11 Emerald ash borer, black ash, and Native American basketmaking

Invasive insects, forest ecosystems, and cultural practices

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Introduction

The significance of forest resources to Native American culture

Native cultures coevolved with the forests of the Great Lakes region following the last ice age. Plentiful water, abundant game, and fertile soil supported fishing, hunting, and gathering, as well as subsistence agriculture. Lakes and tributaries facilitated transportation by canoe and trade among tribes. Native Americans developed a semi-nomadic lifestyle, moving seasonally among camps as they harvested and cultivated foods, medicines, supplies, and ceremonial items (Kurtz et al., 2015). They relied on natural resources for clothing, shelter, and food. Their cultures continue to rely on natural resources, including trees and understory plants (wood, bark, branches, leaves, and nuts), nonvascular plants, fungi, and animals.

Many species have special cultural and historical value to tribes. In the Great Lakes region, culturally significant species include sugar maple (*Acer saccharum*), paper birch (*Betula papyrifera*), northern white cedar (*Thuja occidentalis*), hop hornbeam (*Ostrya virginiana*), balsam fir (*Abies balsamea*), and black ash (*Fraxinus nigra*). One of the best-known uses of sugar maple is for syrup and sugar from sap, which is so culturally significant that the Anishinaabe people named one of the 13 moons of the year as the "maple sugar moon" (Erickson, 2006). It is also used for traditional medicine (Meeker et al., 1993). With proper techniques, the bark of the paper birch may be removed from live trees without harm. Bark characteristics vary and, depending on the particular tree, may be suitable for different uses (Emery et al., 2014) including canoes, waterproof shelters, baskets, buckets, and food containers (Morgenstern, 2006).

Tribes have many cultural uses for northern white cedar, which holds great spiritual meaning, and it plays a central role in traditional sacred stories and is honored with the name *Nookomis Giizhik*, "Grandmother Cedar" (Densmore, 1974). The wood is used for canoe push poles, ricing knockers for wild rice, spigots for tapping and paddles for stirring maple syrup, cradle boards, and canoe ribs and planks. The bark is used to cover lodges, as an insect repellant, and for bedding. Leaves, twigs, and buds are used for incense, tea, wreaths, decorations, and medicine (Danielsen, 2002). Hop hornbeam bark and inner wood are used for medicinal purposes. In addition, its buds and catkins are an important food source for wild turkey, sharp-tailed grouse, and other wildlife significant to Native American culture (Ritz, 2012). Tribes use balsam fir needles for medicine and its sap or resin blisters to caulk boats. It also provides food for moose, American red squirrels, crossbills, and chickadees, as well as shelter for moose, snowshoe hares, white-tailed deer, ruffed grouse, and other small mammals and songbirds important to Native American culture (Fuller, 2015).

Black ash has special importance for American Indian and First Nations peoples in the Great Lakes region. Its ring-porous wood allows layers of xylem to be easily separated (U.S. Department of Agriculture Natural Resources Conservation Service, 2014) into strips for basket-making. Its wood is used for fish weirs, pipe stems, and lacrosse sticks (Benedict and David, 2003; Mundell, 2008). Revival of the centuries-old tradition of black ash basketmaking is part of the cultural renaissance among tribes in the region and central to the household economies of skilled Native American artisans.

Invasive species threaten culturally important tree species

Invasive forest insects threaten these culturally important species. For example, the Asian long-horned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae), imperils urban and forest hardwoods and has a broad host range but prefers maples in North America (Haack et al., 2006). The wood-boring Japanese cedar long-horned beetle, *Callidiellum rufipenne* (Coleoptera: Cerambycidae), attacks only weakened or freshly felled conifers in its native East Asian range. Eastern U.S. infestations have been found in healthy American arborvitae (northern white cedar) nursery stock and reared from logs of northern white cedar, *Juniperus virginiana* (eastern red cedar), and *Chamaecyparis nootkatensis* (Alaska or yellow cedar) (Maier, 2007). The balsam woolly adelgid, *Adelges piceae* (Hemiptera: Adelgidae), is a tiny sucking insect native to Eurasia where host trees are relatively resistant, but it is a significant invasive pest in both eastern and western North America where it has caused significant mortality to true firs. Infestations occur on balsam fir in the Northeast (Ragenowich and Mitchell 2006).

The emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) is the most destructive invasive forest insect yet to infest North America. It threatens North America's ash resources, including black ash (Poland and McCullough, 2006) and the Indigenous cultures and traditions that rely on it.

Statement of the issue

The challenge of responding to invasive species such as the emerald ash borer while preserving Indigenous cultural traditions requires integrating information from both traditional ecological knowledge and Western science. Traditional ecological knowledge is a "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes, 1999). It provides detailed local observations, as well as a basis for understanding the values of natural resources and actual practices related to them. By contrast, Western science provides a systematic way of evaluating questions arising from these relationships. Questions pertaining to emerald ash borer and traditional black ash basketmaking being addressed through scientific experiments include: (a) Does submersion of infested black ash logs kill emerald ash borer larvae? (b) How long must logs be submerged for this to happen? (c) Are splints made from submerged wood good enough for basketmaking? and (d) Are traditional submersion practices compatible with federal quarantine regulations?

