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The Precarious State of a Cultural Keystone Species: Tribal and Biological Assessments of the Role and Future of Black Ash

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Black ash (*Fraxinus nigra* Marsh.) plays a central role in several Native American teachings (including a Wabanaki creation story) and has long been used for basketry, yet relatively little is known about the species' ecology. The recent and ongoing invasion of emerald ash borer (*Agrilus planipennis* Fairmaire), an invasive beetle killing millions of ash trees in eastern North America, threatens the future of black ash and the centuries-old basketry tradition. In recognition of the precarious state of this cultural keystone species, basketmakers, basket-tree harvesters, and researchers assembled to discuss traditional ecological knowledge and research advancements related to black ash. Here we provide an overview of basket-quality ash, synthesize current knowledge of black ash biology and ecology, and report findings from this successful tribal and scientific collaboration. Management recommendations were developed and future research needs outlined in hopes of sustaining an ecologically important tree species and maintaining a Native American tradition that has cultural and spiritual significance.

Keywords: *Agrilus planipennis*, emerald ash borer, *Fraxinus nigra*, basketry, invasive forest pest, traditional ecological knowledge

Black ash (*Fraxinus nigra* Marsh.) is a unique and significant tree species from ecological, economic, and cultural perspectives. The species occupies a particular ecological niche in forested wetlands where few other woody plants thrive. Ecosystems containing black ash stands also play an important role in supporting other unique species, including flooded jellyskin (*Leptogium rivulare* [Ach.] Mont.), a threatened arboreal lichen that preferentially occurs on the basal bark of mature black ash (Lee 2004). In addition, Native American and European American basketmakers derive socioeconomic benefit

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from black ash via a variety of basketmaking traditions.

Like many of the Native Americans and First Nations people in the native range of black ash, the Wabanaki tribes in Maine (Aroostook Band of Micmac Indians, Houlton Band of Maliseet Indians, Passamaquoddy Tribe, and Penobscot Indian Nation) and the Saint Regis Mohawk Tribe in New York and Canada have a long history of harvesting black ash for basketry (Benedict and Frelich 2008, Diamond and Emery 2011). Specific wood qualities, such as strength and flexibility, make black ash unique and explain in part why it is highly preferred for basketry (Benedict and David 2004). Yet the species' cultural significance goes beyond weaving baskets; black ash is at the spiritual center of the tribes' teachings, including one of their creation stories (Leland 1884, Benedict and David 2004). Many basketmakers rely on "basket-tree harvesters": these individuals are tribal members who have learned to identify favorable sites and recognize individual black ash trees that are likely to produce basket-quality materials. As such, they are also responsible for maintaining and passing on tribal knowledge about the species from generation to generation.

Emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire), an invasive insect native to Asia that feeds on ash (*Fraxinus* spp.), has caused the Wabanakis, Mohawks, and others great concern about the future of black ash. Initially detected in southeastern Michigan and southern Ontario in 2002, the EAB invasion has spread rapidly (Siegert et al. 2014b) and is responsible for killing millions of North American ash trees (Cappaert et al. 2005, Herms and McCullough 2014). As of July 2016, EAB has been detected in 27 states and the Canadian provinces of Ontario and Québec.[1] Although black ash stands in many locations still have valuable, basket-quality trees, including those in Maine where to date no EAB detections have occurred, the EAB invasion nonetheless continues to spread and threaten what remains of this unique resource (Siegert et al. 2015).

In addition to its significance as a cultural resource, black ash has commercial value and can be used for veneer, cabinets, and furniture (Ross 2010). Yet relatively little is known about this important species (Wright and Rauscher 1990), and the scientific literature on black ash biology and ecology is often contradictory. For instance, the reported shade tolerance of black ash varies widely (e.g., Sims et al. 1990, Wright and Rauscher 1990, Gustafson and Sturtevant 2013, Reyes et al. 2013). Because of the minimal information available on black ash and the imminent threat from EAB, it is essential to compile and distribute up-to-date, comprehensive information on black ash before EAB devastates the resource.

To assess current knowledge about black ash, a group of basket-tree harvesters from Maine (Wabanaki tribes) and upstate New York (Saint Regis Mohawk Tribe), along with a group of black ash researchers, assembled at the University of Maine's Black Ash Symposium in November 2014. The group discussed traditional ecological knowledge related to black ash and the basketry tradition, recent advancements in black ash ecological research, misconceptions about the species' biology and ecology, and the threat EAB poses to the black ash resource. The group then visited four black ash stands in Maine where they assessed the species' current status and discussed potential responses to EAB infestations. Based on these assessments, recommendations were developed to address best basket-tree harvesting practices and to maintain black ash on the landscape in the presence of EAB. Additional research needs were also outlined to fill knowledge gaps and test initial recommendations. Here we provide a general overview of basket-quality ash, synthesize current knowledge on black ash biology, and report findings that resulted from the diverse collaboration of tribal, university, state, and federal partners.

Traditional Ecological Knowledge on Basket-Quality Ash

Basket-tree harvesters and basketmakers are the primary forces driving black ash ecological research in Maine and other regions. Maine tribes formed the Black Ash Task Force in the early 1990s to address concerns about black ash decline. The Task Force, which is a partnership of tribal, university, and state and federal personnel, remains active and is currently addressing the potential loss of black ash due to EAB. One approach is to identify individual traits and site characteristics that produce suitable basket-quality trees which, in turn, can guide priorities for tree and stand management before, during, and after the EAB invasion occurs.

