutrient rich mesic sites. WDNR (2015) also states that while “extended rotation is not recommended for this short-lived, early successional species….some vigorous stands and vigorous individual trees on good sites could potentially be managed to 100 years or more.”  Rotation periods on managed forest land are rarely this long, however.

Logging frequently has significant unwanted side effects (Perala and Alm 1990b, WDNR 2015). Areas used for birch regeneration are often in sand plains, on poor, droughty soils. Without the cooling effects of the canopy, warm, dry summer weather can inhibit seedling establishment. The young, vigorously growing stump sprouts and suckers created by clearcutting attracts deer, and high populations of deer often decimate birch seedlings. Aggressive aspen suckers can rapidly overtop and shade out birch seedlings and young saplings. Large paper birch that have spent their lives in closed forest are highly susceptible to dessication and windthrow if the surrounding trees are removed (WDNR 2015). After logging in stands 70-90 years old, competition from herbs, coppice, and suckers seriously limits the establishment and growth of paper birch seedlings (Perala and Alm 1990b). Logging with heavy equipment also compacts the soil, leading to restricted root growth and surface runoff and erosion during heavy precipitation events.

Logging has the potential to spread plant diseases. Cutting in areas with oaks between April and August (even into fall) can result in the oaks becoming infected by the oak wilt fungus, through cut stumps or damage to remaining trees. Oaks in the red oak group are highly susceptible to oak wilt.

Logging is a major vector for the introduction of various European earthworm species into previously uninfested forest. These earthworms have major, cumulative negative impacts on community composition and ecosystem functioning of northern mesic and boreal forests, causing significant declines in the diversity and cover of native herbaceous plants and tree seedling abundance, and facilitating the introduction and spread of invasive plants such as garlic mustard (*Alliaria petiolata*) and common buckthorn (*Rhamnus cathartica*) (Frelich et al. 2006).

## *Other views and strategies*

According to Mason et al. (2012), “management” is not a traditional concept of Indian people because it reflects an anthropocentric attitude that man is separate and apart from the environment, and able to control nature to meet his needs. They relate a statement made by a tribal elder they interviewed that “The earth does not belong to us; we belong to the earth.”

A major factor in how large paper birch will grow on a site is how often a site is logged, and whether the birch trees are left standing. When asked how he decides where to look for harvestable birch, the first thing one expert canoe-maker (Boycee) said was that he looks for good-quality canoe birch in ravines, steep slopes, and other “places where they couldn't get their logging equipment in.” The sites with the largest birch in this study all were in areas that were either protected from logging or that hadn’t been logged for a long time.

Tribes across North America once made targeted and extensive use of fire for hunting, growth and yield of berries, edible seeds, root crops and other vegetation, regenerating browse for deer, elk, buffalo and other grazers, maintaining prairies and savannas, controlling insect and rodent pests, fireproofing around villages, warfare, control of resource access, clearing for travel, felling trees, and to improve riparian habitat for waterfowl, beaver and other wildlife (Kimmerer and Lake 2001, Mason et al. 2012). Intentional burning on dryer sites may have promoted birch stands along with berries and other food plants (Lynch 1997). Burning of the wetter eastern forest was less extensive, but created smaller openings for agriculture (Pyne 2000). Tribes typically set fires that were not destructive of entire forests or ecosystems, relatively easy to control, and designed to encourage new vegetation growth (Pyne 2000, Williams 2000, Williams 2002). European settlement and fire suppression led to widespread changes in native ecosystems, to the point that large areas bear little resemblance to their presettlement condition (Pyne 2000, Williams 2000, Kimmerer and Lake 2001). It is an open question as to whether any of the prairie or forests communities of North America developed independently of human-caused fire (Williams 2002).

Past decades of fire suppression on fire-dependent forests have led to many of the fuel build-up and insect and disease problems that North America's forests are facing today. Fire-dependent ecosystems in the Ceded Territories are generally dominated by jack, red, and white pines (*Pinus banksiana*, *P. resinosa* and *P. strobus*, respectively) and northern red and northern pin oaks (*Quercus rubra* and *Q. ellipsoidalis*), and typically occur on sandy, acid soils with low to moderate fertility (Swaty 2016/2017). These are the types of forests that often support populations of large birch. Swaty calculates that roughly 1.4 million acres would have burned annually across Michigan before European settlement. He also estimated that 20% percent of the Upper Peninsula would have had at least one natural fire in the last 100 years if natural fire regimes were intact. Most of these would have been surface fires that would have burned off needles, branches, leaves and understory vegetation, leaving bare soil for fire-adapted trees like paper birch to get started.