The emerald ash borer is native to Asia and feeds on the phloem of ash (Yu, 1992). First detected in North America near Detroit, Michigan, in 2002 (Poland and McCullough, 2006), it has since killed hundreds of millions of trees and spread to 31 states and 2 provinces (EAB info, 2017). All North American ash species encountered to date are susceptible. Black (*Fraxinus nigra*), green (*Fraxinus pennsylvanica*), and white (*Fraxinus americana*) ash are the most common ash species in the Great Lakes region and are highly vulnerable (Klooster et al., 2014). Adult beetles emerge in late spring and feed on leaves throughout their lifetime. After mating, females deposit eggs in bark cracks and crevices. Larvae feed in the phloem and cambial region, forming serpentine-shaped tunnels under the bark (Bauer et al., 2004) which disrupt translocation, killing trees within two to three years of infestation (Poland and McCullough, 2006). Larval development can take one to two years (Tluczek et al., 2011), after which adults chew out through the bark, leaving characteristic D-shaped exit holes. Adults may fly up to a few kilometers (miles) (Taylor et al., 2010) and are transported long distances through human-assisted movement of infested firewood, nursery stock, logs, and other wood products.

Black ash seed is being collected to help preserve genetic material for future restoration (Benedict and David, 2003; Agricultural Research Service, 2014). Nevertheless, there is great immediate concern about the availability of black ash for basketmaking in the near future to continue and pass on cultural traditions. In addition, there is concern about movement of infested black ash from areas where it is cut to other lands, including tribal lands, where it is pounded and split to make baskets.

Submergence in water is a traditional method of holding black ash logs from cutting until they are needed for basketmaking. Submergence for at least a month was found effective in killing buprestid beetle larvae (Gardiner, 1962). Therefore, submergence of logs may allow preservation of the wood for basketmaking in the near future and may also be an effective treatment for killing emerald ash borer and preventing artificial spread of this devastating invader.

Black ash are cut for basketmaking throughout the year, but some harvesters prefer cutting at certain times. Basket-grade trees often grow in wetlands;

thus access may be easiest in winter when the ground is frozen (Benedict and David, 2003). Other harvesters prefer cutting trees in the spring when buds begin to swell and sapwood moisture content is high, loosening the bark and annual growth rings (Severn, 2010). Trees may be harvested individually and processed promptly as the need arises, or several may be cut at the same time, then buried or submerged to retain moisture and provide material to work with over time (Severn, 2010). Prolonged submergence for longer than a year may cause wood decay (Wetherbee, 1985).

In the Great Lakes region, traditional methods to process black ash for basketmaking involve systematically pounding debarked, whole logs to delaminate the growth rings from one another using a heavy wooden mallet or the back of an axe (Mundell, 2008). An axe blade or knife is used to score a splint, or strip of thin wood, along the true grain. Each splint is pulled from the log, then rolled up. Splints may be coiled and held in airtight containers for later use and further processing before being woven into baskets. Processing techniques and tools vary from tribe to tribe and by individual. Some artisans use a variety of hand and small shop-made mechanical devices to separate growth rings.

Methods

U.S. Forest Service scientists partnered with basket-makers from the Match-E-Be-Nash-She-Wish Band of Pottawatomi Indians of Michigan (the Band) to test whether infested logs could be submerged to kill within-tree life stages of the insect and retain the wood's color and pliability for basketmaking (Poland et al., 2015). The Band's basketmakers, who come from a long line of master basketmakers, ensured that research methods respected traditional practices from tree selection through the study's design and evaluation of submerged logs' suitability. Suitable trees grow in moist soil or marshy conditions with at least 2 to 3 meters (6.6 to 9.8 feet) of straight, clear lower bole that is fairly large in diameter. A small chink is cut out of the trees to assess tree rings, which should be creamy white and approximately the thickness of a U.S. nickel or quarter (~ 2 millimeters [0.08 inches]). Wood must be moist so it is sufficiently pliable and not break when woven. We submerged the logs in running water deep enough to completely cover the logs, minimizing wood rot that may occur in stagnant water. Following submergence and dissection, logs were transported to Band lands, where they were processed in accord with traditional practices.

Three experiments took place at different times of the year and for various periods. For the first experiment, five trees, approximately 25 centimeters (10 inches) in diameter at breast height, infested with overwintering larvae, were felled in southern Michigan in late April 2010. They were cut into logs approximately 65 centimeters (26 inches) long. Eight logs were randomly assigned to five different treatments: (a) unsubmerged control logs, or logs submerged for (b) 1 week; (c) 4 weeks; (d) 10 weeks; or (e) 16 weeks. We submerged the logs on May 10, 2010, in the Red Cedar River in Okemos, Michigan, with a cinder block attached to an eye bolt at one end. A long rope was attached to the other end of each log, which was secured to a tree along the shoreline to anchor it