Each black ash basket-tree harvester has a range of knowledge and opinions regarding the specific attributes associated with basket-quality trees. After a suitable basket-quality tree is identified and felled, the trunk is "pounded" to separate the annual growth rings, thus creating thin splints that can be manually smoothed and gauged. Different wood qualities may be sought for different types of baskets, from sturdy pack baskets or potato baskets (Figure 1) to delicate, decorative fancy baskets. As a result, each harvester will vary in his or her selection of the "ideal" tree. What follows is an attempt to characterize attributes that can provide an initial indication of basket-quality trees in the field, based on the observations of one or more basket-tree harvesters. Whether a tree is ultimately selected for basketmaking depends on the needs and preferences of each harvester.

Management and Policy Implications

Biological invasions of nonnative organisms in forested ecosystems can have profound economic and ecological impacts. Black ash is a cultural keystone species in the United States and Canada and is currently threatened by the nonnative emerald ash borer (EAB). A better understanding of black ash biology and ecology in light of this threat will have significant implications for its future management, survival, and continued use as a source of cultural heritage and basketmaking traditions. To address gaps in black ash knowledge that influence basket-quality ash, researchers are encouraged to concentrate efforts on studying the following: stand dynamics across a range of hydrologic regimes; the role of genetics on basket-quality black ash; and EAB population dynamics in infested black ash stands and the effect on regeneration of basket-quality ash. Researchers are also encouraged to collaborate with tribal partners and basketmakers during these studies. Diverse collaboration toward a common cause can result in a synergy of traditional ecological knowledge and scientific knowledge that leads to effective and informed management and policy decisionmaking. To that effect, resource managers and policymakers are also encouraged to cooperate with one another to locate, maintain, and manage existing black ash populations, while simultaneously considering accessibility to high-quality black ash trees for cultural and basketmaking traditions, before basket-quality black ash in North America are decimated by the EAB invasion.

Figure 1. Black ash basket. Black ash baskets take many shapes and forms, from sturdy pack baskets to decorative, fancy baskets. Other baskets mix utility with decoration. In Maine potato baskets are common, including this basket by Richard Silliboy of the Houlton Band of Micmacs.

Site Hydrology

Whereas black ash is commonly associated with poorly drained wetland sites, basket-quality black ash is frequently found on sites where water flows or seeps through the site; it is not stagnant (Diamond and Emery 2011; Costanza 2015; Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013). Black ash often grows more slowly, with smaller annual growth rings, when there is ponded water at the surface. However, soils that are saturated from a nearby source via capillarity provide ideal basket-quality conditions: soils are wet enough to allow black ash to outcompete other species, but not overly saturated to inhibit radial growth (Telander et al. 2015; Robert Slesak, Minnesota Forest Resources Council, pers. comm., June 5, 2015). Because of this, sites that are wet because of proximity to water or topography (e.g., swales) produce better-quality ash trees than sites where hydrology is driven by a constraining soil horizon or property, which is why some harvesters associate basket-quality black ash with river terraces and floodplains (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013).

Rooting Depth

Sites that are saturated later into the growing season and are nutrient poor typically do not produce basket-quality black ash. If there are swollen root buttresses or roots that are exposed and easily visible, it indicates that the tree and site are probably inadequate for basketry. These attributes typically represent shallow rooting depth because of impenetrable soils or high subsurface water tables, both of which produce poor-quality black ash with annual rings that are too narrow for basketry (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013; Symposium field observations, November 2014).

Annual Ring-Width

For many harvesters, annual ring-width is the most important factor in determining the basket quality of black ash. Good basket-quality wood contains growth rings $\geq$0.08 in./year for 10 or more consecutive years (Benedict and Frelich 2008), but ideally annual growth is relatively consistent throughout the tree's life. If growth rings are too narrow (e.g., $<$0.04 in.), they are unusable for weaving. However, growth rings that are too large (e.g., $>$0.20 in.) are also undesirable, because they result in thick splints that are difficult to work with (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013). A high-quality basket tree typically produces 8–12 splints per radial inch (ca. 0.08–0.12 in. ring-width/year).

Stand and Species Composition

A typical stand can contain both good- and poor-quality black ash. Whereas there are specific site characteristics that often lead to the production of basket-quality ash trees (see above), microsite and stand characteristics are also important. Light availability is critical: basket-quality ash trees tend to be more open grown, receiving intermediate to moderate light. Likewise, microtopography is also critical: within a few inches dramatic changes in soil, water table depth, and rooting depth can be observed (Symposium field observations, November 2014).

Basket-quality ash trees are often associated with reduced competition from other species, which in turn increases light availability (Symposium field observations, November 2014). Good sites frequently contain few, if any, conifers such as northern white-cedar (*Thuja occidentalis* L.) and balsam fir (*Abies balsamea* [L.] Mill.). When conifers are present, some harvesters have observed an increase in the brittleness of black ash wood collected from the site, making their splints more likely to crack and break. Furthermore, common conifer associates of black ash (e.g., northern white-cedar, balsam fir, and red spruce [*Picea rubens* Sarg.]) can be indicative of poorly drained soil conditions, which result in poor-quality black ash trees (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013).