Today widespread human settlement has precluded use of fire in many areas. Nonetheless it seems advisable to work with land management agencies to reintroduce fire to ecosystem management as much as feasible.

# Conclusions

During the 2014-2015 harvest season, a total of 2,074 tribal members from the 11 GLIFWC member tribes obtained a Miscellaneous Forest Product (MFP) permit for gathering in National Forest and select Wisconsin state properties (Wrobel 2015). Permit stamps to collect birch bark were issued to 1,237 of these permit holders. When tribal members received their permits, they were asked to fill out a paper survey detailing their harvest activity from the previous season (2013-2014). The MFP permit-holders who responded (11% of permit-holders) harvested bark from 109 birch trees. Of the 11 tribes, Sokaogon (Mole Lake) members reported harvesting the most birch bark.

Moser et al. (2010) found that the Ceded Territory paper birch population is aging, and the number of paper birch trees is declining. In order to sustain adequate numbers of large paper birch on the landscape, birch recruitment success must increase as well.

It seems little has changed since Lynch (1997) pointed out that birch populations in the Ceded Territories were declining, and identified the forestry practices and other factors behind the decline. She gave recommendations that are still applicable today.

- On sites with healthy large birch, the birch should be retained. Birch should be allowed to grow beyond the 10-12 inches dbh typical in standard forestry practices.

- On production forest land a modified shelterwood method would seem to have the most potential for maintaining birch populations. Retaining more of the overstory (including the large birch) during the second cut rather than mostly or entirely removing the overstory might result in conditions in which (like the AINL site in this study) all birch age classes can thrive. As WDNR (2015) points out, birch saplings do poorly (or don't survive at all) in deep shade, while full sunlight can limit height growth due to high temperatures and reduced soil moisture. Roughly 50% of full sun is optimum for paper birch saplings (WDNR 2015). In northern mesic forest stands that are periodically select-cut, paper birch should be retained (Lynch 1997).

- Paper birch trees are highly susceptible to logging damage (Lynch 1997). Therefore logging practices that minimize damage to tree roots and stems should be used.

- Herbivory by deer and (in limited areas) elk can seriously impact birch seedlings and saplings as well as other forest trees, shrubs and herbs (Lynch 1997, Rooney and Waller 2003). Lynch recommends that steps be taken to reduce the impact of deer and elk herbivory on regenerating birch, though given the currently high white-tailed deer population and the political push for even higher deer populations, this may be easier said than done.

- Paper birch is sensitive to severe drought and elevated soil temperatures, problems that a warming climate will undoubtedly make worse. Forest sites on north-facing slopes, especially those within a few miles of Lake Superior, will likely maintain the cooler, moister conditions that benefit paper birch. If they are close to the lake, periodic blowdown events may maintain the stands in a naturally-occurring mid-successional stage.

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# REFERENCES

Adney, Edwin Tappan and Howard Irving Chapelle. 2007. Bark canoes and skin boats of North America. Edition illustrated. Skyhorse Publishing Inc., New York. 242 pages.

Barbour, Michael G., Jack H. Burk and Wanna D. Pitts. 1987. Terrestrial plant ecology, 2nd ed. Benjamin Cummings Publishing Company, Menlo Park, CA.

Buol, Stanley W., Francis D. Hole, and Ralph J. McCracken. 1989. Soil genesis and classification, 3rd ed. Iowa State University Press, Ames. xiv + 446 pages.

Burger, Timothy L. and John Kotar. 2003. A guide to forest communities and habitat types of Michigan. Department of Forest Ecology and Management, University of Wisconsin, Madison. 392 pages.

Burt, Rebecca and Soil Survey Staff. 2014. Kellogg soil survey laboratory methods manual. Soil survey investigations report no. 42, version 5.0. Kellogg Soil Survey Laboratory, National Soil Survey Center, Natural Resources Conservation Service, U.S. Department of Agriculture, Lincoln, Nebraska. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1253871.pdf (accessed 2016 November 18).