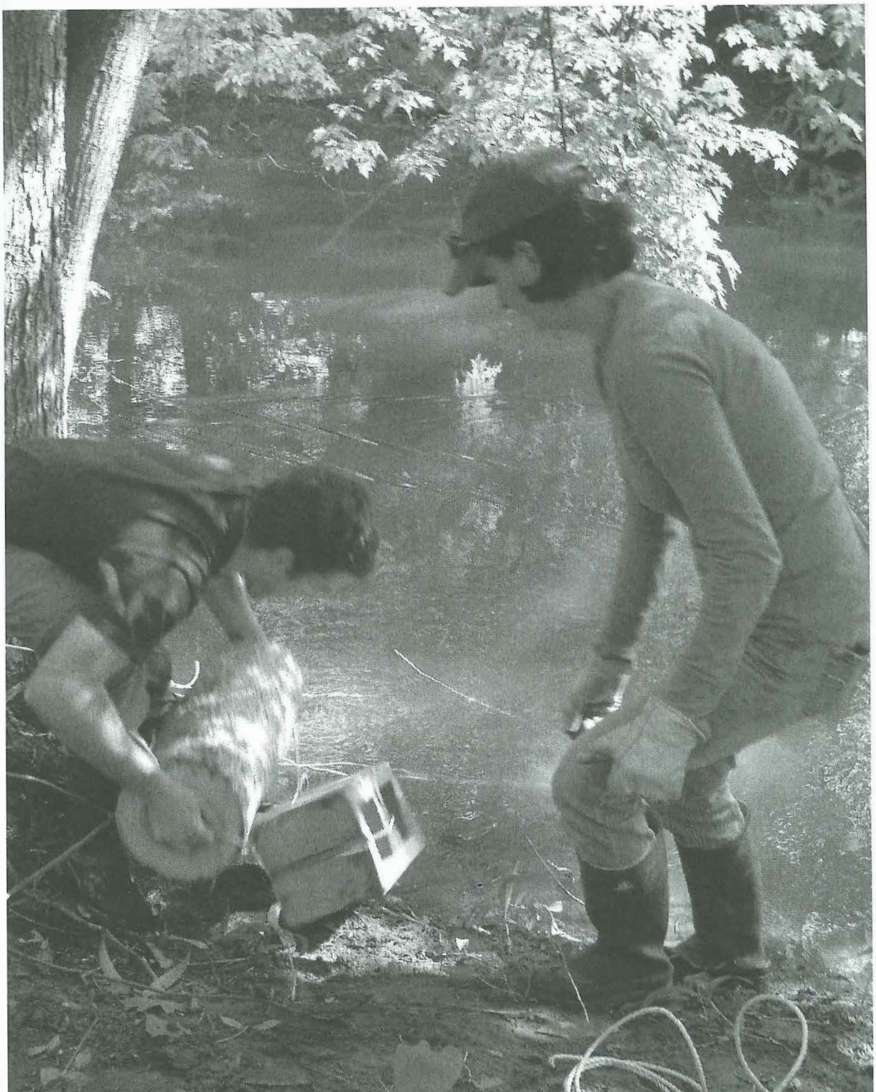

Figure 11.1a U.S. Forest Service technicians Tom Baweja and Tina Ciaramitaro submerging black ash logs in the river.

Source: Therese M. Poland

and facilitate retrieval. We periodically measured water depth, temperature, and surface flow rate. When logs were retrieved, half were dissected to determine the density of live and dead emerald ash borer individuals of each life stage. The other half were placed in rearing tubes to allow any living emerald ash borer

Figure 11.1b Ed Pigeon pounding logs with back of axe to separate rings of sapwood.
Source: Therese M. Poland

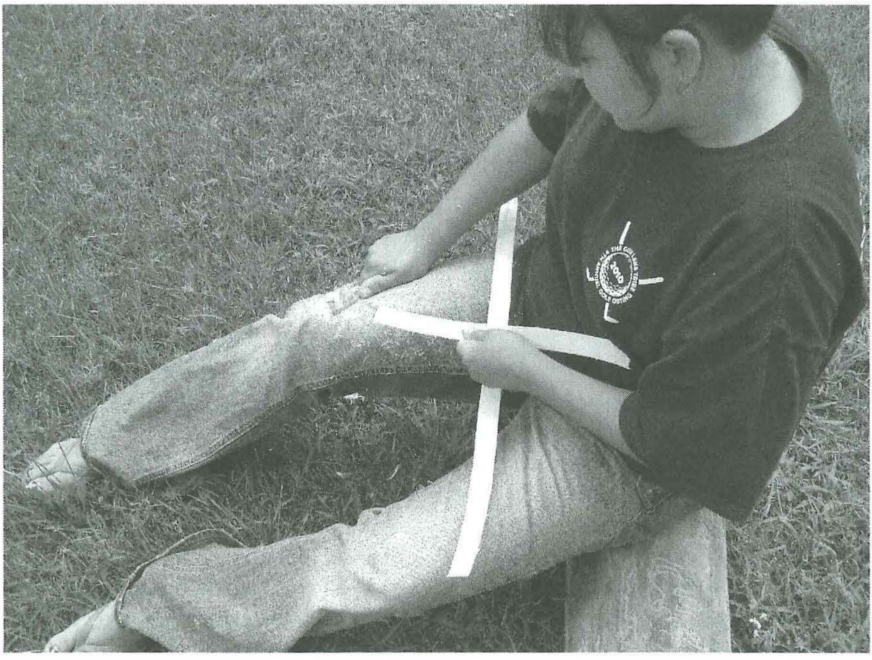

Figure 11.1c Angie Pigeon shaving black ash splints to remove rough fibers.
Source: Therese M. Poland