Canopy

Trees in the overstory (dominant or codominant), with full, deep crowns that cover more than 50% of the height of the bole are preferred for basket-quality trees. If dead limbs or epicormic branching are present, the tree is considered unhealthy and often avoided. However, dying trees are occasionally used if the annual ring-width (described earlier) looks acceptable (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013).

Bark

Trees with increased bark texture and bark depth are preferred; however, black ash rarely displays the distinct furrows seen on green or white ash (Diamond and Emery 2011). If the bark takes on a "corky" appearance (slightly flexible, moist, and sticks out from the bole) (Figure 2A), it is frequently associated with annual growth rings ideal for basketry (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013). One possible explanation for this association is that thicker xylem increments imply good growth conditions that would also produce thicker phloem and cork from lateral meristems, which would result in corky bark. Faster growth in lateral meristems probably results from increased light availability and more favorable site hy-

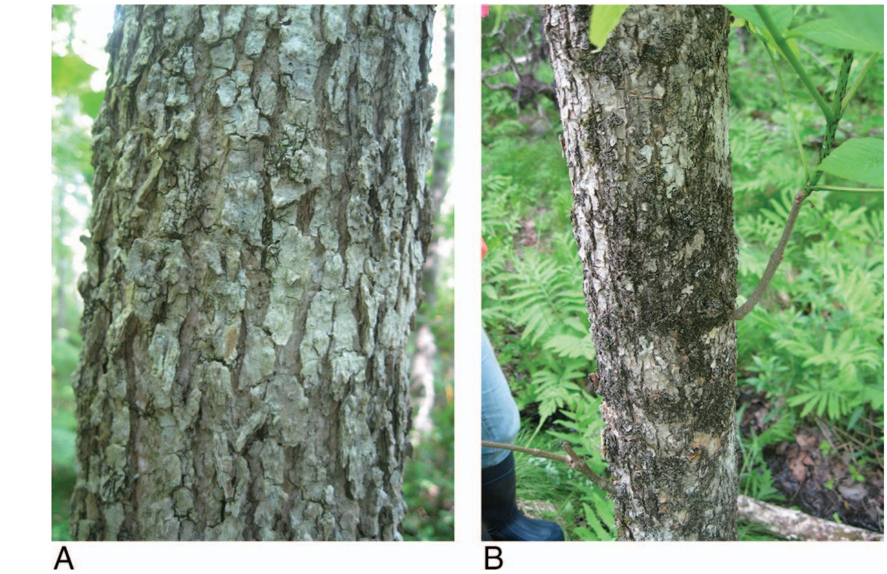

Figure 2. Comparison of black ash bark quality. Black ash bark takes on a variety of appearances. Basket-tree harvesters frequently associate spongy, corky, thicker bark (A) with high-quality basket wood. Conversely, bark with long, thin, brittle flakes (B) is frequently associated with poor-quality black ash.

drology (Symposium field observations, November 2014). Bark characteristics were a key indicator for many basket-tree harvesters taking part in the Symposium. Furthermore, participants in the Symposium observed that increment borer holes healed faster in trees with "corky" bark (Figure 2A) than in those with "noncorky" bark (Figure 2B). Bark color can also indicate tree quality. A yellow-tinted bark was often associated with increased annual growth and improved wood quality, whereas a gray-tinted bark was associated with poorer quality and brittle wood.

Tree Attributes

Specific features within the tree can affect its usability. The sapwood (aka "white wood") is typically used for fancy baskets, whereas the heartwood (aka "brown wood") is commonly used for pack and potato baskets. Stem defects such as cracks, branch stubs, or holes can make the wood unusable for splints. In addition, if the tree bole is too curved it cannot be processed ("pounded") for splints. A harvester can work with a moderate sweep in the bole, but it takes more time and effort to pound (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013).

A good-quality tree will have a straight bole for 4.5–6 ft (or more) and that section will be free of defects. Tree size can range anywhere from 5 to 25 in. dbh (breast height = 4.5 ft), but selection is highly dependent on how the tree will be transported (e.g., on the harvester's shoulder, four-wheeler, or truck) (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013).

General Black Ash Biology

Black ash grows on a range of soil types, from peat bogs and mineral soil wetlands to well-drained stream edges and ridges (Sims et al. 1990, Wright and Rauscher 1990, Ehrenfeld 2012). The species is most frequently found on flooded or seasonally wet sites, probably due to reduced competition from other species incapable of establishing in hydric conditions. Tardif et al. (1994) reported that young black ash stems can produce hypertrophied lenticels to increase gas exchange, as well as use adventitious roots (Sena Gomes and Kozlowski 1980, Tardif et al. 1994, Mendelssohn et al. 2014). Both of these adaptations allow young stems to persist on wet sites.

When black ash becomes established on better-drained mesic sites, the species frequently exhibits increased annual growth and larger dbh (Costanza 2015; pers. observ. of authors, 2015). Conversely, in stands saturated throughout the growing season, black ash trees typically have narrower annual growth rings, reduced dbh, exposed roots, and numerous sprouts. One explanation is that black ash is often classified as having a shallow root system (Wright and Rauscher 1990), which is more affected by water table fluctuations, in turn affecting annual growth rates. Although long-term saturation produces poor-quality ash, sites with spring flooding followed by surface drying in the summer favor black ash growth (Sims et al. 1990, Lenhart et al. 2012, Slesak et al. 2014). These better-drained mesic sites are therefore locations where basket-tree harvesters frequently search for basket-quality trees. Further, these differences in site hydrology that influence black ash growth and quality may be captured in the Natural Community classifications that many states and provinces have developed to describe vegetation, soils, and site conditions of common communities (see Supplemental Table S1[S]).

