Planning for the Future: Assessing potential impacts and management options for invasive forest pests at the Offield Nature Preserve

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Abstract

Invasive forest pests are having profound effects on the composition and structure of forests across North America and in some cases management can help to mitigate some of the impacts of these disturbances. We studied the composition and structure of the northern hardwood forest at the Offield Family Nature Preserve in northern Lower Michigan to evaluate the likely impacts that Emerald Ash Borer and Beech Bark Disease will have on the forest. We focused our analysis on two stands, one beech (*Fagus* grandifolia) dominated and one with a significant white ash (*Fraxinus americana)* component. Both stands had a large component of susceptible species in the canopy layer, and also had an understory dominated by beech and sugar maple (*Acer saccharum*). Due to variation in canopy structure and dominance the disturbance will create larger gaps in the beech-dominated stands. However, the disturbance in both stand types is likely to reduce canopy species diversity and resilience to future disturbances such as subsequent pest outbreaks. The currently ash dominated stands will likely transition to almost complete sugar maple dominance, while the beech=dominated stands will potentially undergo a transitional phase of dominance by small beech stems before also becoming sugar maple monocultures. We outline potential management strategies that could be implemented to attempt to combat these trajectories, which include combinations of seedling planting, understory clearing, and overstory thinning or salvaging. We suggest a management regime based around planting and understory clearing, with targeted overstory thinning designed to promote establishment of a diversity of canopy species including some with intermediate shade tolerance.

Introduction

Invasive species have been a major driver of ecological change in North American forests in the past century (Pimentel et al. 2005). They can be agents of change in both community composition and the abiotic environment. Especially damaging to trees and forests are invasive pests and pathogens (Dukes et al. 2009). A steady stream of pest introductions has occurred over the past 100-150 years, some of which have lead to massive changes in forest structure, species composition, and functional value. Some pests such as Chestnut Blight have removed species (e.g., American chestnut; *Castanaea dentata*) that are foundational to the functioning of natural forest systems (Ellison et al. 2005). Others such as Dutch Elm Disease have had an especially large impact on urban trees and forests (Schlarbaum et al. 1997). Prior to World War I, elms lined the streets of America's urban areas, valued for their aesthetic and cultural significance. However, the spread of a vascular wilt disease soon after the end of the war ended the legacy of the American elm (*Ulmus americana*). Other diseases have had significant impacts on the economic value and management of forest resources, for example White Pine Blister Rust (Maloy 1997) removal of eastern white pine (*Pinus strobus*). A number of emerging pests and pathogens are currently threatening the forests of Michigan, but the two most prevalent are Beech Bark Disease and Emerald Ash Borer.

Emerald Ash Borer

Following the destruction associated with Dutch Elm Disease, urban planners fatefully began replacing monocultures of elms with large numbers of ash (*Fraxinus* spp.) trees (Smalley & Guries 1993; Santamour Jr 2004). Currently, an invasive exotic pest known as Emerald Ash Borer (EAB) is wiping out ash trees throughout the United States and the Great Lakes Region. EAB first emerged as an invasive pest in Detroit where it was discovered in 2002 amidst the dying ash populations of the city (Poland & McCullough 2006).

In addition to depleting urban tree populations, EAB also affects sixteen endemic species of ash in forests and timberland around the United States (Poland & McCullough 2006). Ash species are rarely a dominant part of any forest ecosystem except for black ash swamps that are especially common in the upper Great Lakes region. There are some commercially valuable ash species, especially white ash which is utilized in making furniture and baseball bats. The increasing range of this EAB throughout North America is due to both human transportation of infested wood (such as firewood, shipping containers) and the dispersal capabilities of EAB, whose mated females may have the specific ability to disperse long distances (Taylor et al. 2005).

EAB feeds on the cambium, phloem, and sapwood under ash tree bark, effectively girdling the tree and cutting off its nutrient supply generally in a period of 2-3 years (Wang et al. 2010). This process is to the detriment of ecosystems which depend on ash trees for provision of important ecosystem services. Ashes seed prolifically, feeding a variety of birds, mammals, and insects. Additionally, beaver, rabbits, and porcupines feed on the bark of the trees.

Beech Bark Disease

American beech (*Fagus grandifolia*) is one of the primary late-successional canopy dominants across the eastern portion of the range of northern-hardwood forests in North America. Beech formerly achieved high canopy dominance in many eastern forests, but has recently begun to decline in abundance due to the effects of Beech bark disease (BBD), a complex of a non-native insect and one of several fungi in the genus *Nectria* (usually native to North America). The BBD syndrome was first identified in North America in eastern Canada in 1920 and has since invaded across approximately 30% of the total range of American beech (Morin et al. 2007). BBD was first detected in Michigan in 2001 and by 2003 the disease was known to be established in the western lower peninsula and the eastern upper peninsula (McCullough et al. 2001). Projections from previous surveys estimate its current range to extend over the north-western half of the lower peninsula and the eastern 2/3 of the upper peninsula. Though the insect stage of the disease can be removed from individual trees by scrubbing, this is not a viable option for widespread treatment (McCullough et al. 2001). It is likely that the spread of the disease cannot be prevented.