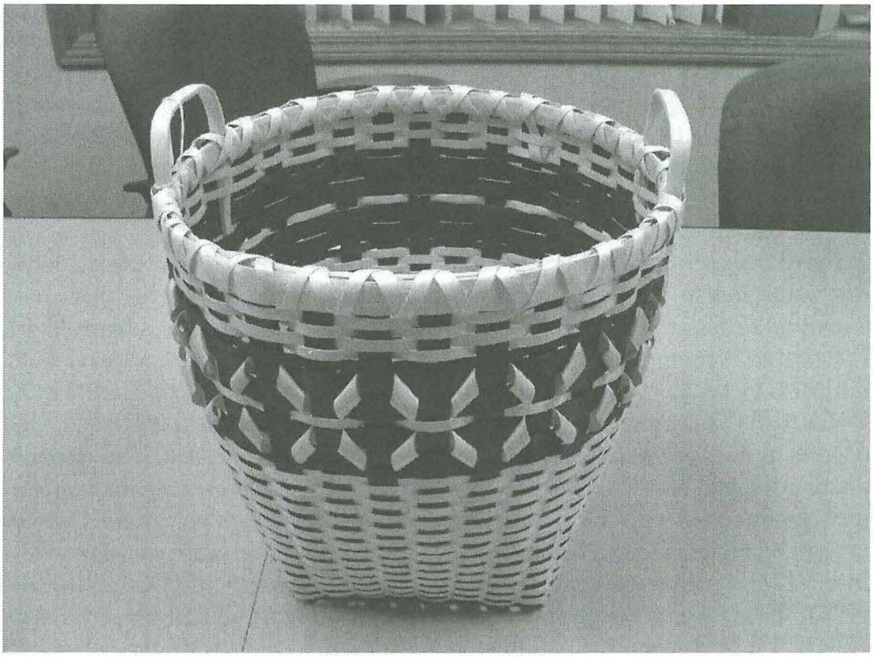

Figure 11.1d Finished Pigeon family black ash basket.

Source: Therese M. Poland

to complete development and emerge as adults. Insects removed during dissection were held at room temperature for 24 hours and observed for movement to determine if they were alive. After dissection, logs were pounded and peeled into splints using traditional practices, and splints were assessed for color and pliability (Figures 11.1a–d)

For the second experiment, nine infested trees were felled in February 2011 and cut into logs. Six to eight logs were randomly preassigned to one of six treatments: (a) unsubmerged control, or submerged for (b) 10 weeks; (c) 18 weeks; (d) 26 weeks; (e) 52 weeks; and (f) 78 weeks. We submerged logs in early March when water temperatures were near freezing. We dissected control logs and logs submerged for 10 or 18 weeks within 24 hours of removal from the river. Insects removed during dissection were held at room temperature for 48 hours and observed for movement to determine mortality status. The outer bark had begun to decay and fall off logs submerged for 26, 52, or 78 weeks; therefore, we could not dissect them to assess larval survival. All the logs for each treatment duration were pounded and peeled into splints to assess the impact of prolonged submergence on splint properties.

For the third experiment, infested logs were submerged on May 12, 2011, when water temperature was 5.5°C (42°F). Logs were randomly assigned to one of nine treatments: (a) unsubmerged control logs, or logs submerged for (b) 4 weeks; (c) 5 weeks; (d) 6 weeks; (e) 7 weeks; (f) 8 weeks; (g) 9 weeks; (h) 13 weeks; or (i) 14 weeks. Initially, we assigned eight logs per treatment with four logs designated for dissection and four logs for rearing each week from 4 weeks to 9 weeks. However, by week 6, when we still found little mortality of larvae during dissection, we decided to prolong the experiment by pulling only four logs for dissection each week and foregoing rearing, thus allowing those logs to remain submerged for up to 14 weeks. At 14 weeks, we placed the final set of four logs in rearing tubes to determine adult survival and emergence.

For each experiment, we first confirmed that differences in initial attack densities were random, with no significant differences among treatments that could confound or bias the results. We compared the percentage of dead emerald ash borers of all life stages among treatments by a general linear mixed model (PROC GLIMMIX) because assumptions of analysis of variance were violated (PROC UNIVARIATE). Duration of submergence was tested as a fixed effect, and degrees of freedom were determined using the ddfm KR method. The response distribution was beta with the link function set as logit. Differences among treatments were tested with the Tukey-Kramer means comparison procedure. Data for density of adults emerged from logs placed in rearing tubes were transformed by $\ln(y + 1)$ and then tested for normality and homoscedasticity (PROC UNIVARIATE). We compared transformed data among treatments by analysis of variance (PROC GLM) followed by the Tukey HSD multiple comparison procedure. All analyses were conducted using the SAS 9.4 for Windows statistical package (SAS Institute, 2012) with an α-level of 0.05.