Black ash regeneration also varies widely. The species is capable of both producing seed and sprouting when cut or stressed, yet sprouts from the root collar tend to have a higher growth rate as they are growing from an already developed root system (Tardif and Bergeron 1999). These sprouts also tend to be more tolerant of flooding and droughts (Sims et al. 1990, Tardif and Bergeron 1999). Further, site conditions (e.g., flooding and drought) may heavily influence seedling survival and establishment. Two consecutive dry/reduced flood years may be needed for successful establishment; the first year allows the seed to break dormancy and germinate, whereas the second year helps establishment and survival of future flooding (Symposium field observations, November 2014). Ash can also produce persistent seeds, which is a benefit in sites with fluctuating hydrologic regimes. However, several biotic or abiotic site factors may influence the survivorship of this seed bank including insects, moisture, fungi, and others (Klooster et al. 2014).

Based on four recent studies, average tree age in black ash dominated stands typically ranges from 35 to 100 years old, with a few black ash trees greater than 200 years old (Table 1) (Tardif and Bergeron 1999, Benedict and Frelich 2008, Townshend 2011, Costanza 2015). Although large old-growth black ash forests (>200 years old) exist in North America, they are not common.

[S] Supplementary data are available with this article at http://dx.doi.org/10.5849/JOF-2016-034R1.

Table 1. Black ash average tree age in North America, based on four studies that sampled a variety of black ash stands across the northern United States and southern Canada.

Location	Study	Maximum black ash age (>4 in. dbh)	Average black ash age (>4 in. dbh)	No. of black ash stands
		. . . .(yr)	. . . .	
Maine	Costanza 2015	273	59	24 stands (⅙ ac)
Chippewa National Forest, Minnesota	Benedict and Frelich 2008	164/131/135[1]	96/98/65[1]	67 stands (16.4 ft radius): 24/24/19[1]
Northern New York[2]	Costanza 2015	146	70	16 stands (⅙ ac)
Ontario, Canada	Townshend 2011	161[3]	61	16 stands (1⁄10 ac)
Lake Duparquet, Québec, Canada	Tardif and Bergeron 1999	320[4]	34	5 stands (composed of 54 plots, 1⁄40 ac each)

Research sites ranged from pure black ash to mixed forest stands and from old-growth to anthropogenically disturbed stands.
[1] Values correspond to three types of sites: lowlands/uplands/woodland ponds. Maximum and average tree ages were taken from stand data that included all species; however, stands were dominated by black ash. A total of 166 black ash were sampled.
[2] In northern New York, samples were collected in St. Lawrence and Lewis counties.
[3] Oldest veteran black ash tree throughout sample area was 161 years old. Oldest veteran black ash tree in each stand ranged from 63–161 years old.
[4] The oldest black ash was sexually reproduced. The oldest black ash sprout was 120 yr old.

In more disturbed areas (both naturally and anthropogenically), average tree age is younger. Given basketmakers' preference for 0.08–0.12 in. ring-widths and trees 5–25 in. dbh, this typical black ash age range matches the typical expectations of basket-quality trees.

Reports on black ash shade tolerance differ. One perspective describes the species as shade intolerant (Wright and Rauscher 1990, Gustafson and Sturtevant 2013), whereas another describes the species as moderately shade tolerant, becoming more intolerant with age (Sims et al. 1990, Barnes and Wagner 2004). Tolerance may also depend on origin: seedlings and sprouts may have different levels of shade tolerance. Based on several recent observations (Reyes et al. 2013, Fisichelli et al. 2014, Looney et al. 2016; Symposium field observations, November 2014), the species appears to be moderately shade tolerant. Black ash is capable of germinating and surviving in the understory for several years, although low to moderate light is required for survival; a closed canopy will result in little to no seedling survivorship. In Ontario, Townshend (2011) found black ash trees of substantial age (e.g., up to 80 years old) under the main forest canopy, suggesting that the species is capable of withstanding long periods of suppression. If black ash can persist in the understory, the surviving seedlings could be an important source of future black ash stems during the EAB invasion.

Site characteristics, regeneration strategies, and stand dynamics all play a key role in the quality of black ash trees and heavily influence basketmaking traditions. By improving our understanding of black ash biology/ecology in Maine and other black ash habitats, improved management strategies that simultaneously target EAB control and black ash preservation, which will serve to maintain this cultural keystone species, can be developed.

Case Study: Four Black Ash Stands in Maine

In November 2014, basket-tree harvesters and researchers visited four black ash sites in Maine as part of the Black Ash Symposium. These sites were representative of two common black ash stand types found in a statewide study: black ash swamps and hardwood river terraces (Gawler and Cutko 2010, Costanza 2015; see also Supplemental Table S1); two sites from each stand type were visited (Figures 3–6). The site visits allowed Symposium participants to share their knowledge of black ash, while also assessing the potential impact of EAB on these types of stands and on basket-quality ash. What follows is a summary of the discussions and observations from the Symposium site visits.