Densmore, Francis. 1974. How Indians use wild plants for food & crafts (formerly titled Uses of plants by the Chippewa Indians). Dover Publications, New York. 307 pages. Smithsonian Institute: Bureau of American Ethnology Report No. 44: 273-379.

Emery, Marla R., Alexandra Wrobel, Mark H. Hansen, Michael Dockry, W. Keith Moser, Kekek Jason Stark, and Jonathan H. Gilbert. 2014. Using traditional ecological knowledge as a basis for targeted forest inventories: paper birch (*Betula papyrifera*) in the US Great Lakes region. Journal of Forestry 112(2): 207-214.

Frelich, Lee E., Cindy M. Hale, Stefan Scheu, Andrew R. Holdsworth, Liam Heneghan, Patrick J. Bohlen, and Peter B. Reich. 2006. Earthworm invasion into previously earthworm-free temperate and boreal forests. Biological Invasions 8(6): 1235-1245.

Freyman, William A., Linda A. Masters and Stephen Packard. 2015. The Universal Floristic Quality Assessment (FQA) calculator: an online tool for ecological assessment and monitoring. Methods in Ecology and Evolution, pages 1-4. http://breadorpyramid.org/assets/pdf/2015_Freyman_Masters_Packard_FQA.pdf (2017 January 23).

Furlow, John J. 1997. *Betula* Linnaeus. In Flora of North America north of Mexico, volume 3, Magnoliophyta: Magnoliidae and Hamamelidae. (Flora of North America Editorial Committee, editors). Oxford University Press, New York.
http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=10101 (2016 December 27).

Garibaldi, A. and N. Turner. 2004. Cultural keystone species: implications for ecological conservation and restoration. Ecology and Society 9(3): 1 [online]. http://www.ecologyandsociety.org/vol9/iss3/art1/ (2016 December 27).

Geniusz, Wendy M. 2009. Our knowledge is not primitive. Decolonizing botanical Anishinaabe teachings. Syracuse University Press, Syracuse, NY. 214 pages.

Gleason, Henry A. and Arthur Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. New York Botanical Garden, New York. ixxv + 910 pages.

[GLIFWC] Great Lakes Indian Fish & Wildlife Commission. 2000-2002. *Wiigwaas* elder approved national forest potential gathering sites. GIS layer derived from "Anishinaabe wild plant traditional environmental knowledge and wisdom/scientific knowledge integration project". Project funded under grants 90NA7252/01 and 90NA7252/02, US Department of Health and Human Services, Administration for Native Americans.

Halman, Joshua M., Paul Schaberg, Gary J. Hawley, and Christopher F. Hansen. 2011. Potential role of soil calcium in recovery of paper birch following ice storm injury in Vermont, USA. Forest Ecology and Management 261: 1539-1545. https://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_2011_halman_001.pdf (2017 May 21).

Herman, Kim D., Linda A. Masters, Michael R. Penskar, Anton A. Reznicek, Gerould S. Wilhelm, William W. Brodovich, and Kevin P. Gardiner. 2001. Floristic Quality Assessment with wetland categories and examples of computer applications for the State of Michigan - revised, 2nd edition. Michigan Department of Natural Resources, Wildlife, Natural Heritage Program, Lansing, MI. 19 pages + appendices.

Jones, Elizabeth A., David D. Reed, Glenn D. Mroz, Hal O. Liechty, and Peter J. Cattelino. 1993. Climate stress as a precursor to forest decline - paper birch in Northern Michigan, 1985-1990. Canadian Journal of Forest Research 23(2): 229-233.

Kimmerer, Robin W. and Frank Kanawha Lake. 2001. Maintaining the mosaic: the role of indigenous burning in land management. Journal of Forestry 99(11): 36-41.

Kotar, John, Joseph A. Kovach and Timothy L. Burger. 2002. A guide to forest communities and habitat types of northern Wisconsin, 2nd ed. Department of Forest Ecology and Management, University of Wisconsin – Madison.