Findings

In experiment 1, the density of adults that emerged from logs decreased significantly as the duration of submergence increased ($F = 5.20$; df = 4, 21; $P = 0.005$). Some emerged from logs submerged for 1 or 4 weeks, but none from logs submerged for 10 or 16 weeks (Figure 11.2). On the other hand, the percentage of dead larvae, prepupae and pupae increased from 7 percent in control logs, to 35 percent after 1 week and 100 percent after 10 or 16 weeks of submergence ($F = 10.8$; df = 4, 17; $P = 0.0002$). It appeared that some larvae actually continued to develop during the first four weeks of submergence because no live or dead pupae were found during dissection of unsubmerged control logs or logs submerged for one week. However, we found live pupae in logs submerged for 4 weeks and dead pupae in logs submerged for 10 or 16 weeks (Poland et al., 2015). The color quality of splints was similar for all treatments; pliability of splints did not decrease after 16 weeks of submergence, and we observed no cracking, splitting, or decay of splints. Water temperature was 13.5°C (56°F) at initial submergence and increased to 21.2°C (70°F) within 12 weeks.

For experiment 2, the percentage of dead larvae and prepupae increased from 5 percent in unsubmerged logs to 100 percent in logs submerged for 18 weeks ($F = 21.8$; df = 2, 16; $P < 0.0001$) (Figure 11.3). Water temperature was freezing

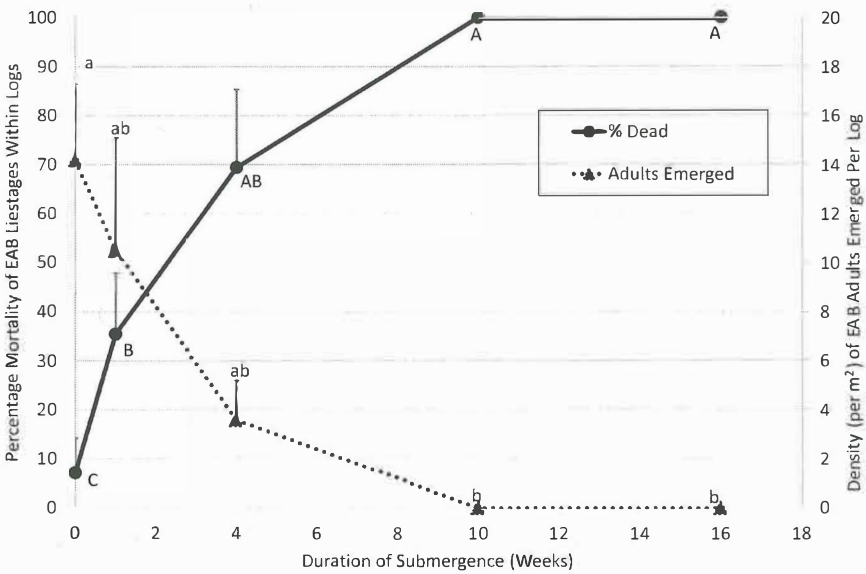

Figure 11.2 Mean (+SE) percentage mortality of emerald ash borer life stages within ash logs and density of adults emerged from ash logs after submergence in the Red Cedar River for various lengths of time in spring/summer 2010. Mean percentage mortality with different upper case letters and mean density of adults emerged with different lowercase letters are significantly different, Tukey multiple comparison procedure, $P < 0.05$. (N = 8 logs per submergence time treatment.)

and remained near 0°C (32°F) for the first 4 weeks, then increased to 5.5°C (42°F) by 2 months, 14.4°C (58°F) by 3 months, 15.5°C (60°F) by 4 months, 21.1°C (70°F) by 5 months, and 25.5°C (78°F) by 6 months, and then gradually decreased back to freezing by 12 months. The bark and first few outer rings of sapwood had begun to decay on logs submerged for 26, 52, or 78 weeks. Most bark had fallen off the logs, and large pieces of decaying bark fell off when they were removed from the river. Therefore, we could not dissect these logs to recover dead larvae, prepupae, and pupae; undoubtedly, they had all died. The inner rings of sapwood were sound, and we pounded and peeled splints from the logs submerged for 26, 52, and 78 weeks in the same manner as those dissected after shorter submergence. Although the outer one to three rings of sapwood began to decay on logs submerged for 26 weeks or longer, color and pliability of splints from the inner rings of sapwood did not decrease even after 78 weeks of submergence; we observed no cracking, splitting, or decay. Logs submerged for at least 26 weeks had a mild pungent odor that completely dissipated when the bark and outer rings of sapwood were removed and the inner rings were exposed to air for a few hours.