The four black ash stands visited are examples of old-field, early-successional forests (<100 years old) common in central and southern Maine, which regenerate on abandoned agricultural land. The two black ash swamps were characterized by standing water, ponding, and relatively flat topography with limited pits and mounds (Figures 4 and 6). The two hardwood river terraces, in contrast, had little to no standing water, slight downstream slopes, and small streams draining the sites (Figures 3 and 5). Based on increment cores collected in 2012 (Costanza 2015), the highest basket-quality black ash trees were found on the two river terrace sites. Harvesters attending the Symposium supported this finding, noting that they often associate high-quality black ash with river banks and floodplains with low to moderate stand densities.

The four Maine stands had significantly lower black ash densities than documented stands found in Minnesota, Ontario, and Québec (Table 2). Stands visited ranged from 90–162 black ash stems·ac^{-1}, with the swamps producing higher black ash densities than the river terraces. One possible explanation for these reduced stand densities is that most Maine stands are early-successional forests growing in previously harvested stands or old fields. Studies outside of Maine have focused on well-established forests where black ash maintains high densities and canopy dominance. It is also possible that black ash trees in Maine recruit differently from those in other regions; however, recruitment strategies and shade tolerance need to be further studied to draw significant conclusions. During the Symposium site visits, basket-tree harvesters and researchers both noted that basketry is more prevalent in Maine, New York, and southeastern Ontario. Lower stand densities and different recruitment patterns, along with cultural traditions, may influence the proportion of basket-quality black ash trees in these regions compared with others within the black ash range.

Unlike those in many other regions, black ash trees in Maine frequently occur in mixed species stands, which can include northern white-cedar, balsam fir, American elm (*Ulmus americana* L.), red maple (*Acer rubrum* L.), and yellow birch (*Betula alleghaniensis* Britton) (Gawler and Cutko 2010, Costanza 2015). Pure black ash stands are uncommon, unless the site is a swamp or an old-growth black ash stand (Ehrenfeld 2012, Costanza 2015). Of the sites visited

Maine and other regions are likely to respond to EAB infestations.

The EAB Impact

The potential economic and ecological impacts of the EAB invasion are staggering (Kovacs et al. 2010, Aukema et al. 2011) and will drastically alter the ash components of North American forests (Cappaert et al. 2005, Herms and McCullough 2014). Black ash, in particular, is highly susceptible to the insect (Anulewicz et al. 2006, Pureswaran and Poland 2009, Siegert et al. 2014a) and dies within 2–4 years of being infested (Siegert et al. 2005, 2014b) (Figure 7). In EAB-infested areas, research has yet to fully address the ecological impacts to black ash. Several studies report ash mortality rates as a pooled statistic, including white, green, and black ash (e.g., Kashian and Witter 2011, Klooster et al. 2014), whereas other studies only address early infestation periods (2004–2008) and focus on Michigan and Ohio (e.g., Siegert et al. 2005, Smith et al. 2015, Kashian 2016). Researchers in Minnesota have focused on black ash stands, simulating EAB mortality by girdling black ash trees (Slesak et al. 2014, Looney et al. 2015). However, additional research is needed to more critically evaluate black ash stand dynamics through the course of an EAB invasion and in the different habitats and hydrologic regimes where black ash occurs.

Based on green ash studies conducted in Michigan after EAB infestation (Kashian 2016), it is possible to make a few inferences about the potential response of black ash stands to EAB. In Michigan, green ash trees are persisting with sprouts, released advanced regeneration, and seedlings produced from sprout-borne seeds on sites where green ash densities were relatively high. Conversely, preliminary work suggests sprouting from EAB-killed black ash may be extremely limited (N.W. Siegert, USDA Forest Service, unpubl. data, 2010). Reduced densities of black ash will probably leave stands depleted, with fewer and smaller stems following the initial wave of the EAB invasion. Any surviving black ash trees will probably be small (<3 in. dbh) unless established EAB infestations are radically suppressed. One study in southeastern Michigan, conducted when EAB populations were relatively high, found that sprouts from harvested trees were recolonized by EAB within 1 year (Petrice and Haack 2011). Further, work by Tardif and Bergeron (1999) indi-

Figure 3. Site 1: hardwood river terrace. Site 1 is a sparse to moderately dense black ash, mixed hardwood stand. The stand is separated from a neighboring conifer stand by a small stream (A). The majority of black ash >4 in. dbh at this site are high quality (B).

during the Symposium, the black ash swamps had moderate conifer densities (primarily balsam fir), whereas the hardwood river terraces were mixed hardwood stands composed of red maple, American basswood (*Tilia americana* L.), green ash, and white ash (*Fraxinus americana* L.). Harvesters and researchers both noted the improved quality of ash on the river terraces and often associated these basket-quality trees with the lack of conifers in/near the stand.

At the end of the Symposium, several conclusions about Maine's black ash population emerged. Unlike those in other regions of North America, the four black ash stands we visited were early-successional stands characterized by low to moderate stand densities, mixed species composition, and reduced black ash regeneration. In addition, harvesters confirmed that these characteristics (site hydrology, species composition, and stand structure) play a key role in the quality of black ash trees produced. With regard to management implications, the sites visited were similar to stands in Ontario where black ash is a secondary or minor component (Jeffrey Dech, Nipissing University, pers. comm., Feb. 2, 2016) and many green ash stands in southeastern Michigan (Kashian 2016). Therefore, research from these stands may provide valuable insight into how similar stands in

Figure 4. Site 2: black ash swamp. Site 2 is a moderately dense mixed hardwood-conifer stand with black ash, red maple, and balsam fir. The site is characterized by minimal ponding (A), root buttressing (A), and small black ash trees, typically <6 in. dbh (B). The majority of black ash >4 in. dbh are poor quality.

cates a greater abundance of black ash sprouts than seedlings in young age classes, in addition to higher mortality rates in sprouts. To fully understand how black ash sprouts may persist in EAB-infested stands, further investigation is needed on sprouting processes, the survivorship of black ash sprouts, the relationship to EAB population cycles, and the ability of these sprouts to become basket-quality trees.