Krebs, Charles J. 2014. Similarity coefficients and cluster analysis. Chapter 12 in: Ecological methodology, 3rd ed. (in prep). http://www.zoology.ubc.ca/~krebs/downloads/krebs_chapter_12_2014.pdf (2017 January 17).

Lichvar, Robert W. 2012. The National Wetland Plant List. Report no. ERDC/CRREL TR-12-11. US Army Corps of Engineers, Engineer Research and Development Center, Hanover, NH. 224 pages.

Lichvar, Robert W., Darin L. Banks, William N. Kirchner and Norman C. Melvin. April 28, 2016. The National Wetland Plant List: 2016 wetland ratings. Phytoneuron 2016-30: 1–17. http://www.phytoneuron.net/2016Phytoneuron/30PhytoN-WetlandRatings2016.pdf (2017 January 9).

Lynch, Beth. 1997. Ecology, silviculture, and status of paper birch (*wiigwass*) in the 1837 and 1842 Ceded Territories. Project Report 97-01. Great Lakes Indian Fish & Wildlife Commission, Odanah, WI.

Magurran, Anne E. 2004. Measuring biological diversity. Blackwell Science Ltd., Oxford, UK. 256 pages.

Marquis, David A., Dale S. Solomon, and John C. Bjorkborn. 1969. A silvicultural guide to paper birch in the northeast. Res. Pap. NE-130. Upper Darby, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 47 pages. http://www.fs.fed.us/ne/newtown_square/publications/research_papers/pdfs/scanned/OCR/ne_rp130.pdf (2016 December 14).

Mason, Larry, Germaine White, Gary Morishima, Ernesto Alvarado, Louise Andrew, Fred Clark, Mike Durglo Sr., Jim Durglo, John Eneas, Jim Erickson, Margaret Friedlander, Kathy Hamel, Colin Hardy, Tony Harwood, Faline Haven, Everett Isaac, Laurel James, Robert Kenning, Adrian Leighton, Pat Pierre, Carol Raish, Bodie Shaw, Steven Smallsalmon, Vernon Stearns, Howard Teasley, Matt Weingart, and Spus Wilder. June 2012. Listening and learning from traditional knowledge and western science: a dialogue on contemporary challenges of forest health and wildfire. Journal of Forestry pages 187-193. https://www.fs.fed.us/rm/pubs_other/rmrs_2012_mason_l001.pdf (18 January 2017).

McCormick, L. H. and K. C. Steiner. 1978. Variation in aluminum tolerance among six genera of trees. Forest Science 24: 565-568.

McLean, E. O. 1982. Soil pH and lime requirement. Pages 199-224 In: A. L. Page, R. H. Miller, and D. R. Keeney, editors. Methods of soil analysis, 2nd ed., Part 2: chemical and microbial properties. Agronomy No. 9, Part 2. American Society of Agronomy, Madison, Wisconsin.

Moser, W Keith, Mark H. Hansen, Dale Gormanson, Jonathan Gilbert, Alexandra Wrobel, Marla R. Emery, and Michael J. Dockry. 2014. The paper birch resource of the Lake States, 1980–2010: with special emphasis on the birch bark resource in the territories ceded in the treaties of 1836, 1837, 1842 and 1854. USDA Forest Service, General technical report NRS-149, Northern Research Station, Newtown Square, PA.

Parker E. C., M. Curran, Z. S. Waechter, and E. A. Grosskopf . 2014. Wisconsin FQA (Floristic Quality Assessment) databases for Midwest and Northcentral-Northeast Regions for Universal FQA Calculator web site http://universalfqa.org/).

Perala, Donald A. and Alvin A. Alm. 1990a. Reproductive ecology of birch: a review. Forest Ecology and Management 32(1): 1-38.

Perala, Donald A. and Alvin A. Alm. 1990b. Regeneration silviculture of birch: a review. Forest Ecology and Management 32(1): 39-77.

Pyne, Stephen J. Summer 2000. Where have all the fires gone? Fire Management Today 60(3): 4-6. USDA Forest Service, Washington, DC. https://www.fs.fed.us/fire/fmt/fmt_pdfs/fmn60-3.pdf (2017 January 17).