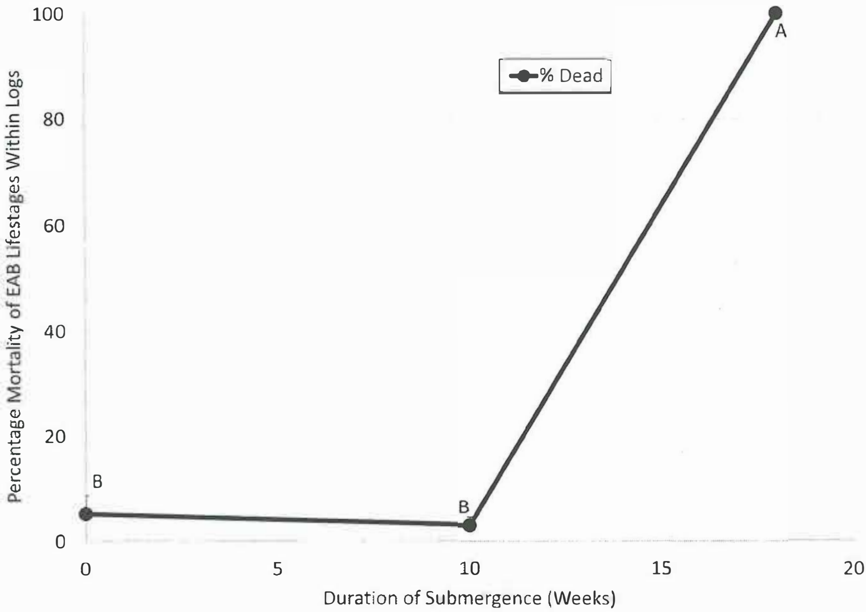

Figure 11.3 Mean (+SE) percentage mortality of emerald ash borer life stages within ash logs after submergence in the Red Cedar River for various lengths of time in winter/spring 2011. Mean percentage mortality with different uppercase letters are significantly different, Tukey multiple comparison procedure, $P < 0.05$. (N = 8 logs per submergence time treatment.)

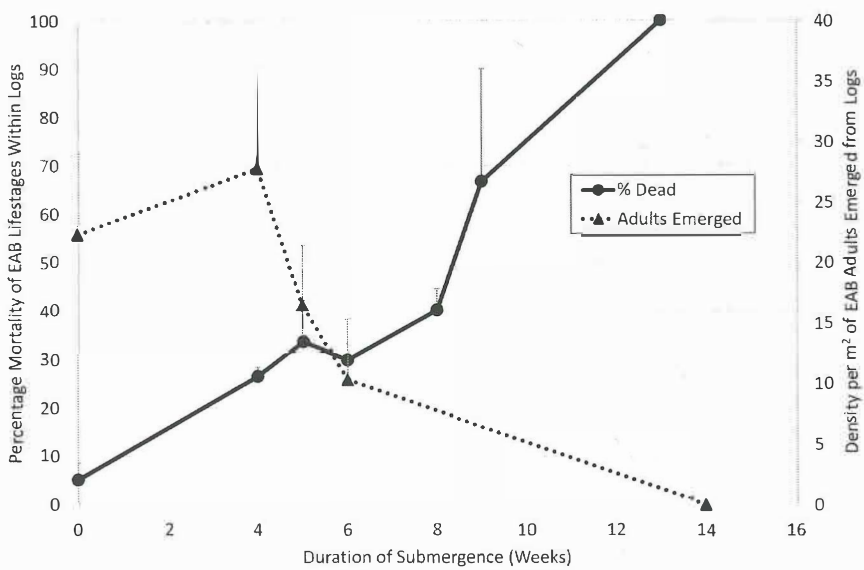

Figure 11.4 Mean (+SE) percentage mortality of emerald ash borer life stages within ash logs and density of adults emerged from ash logs after submergence in the Red Cedar River for various lengths of time in spring/summer 2011. (N = 4 logs per submergence time treatment.)

For experiment 3, the percentage of dead emerald ash borers increased from 5 percent in unsubmerged control logs to 26 percent after 1 week and 100 percent after 13 weeks (F = 3.25, df = 7, 23; P = 0.01). Some live adults emerged from logs submerged for up to six weeks. No logs were placed in rearing tubes between 7 and 13 weeks after submergence. No adults emerged from logs submerged for 14 weeks (Figure 11.4). Water temperature was 5.5°C (42°F) at submergence and increased to 21.1°C (70°F) by 12 weeks.

Discussion and conclusions

Submerging infested black ash logs effectively killed larvae and prepupae. However, submergence time required for complete mortality varied among experiments and likely depended on time of year, water temperature, and other factors. All larvae, prepupae, and pupae had died, and no adults emerged from logs submerged for 10 weeks during spring 2010 in experiment 1. On the other hand, some larvae survived in logs submerged for 10 weeks during winter 2011 in experiment 2. We did not find complete mortality until 18 weeks of submergence. Similarly, in experiment 3 we did not find complete mortality until 13 weeks of submergence in spring 2011. Temperature conditions may have influenced survival times in submerged logs. Water temperatures were much warmer (starting at 13.5°C [56°F] and warming to 21.2°C [70°F] within 12 weeks) in spring 2010 during experiment 1 compared to winter 2011 and during experiment 2, when temperatures remained near 0°C [32°F] for the first four weeks and gradually warmed to 21.1°C [70°F] over a five-month period. Initial water temperature (5.5°C [42°F]) was also cooler in spring 2011 during experiment 3 compared to experiment 1.

Colder temperatures were found to prolong survival of immersed Douglas fir beetle adults, *Dendroctonus pseudostugae*, (Coleoptera: Curculionidae: Scolytinae), which were able to withstand up to 1,000 hours (5.9 weeks) at 4.5°C (40°F) but only 256 hours (1.5 weeks) at room temperature (Johnson, 1967). When logs are submerged in winter, larvae and prepupae are dormant and acclimated to the cold. They may be able to maintain dormancy and prolong survival while water temperatures remain near freezing. On the other hand, when logs are submerged in spring, larvae have higher metabolic activity and may actively feed and develop. Siegert et al. (2014) found that emerald ash borer larvae feeding in the phloem experienced higher mortality after shorter periods of submersion than those in prepupal chambers.