After a few years of EAB infestation, once the overstory has been killed, established black ash seedlings, if present, may be released if the resulting gaps are not quickly filled in by neighboring trees. However, because EAB is known to infest and kill trees ≥1 in. dbh (Herms and McCullough 2014), it is likely that most seedlings in mixed or low-density stands will not achieve a larger size (remain <3 in. dbh), and the mean stand diameter will remain low. Where black ash is a dominant component of the stand, changes in evapotranspiration after overstory loss may result in water table rise (Slesak et al. 2014) and conversion to a more open-water wetland condition (Erdmann et al. 1987), further threatening ash persistence in the stand. In addition, gap formation will probably result in an increased risk of competition from residual non-ash understory trees unaffected by EAB, as well as shrubs and herbaceous vegetation (Slesak et al. 2014). Based on the rapid, detrimental impact of EAB, it is critical to identify what additional information and efforts are needed to prepare for the insect's arrival in many black ash stands.

Recommendations

The first step in preparing for and managing EAB is early detection. If and when EAB is detected, efforts should focus on slowing the insect's spread (Siegert et al. 2015) so the availability of existing basket-quality ash trees can be extended as long as possible. Management strategies may be implemented to complement this effort by reducing EAB population densities (McCullough et al. 2015). In doing so, guidelines should be developed that limit anthropogenic spread of EAB-infested material while allowing harvesters to safely transport basket-quality black ash material without risk of transporting EAB to non-infested areas. For instance, two recent studies reported that submerging infested black ash logs in water for 8–16 weeks killed all EAB, while still maintaining useable basket-quality wood (Siegert et al. 2014a, Poland et al. 2015).

If harvesters are available, basket-quality trees should be harvested, pounded, and split as soon as an EAB infestation is detected in the vicinity. This harvesting increase would have a considerably different impact on forests, and on black ash in particular, than tribal traditions historically had. However, dried black ash splints can be stored for several years (Basket-tree harvesters, Maine Indian Basketmakers Alliance, pers. comm., May–August 2013); increasing harvesting would allow harvesters to use wood that would otherwise be lost to EAB. Lightly infested black ash trees remain suitable for basketmaking materials but degrade rapidly as EAB density increases, reducing yields from a given log to the point where it may be unusable for splints (Siegert et al. 2014a, Poland et al. 2015). In addition, some have recommended increasing black ash harvesting now, before EAB arrives. This would potentially reduce concerns about quarantines, accidental insect transport, and loss of basket-quality wood after an EAB infestation.

Last, we recommend collaboration between state, federal, and tribal agencies to develop memorandums of understanding or joint agreements, before the arrival of EAB

Figure 5. Site 3: hardwood river terrace. Site 3 is a moderately dense mixed hardwood stand with occasional conifer (A). A small stream runs northeast to southwest, and an unpaved road runs west to east through the stand. In better-drained areas, large, high-quality black ash are produced. Where ponding occurs, black ash tend to be smaller and poorer quality. The majority of black ash >4 in. dbh are high quality (B).

in high-value black ash stands. Such agreements can alleviate confusion and promote action as soon as EAB is detected in or near tribal lands or other traditional black ash harvesting sites. Furthermore, such agreements can help foster discussions on accessibility to black ash trees. To preserve the black ash resource and maintain black ash basketry in the face of EAB, discussions regarding accessibility and response plans need to occur.

Future Research

In addition to making preparations for EAB's arrival in black ash stands, there are countless opportunities to learn more about this still-overlooked tree species. To improve our understanding of black ash trees' potential response to EAB and impacts to cultural traditions, future research directions were discussed during the Black Ash Symposium. What follows is a summary of the three most pressing research needs: influence of black ash stand dynamics and site hydrology on regeneration and quality of black ash; role of black ash genetics in the future of the population; and EAB population dynamics in infested black ash stands and the effect on black ash regeneration.

Influence of Stand Dynamics and Hydrology on Regeneration and Quality

Very little information exists on black ash stand histories, conditions, and natural dynamics in Maine. For example, it is unclear whether Maine black ash stands undergo continuous recruitment and remain stocked over an extended period of time or if black ash is replaced by other species. Natural stand dynamics and succession are poorly understood, partially because there are few old-growth stands in Maine. Locating and studying a few old-growth black ash stands (>200 years old) would greatly improve our current understanding of succession. The inclusion of managed stands would also prove beneficial, allowing researchers to quantify the response of black ash to silvicultural treatments. Furthermore, describing the dynamics of ash across a range of disturbance histories would allow researchers to develop a much needed successional framework for black ash and to develop a description of the species' regeneration niche. In the midwestern United States, recent studies have suggested that the future of black ash stands faced with EAB and climate change will probably center around non-ash replacement species (Looney et al. 2015, Iverson et al. 2016). However, in regions where black ash is a cultural keystone species, replacing black ash is not an optimal management strategy. Describing black ash stand dynamics and recruitment in Maine, as well as in other black ash habitats such as those in Nova Scotia, southern and central Ontario, and Québec, would provide insight on how to maintain the species, both for basketmaking and ecological reasons.