Reznicek, Anton A., Michael R. Penskar, Beverly S. Walters, and Bradford S. Slaughter. 2014. Michigan Floristic Quality Assessment database. Herbarium, University of Michigan, Ann Arbor, MI and Michigan Natural Features Inventory, Michigan State University, Lansing, MI. http://michiganflora.net .

Rooney, Thomas P. and Donald M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181(1-2): 165-176.

Safford, L. O., John C. Bjorkbom, and John C. Zasada. 1990. Paper birch. Volume II: hardwoods. Silvics of North America. USDA Forest Service Agriculture Handbook 654. Russell M. Burns and Barbara H. Honkala, Technical Coordinators. 877 pages. http://www.na.fs.fed.us/pubs/silvics_manual/volume_2/betula/papyrifera.htm (2016 December 14)

Slaughter, Bradford S., Anton A. Reznicek, Michael R. Penskar, and Beverly S. Walters. September 2015. Notes on the third edition of the Floristic Quality Assessment of Michigan. Wetland Science & Practice, pages 28-32.

Swaty, Randy. Winter 2016/2017. Traversing the U.P.: what do you see and what does it mean? U.P. Environment. Upper Peninsula Environmental Coalition, Marquette, Michigan. http://upenvironment.org/wp-content/uploads/2015/05/Winter-2016-17-Newsletter-Draft-V2.pdf (2017 January 23).

[USDA-FS-CNNF] United States Department of Agriculture, Forest Service, Chequamegon-Nicolet National Forest. January 3, 2017. CNNF_FSVeg_20170113. Digital map, posted by Deb Veen, GIS Specialist. Downloaded from Chequamegon-Nicolet National Forest FTP site, 2017 January 22.

[USDA-FS-HNF] United States Department of Agriculture, Forest Service, Hiawatha National Forest. April 4, 2016. FSVegSpR09ExtractVegetationPolygonsRSW. Digital map, posted by Samuel Adams, Forest GIS Coordinator. Downloaded from Hiawatha National Forest FTP site, January 12, 2017.

[USDA-FS-ONF] United States Department of Agriculture, Forest Service, Ottawa National Forest. August 20, 2015. FSVeg2015. Digital map. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3852003.zip (2017 January 15).

[USDA-NRCS] United States Department of Agriculture-Natural Resources Conservation Service. 2017. Soils: guide to texture by feel. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/?cid=nrcs142p2_054167 (March 27, 2017).

Van Lear, Mark. April 2008 (rev. March 2013). Soil texture calculator, version 2.0. Excel spreadsheet. United States Department of Agriculture-Natural Resources Conservation Service. https://prod.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053196.xls (2017 March 10).

Van Lierop, W. 1990. Chapter 5. Soil pH and lime requirement determination. Pages 73-126 in: Westerman, R. L. 1990. Soil testing and plant analysis, 3rd edition. Soil Science Society of America, Madison, WI.

Voss, Edward G. and Anton A. Reznicek. 2012. Field manual of Michigan flora. University of Michigan Press, Ann Arbor.

Williams, Gerald W. Summer 2000. Where have all the fires gone? Fire Management Today 60(3): 8-12. USDA Forest Service, Washington, DC. https://www.fs.fed.us/fire/fmt/fmt_pdfs/fmn60-3.pdf (2017 January 17).

Williams, Gerald W. 2002. Aboriginal use of fire: are there any "natural" plant communities? Charles E. Kay and Randy T. Simmons (eds.). Pages 2-48 in: Wilderness and political ecology: aboriginal land management myths and reality. University of Utah Press, Logan, UT.

[WDNR] Wisconsin Department of Natural Resources. 2015. Silviculture handbook. http://dnr.wi.gov/topic/ForestManagement/silviculture.html (2017 January 23).

[Wisflora] Wisflora: Online virtual flora of Wisconsin. 2017. http://wisflora.herbarium.wisc.edu/ (2017 January 23).

Wrobel, Alexandra. 2015 September. Tribal wild plant gathering on National Forests and Wisconsin state lands during the 2014-2015 season. Administrative report 15-11. Great Lakes Indian Fish & Wildlife Commission Odanah, Wisconsin. http:// data.glifwc.org/archive.bio/Administrative%20Report%2015-11.pdf (2017 January 17).