Insects have a number of adaptations to survive stressful conditions such as hypoxia and immersion (Hoback and Stanley, 2001). Adaptations include altering behaviors, enlarging tracheal system volumes, switching from aerobic to anaerobic metabolic pathways, reducing basal metabolism, and entering a quiescent or dormant state (Hoback et al., 1998; Hoback and Stanley, 2001). Enclosure within a substrate may protect insects from direct contact with water, thereby prolonging survival. Siegert et al. (2014) found that moisture content of the outer 1.3 centimeters (0.5 inches) of ash sapwood increased with duration of submergence. Sapwood moisture doubled from 42 percent before submergence to 81 percent at 12 weeks and 83 percent at 24 weeks after submergence.

The structure of phloem, composed of fibers and sieve tubes with a rapid sealing mechanism in response to stress or wounding (Cronshaw, 1981), may provide some protection from total saturation.

The color quality and pliability of splints did not change significantly with duration of submergence and remained within desirable standards for basketmakers. It is traditional practice to shave rough fibers from the surface of splints to create a brighter and smoother surface. Even after 78 weeks of submergence, splints from all but the first to third outermost rings of sapwood were bright and light-colored. Splints from inner rings also remained pliable after prolonged submergence, without visible splits, crumbling, or decay; however, the outer few rings began to decay after 26 weeks (Poland et al., 2015).

The results suggest that submergence of infested logs during winter or spring and holding them underwater for 13 weeks after water temperatures have warmed above 10–13°C (50–55°F) should ensure complete mortality of emerald ash borer larvae and prevent emergence of adults. These submergence times and conditions preserve wood properties for basketmaking and are compatible with traditional cultural practices.

This study demonstrates how integrating traditional ecological knowledge with scientific ecological knowledge contributes to more sustainable, productive, and locally accepted natural resource management. The emerald ash borer not only threatens forest ecosystems, but also has profound potential implications for American Indian and First Nations communities. The practice of co-managing natural resources has increased in recent decades due to recognition that interagency cooperation and local stakeholder empowerment improve ecological and social outcomes (Conley and Moote, 2003; Bussey et al., 2016). The traditional practice of submerging black ash logs can achieve the immediate goals of providing wood for basketmaking while also killing the emerald ash borer before it spreads. The results may provide guidelines to reduce its inadvertent spread and reduce the threat to black ash, Native American cultural traditions, and livelihoods of basketmakers.

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References

Bauer, L. S., Liu, H., Haack, R. A., Gao, R., Miller, D. L., and Petrice, T. R. (2004). Emerald ash borer life cycle. In: Mastro, V., and Reardon, R. (Compilers), *Proceedings of the Emerald Ash Borer Research and Technology Development Meeting*. Port Huron, MI, 30

September–1 October 2003. Morgantown, WV: U.S. Department of Agriculture, Forest Service Publication FHTET-2004–02, 8.

Benedict, L., and David, R. (2003). Propagation protocol for black ash (Fraxinus nigra Marsh). *Native Plants*: 24–27.

Berkes, F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Management Systems*. Philadelphia and London: Taylor and Francis, p. 217.

Bussey, J., Davenport, M. A., Emery, M. R., and Carroll, C. (2016). A lot of it comes from the heart: The nature and integration of ecological knowledge in tribal and nontribal forest management. *Journal of Forestry*, *114*(2): 97–107.

Conley, A., and Moote, M. A. (2003). Evaluating collaborative natural resource management. *Society and Natural Resources*, *16*: 371–386.

Cronshaw, J. (1981). Phloem structure and function. *Annual Review of Plant Physiology*, *32*: 465–484.

Danielsen, K. C. (2002). Maniwiigwaase-Gather birch bark. *Great Lakes Indian Fish Wildlife Commission Mazina'igan, Supplement 1*: 8.

Densmore, F. (1974). *How Indians Use Wild Plants for Food & Crafts (formerly titled Uses of Plants By the Chippewa Indians)*. New York: Dover Publications.

EAB Info. (2017). *Emerald Ash Borer*. Available at www.emeraldashborer.info/index.cfm

Emery, M. R., Wrobel, A., Hansen, M. H., Dockry, M., Moser, W. K., Stark, K. J., and Gilbert, J. H. (2014). Using traditional ecological knowledge as a basis for targeted forest inventories: Paper birch (Betula papyrifera) in the U.S. Great Lakes region. *Journal of Forestry*, *112*(2): 207–214.

Erickson, S. (2006). Iskigamizigan (Sugarbush): A sequel to growing up Ojibwe. *Mazina'igan, Supplement* 2006: 1–2, 4–8.

Fuller, D. (2015). *Maine Balsam Fir: A Tree of Many Uses*. University of Maine, Cooperative Extension Publication, Bulletin # 2541. Available at https://extension.umaine.edu/publications/2541e/

Gardiner, L. M. (1962). Survival of wood borers (Coleoptera: Buprestidae) in water-stored logs. *The Forestry Chronicle*, *38*: 459–462.

Haack, R. A., Bauer, L. S., Gao, T., McCarthy, J. J., Miller, D. L., Petrice, T. R., and Poland, T. M. (2006). Within-tree distribution, seasonal development, and host suitability in China and Chicago. *The Great Lakes Entomologist*, *39*: 169–183.