Stand dynamics are heavily influenced by stand hydrology, which is poorly understood in Maine and other parts of the black ash range. A few recent studies in Minnesota have explored black ash stand hydrology (Slesak et al. 2014, Telander et al. 2015); however, the extent to which water table fluctuations in black ash stands influence regeneration and recruitment across the entire range should be further explored. For example, in situations where water table dynamics are driven primarily by topography or local surface water, a change in evapotranspiration after overstory loss may not result in a concomitant change in site hydrology (Robert Slesak, Minnesota Forest Resources Council, pers. comm., June 5, 2015). Furthermore, the role of post-disturbance sprouting of black ash in regulating water table dynamics is also unclear, as is the role

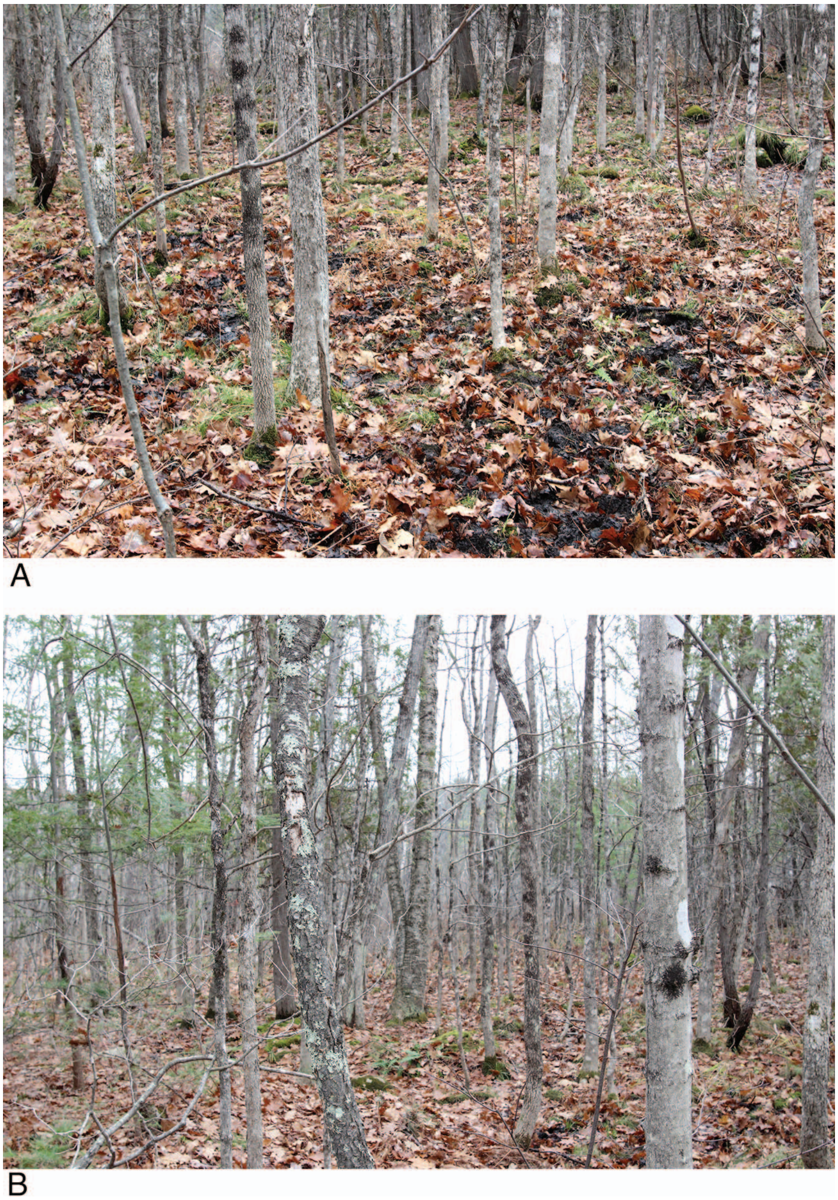

Figure 6. Site 4: black ash swamp. Site 4 is a moderate to highly dense black ash stand. The edge of the stand grades into a lake. The site is characterized by mucky, saturated soils (A) nearly year-round. Most black ash are small, with very few trees >6 in. dbh. Trees frequently have sweeping stems, epicormic branching, and root buttressing (B). Black ash >4 in. dbh are poor quality, with very narrow annual growth (B).

of increased deadwood inputs from EAB-induced mortality on hydrology and stand development. Site hydrology is also a critical factor in determining the quality of black ash trees, yet the impact of EAB-induced changes in hydrology on basket-quality ash have yet to be determined. To address these knowledge gaps, the establishment of long-term experimental and monitoring sites could help track succession and development, assess changes in the water table, quantify changes in basket-quality ash, and monitor for the arrival of EAB.

Role of Black Ash Genetics and Future of Species

When speaking with basket-tree harvesters, several types of black ash, including "ridge," "river," "yellow," "pink," and "swamp" ash, were mentioned. According to harvesters, each of these types produces a different quality basket splint. This leads researchers to ask: Is there any genetic distinction between these types? If so, can specific trees with better-quality wood be targeted for seed collection and management? To address these questions, genetic testing of black ash from various stand types is recommended.

Tree characteristics such as vessel size (both earlywood and latewood) and bark depth play a role in black ash wood quality, but that role is poorly understood. Kames et al. (2016) noted large annual variability in black ash latewood width, as well as variability in earlywood vessel lumen but did not directly look at wood quality associated with this variability. A few other studies observed a marked decrease in latewood width on saturated sites, which resulted in small growth rings unsuitable for basketry (Costanza 2015; Jacques Tardif, Centre for Forest Interdisciplinary Research, pers. comm., Feb. 8, 2016). However, these reports were based on visual observations. To fully understand how site characteristics impact seasonal growth (earlywood/latewood) and vessel size and in turn wood quality for basketry, we propose a study comparing the ratio of earlywood to latewood using previously collected black ash cores from a range of sites (e.g., Tardif and Bergeron 1999, Townshend 2011, Costanza 2015, Telander et al. 2015).

Effects of EAB Infestation on Black Ash Population Dynamics

Much remains to be learned about the long-term impacts of the EAB invasion in black ash stands and how it may affect survival, recruitment, regeneration, and quality of black ash. Establishing permanent plots in uninfested stands to monitor the response of black ash stands after EAB infestation in Maine and elsewhere would generate valuable information that is critically needed. Timelines could be developed for salvaging EAB-infested black ash that can still be used for basketry. Permanent plots would also allow researchers to measure seedling and sprout response for multiple years post-infestation. These stands could be assessed by basket-tree harvesters for abundance and quality of black ash regeneration to determine the presence and frequency of basket-quality wood.

Black ash vegetative reproduction (i.e., sprouting) after EAB infestation has not been evaluated. In black ash stands frequently harvested by basketmakers, harvesters have reported regular occurrences of stump sprouting. Vegetative reproduction through stump sprouting may contribute to maintaining black ash populations in Maine and other regions where basketry is common, at least where the relative density of

Table 2. Black ash stand densities in North America, based on five studies conducted in the northern United States and southern Canada that focused on stands with a significant component of black ash.

Location	Study	Stand density (stems/ac, trees ≥4 in. dbh)	No. of stands
Northeast Minnesota	Palik et al. 2011	228–262[1]	54
Chippewa National Forest, Minnesota	Slesak et al. 2014	228–371[2]	67
Ontario	J.P. Dech, unpubl. data	152–617[3]	16
Lake Duparquet, Northwest Quebec	Tardif and Bergeron 1999	2,049–13,740[4]	5
New York	Costanza 2015	24–162[5]	16
Maine	Costanza 2015	54–186[5]	24

[1] Measured stand densities of black ash stands, primarily composed of black ash.
[2] Black ash comprised 75 to 100% of stand basal area, with pure stands commonly occurring.
[3] Measured stand densities where black ash ranged from 39 to 100% of stand basal area.
[4] Measured all black ash ≥4 in. tall.
[5] Density only includes black ash trees.

black ash is moderate or high. Black ash decline and mortality caused by EAB, however, may deplete root starch reserves, resulting in reduced frequency, vigor, or survivorship of vegetative growth. Furthermore, little is known about the quality of these sprouts regenerated from the stumps of basket-harvested trees. More work is needed in EAB-infested black ash stands, particularly basket-quality stands, to determine the degree to which stump sprouting may influence stand dynamics and whether basket-quality trees may be produced before becoming infested by EAB again. If these sprouts can produce basket-quality trees, implementing a coppicing rotation may be an effective management strategy to maintain a basket-quality black ash population. Such studies would improve our understanding of black ash vegetative reproduction while simultaneously exploring where and how black ash basketry may persist. By knowing where basket-quality ash is being produced and which stands can continue to regenerate basket-quality trees post-EAB, resource managers and tribal members can work to sustain this cultural keystone species and associated cultural traditions for years to come.

Figure 7. EAB infestation in a black ash tree. EAB can easily be identified by the distinctive S-shaped galleries from larvae feeding on xylem tissue. This black ash tree is infested with EAB, with clear galleries underneath the bark.

Conclusions

Throughout this work and via the Black Ash Symposium, harvesters and scientists came together to synthesize current black ash knowledge, in turn developing a recommended action plan for Maine's black ash resource. Our results explicitly demonstrate how traditional ecological knowledge and scientific knowledge can support each other and also how they can be applied to forest health problems to develop collaborative solutions. The recommendations suggested here, while focused on Maine, can be applied in locations with similar black ash habitat. Our findings indicate that Maine's black ash population is typically less dense and produces a relatively large number of basket-quality trees compared with other regions, representing a unique situation. To maintain this cultural keystone species in Maine and other regions, further research on the species' response to EAB infestations is needed, along with a better understanding of the species' ecology and recruitment patterns. This information not only will assist those studying and managing black ash populations but also will benefit basket-tree harvesters, tribal members, and foresters in maintaining basketry and cultural traditions. The recommendations and current research needs described here can help inform black ash management at community, state, and regional levels and are representative of the effective collaboration between tribal members, basket-tree harvesters, and scientists.

Endnote

1. For more information, see the Emerald Ash Borer Information Network at www.emeraldashborer.info.

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