Hoback, W. W., and Stanley, D. W. (2001). Insects in hypoxia. *Journal of Insect Physiology*, *47*: 533–542.

Hoback, W. W., Stanley, D. W., Higley, L. G., and Barnhart, M. C. (1998). Survival of immersion and anoxia by larval tiger beetles, Cincindela togata. *The American Midland Naturalist*, *140*: 27–33.

Johnson, N. E. (1967). The influence of temperature and moisture on the overwintering mortality of the Douglas fir beetle, Dendroctonus pseudotsugae, in Western Washington (Coleoptera: Scolytidae). *Annals of the Entomological Society of America*, *60*: 199–204.

Klooster, W. S., Herms, D. A., Knight, K. S., Herms, C. P., McCullough, D. G., Smith, A., Gandhi, K. J. K., and Cardina, J. (2014). Ash (Fraxinus spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (Agrilus planipennis). *Biological Invasions*, *16*: 859–873.

Kurtz, C. M., Moser, K. W., Hansen, M. H., Gormanson, D. D., Hatfield, M. A., Sowers, P. A., Dockry, M. J., Emery, M. R., Woodall, C. W., Walters, B. F., Domke, G. M., Gilbert, J., and Wrobel, A. (2015). *Forest Resources Within the Lake States Ceded Territories 1980–2013*. USDA Forest Service, Northern Research Station, Newtown Square, PA. Resource Bulletin NRS-96.

Maier, C. T. (2007). Distribution and hosts of Callidiellum rufipenne (Coleoptera: Cerambycidae), an Asian cedar borer established in the Eastern United States. *Journal of Economic Entomology*, *100*(4): 1291–1297.

Meeker, J. E., Elias, J. E., and Heim, J. A. (1993). *Plants Used by the Great Lakes Ojibwa*. Odanah: Great Lakes Indian Fish and Wildlife Commission.

Morgenstern, K. (2006). Plant profile: Birch (Betula spp.). *Sacred Earth Newsletter*, *V*(2). Available at www.sacredearth.com/ethnobotany/plantprofiles/birch.php

Mundell, K. (2008). *North by Northeast: Wabanaki, Akwesasne Mohawk, and Tuscarora Traditional Arts*. Gardener, ME: Tilbury House Publishers.

Poland, T. M., Ciaramitaro, T. M., Emery, M., Crook, D. J., Pigeon, E., and Pigeon, A. (2015). Submergence of back ash logs to control emerald ash borer and preserve wood for American Indian basketmaking. *Agricultural and Forest Entomology*, *17*: 412–420.

Poland, T. M., and McCullough, D. G. (2006). Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry*, *104*: 118–124.

Ragenowich, I. R., and Mitchell, R. G. (2006). *Balsam Woolly Adelgid*. USDA Forest Service, Forest Insect and Disease Leaflet, No. 118. USDA Forest Service, Region 6, R6-NR-FID-PR-04-2006, 1–12.

Ritz, S. E. (2012). *Plant guide for hop Hornbeam (Ostrya virginiana)*. USDA Natural Resources Conservation Service, Appalachian Plant Materials Center. Alderson, WV. Available at https://plants.usda.gov/plantguide/pdf/pg_osvi.pdf

SAS Institute. (2012). *SAS/STAT 9.4 User's Guide*. Cary, NC: SAS Institute.

Severn, J. (2010). Black ash basket making tradition weaves generations together. *Tribal Observer*. Available at www.sagchip.org/tribalobserver/article.asp?article=233

Siegert, N. W., Secord, T., and McCullough, D. G. (2014). Submersion as a tactic to prevent emergence of emerald ash borer Agrilus planipennis from black ash logs. *Agricultural and Forest Entomology*, *16*: 321–325.

Taylor, R. A. J., Bauer, L. S., Poland, T. M., and Windell, K. N. (2010). Flight performance of Agrilus planipennis (Coleoptera: Buprestidae) on a flight mill and in free flight. *Journal of Insect Behavior*, *23*: 128–148.

Tluczek, A. R., McCullough, D. G., and Poland, T. M. (2011). Influence of host stress on emerald ash borer (Coleoptera: Buprestidae) adult density, development, and distribution in Fraxinus pennsylvanica trees. *Environmental Entomology*, *40*: 357–366.

U.S. Department of Agriculture, Agricultural Research Service. (2014). *The NPGS Ash Conservation Project*. Available at www.ars.usda.gov/sp2UserFiles/Place/36251200/Ash_Project/ProceduresPage.html

U.S. Department of Agriculture, Natural Resources Conservation Service. (2014). *Black Ash, Fraxinus nigra Marsh*. USDA NRCS Plant Guide. Available at http://plants.usda.gov/plantguide/pdf/cs-fmi.pdf

Wetherbee, M. (1985). Making a basket from a tree: Splints from lack ash in the Shaker tradition. In: Kelsey, J. (Ed.), *Fine Woodworking: On Bending Wood*. Newtown, CT: Taunton Press, 2–5.

Yu, C. (1992). Agrilus marcopoli Obenberger (Coleoptera: Buprestidae). In: Xiao, G. (Ed.), *Forest Insects of China*, 2nd edition. Beijing, China: Forestry Publishing House, 400–401.

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