Beech bark disease advances in stages. In the first stage, invasive European scale insects (*Cryptococcus fagisuga*) disperse to the stand as larvae from another part of their range. The range of *C. fagisuga* is increasing at a rate of approximately 14.7 km each year, likely aided by humans (Morin et al. 2007). The larvae feed on the bark, developing a fuzzy white coating. The following spring the larvae morph into adults, lay eggs by parthenogenesis, and die. These eggs hatch by midsummer (McCullough et al. 2001). In the second stage, a native hardwood fungus, *Nectaria galligena* colonizes *F. grandifolia* bark that has been damaged by the insect *C.*

fagisuga. Without this insect, fungal colonization seldom occurs. The fungus infects the inner bark and as the bark dies the tree may be girdled and weakens structurally. In the late stages of the disease, the fungus may reproduce sexually in the fall through bright red fruiting bodies called perithecia. They may also reproduce asexually through white or pinkish perithecia. A second fungus, *Nectaria coccinea* var. *faginata* (a European exotic), may invade in a third stage (McCullough et al. 2001).

American beech normally has a fairly smooth bark. Trees which have rough patches are more easily colonized by *C. fagisuga*. Trees declining from BDD have yellowed, immature leaves. As it is invaded by the fungi, it may form tarry, seeping wounds. The tree may attempt to contain the fungi by compartmentalizing it into easily visible calluses. During the early stages of infestation, the trunks may be fuzzy white, but as the bark dies the insects cannot survive and this whiteness lessens.

At late stages of the disease the trees whose trunks have died from the disease may send up root sprouts. In the eastern US, these sprouts can result in thickets, but this form of asexual reproduction is less common in Michigan (McCullough et al. 2001). Trees which have died of BBD may have disfigured wood which is less valuable. Trees damaged by BBD are structurally weak and likely to snap in storms. Trials have shown about 1% of *F. grandifolia* to be resistant to BBD (McCullough et al. 2001). These are easily spotted as healthy trees in forests otherwise devoid of beech.

Little Traverse Conservancy and Offield Nature Preserve

On this project, we collaborated with the Little Traverse Land Conservancy (LTC), an independently funded regional land trust that preserves large tracts of land in northern lower and eastern upper Michigan. We worked at the Offield Family Nature Preserve, a site the LTC acquired in 2009. The site is 380 acres and incorporates multiple different stand types. 52% of the preserve is dominated by northern hardwood stands. These stands are mostly dominated by red maple (*Acer rubrum*) and sugar maple (*Acer saccharum*), but American beech and several other species are also prominent. The rest of the Offield Preserve is mainly composed of red pine plantations (30%), and small stands of tamarack (*Larix laricina*) and aspen (*Populus* spp.). As well as a bog and old orchard with remnant apple (*Malus* spp.) trees.

The property is enrolled in the Commercial Forest Act, an initiative under which the land owner receives a tax break if the public gains access to the land for recreational purposes. Additionally, the landowner must create a comprehensive forestry management plan that commits to limited agricultural and development practices. The LTC is interested in revising the plan that existed for the property prior to their acquisition to fit more closely with their mission of conservation and ecological land stewardship.

In pursuit of this goal, we surveyed areas of the property that may be especially susceptible to beech bark disease and the Emerald ash borer to assess their likely impact on the property and to develop possible ecologically-based management strategies to be implemented in response to these threats. In the northern hardwood forest section of the Offield Preserve, beech and white ash make up 12% and 3 % of the total basal area respectively. We hypothesized that areas of the forest with high levels of ash or beech dominance would be especially heavily affected in both composition and structure once these infestations fully manifest themselves. Therefore, our primary focus was on developing management strategies for these highly susceptible areas.

Project Objectives

The overarching goal of this project was to better understand how the disturbances caused by emerald ash borer and beech bark disease will impact the northern hardwood forests of this region, specifically within the Offield Family Nature Preserve. The effects of these pests will have major implications for forest ecosystem health in the future, and we had several specific objectives to help determine what these implications might be.

One primary objective was to gain an understanding of how the disturbances created by emerald ash borer and beech bark disease will affect forest composition and structure. Gap formation will have huge impacts on the post-disturbance forest, therefore, determining the size of the canopy gaps that may be created was another main goal. With gap formation in the overstory, many understory saplings and sprouts will gain access to light resources and will form the future canopy of the forest. Knowing what species are ready to take advantage of the gap is crucial to predicting the long term effects of these disturbances on the forest, and was a target of our data collection. In many cases, some type of forest management strategy will be implemented to help remedy the indirect effects of these pests, such as species diversity, composition and density. Our last objective was to investigate what type of management might be most appropriate for the Offield site. This will be largely determined by the size of the gaps created, the productivity of the sites, and the tree species that will be present in the gaps. Investigating differences in current structure and likely future outcomes between the beech and ash dominated sites was also a goal of our data analysis.

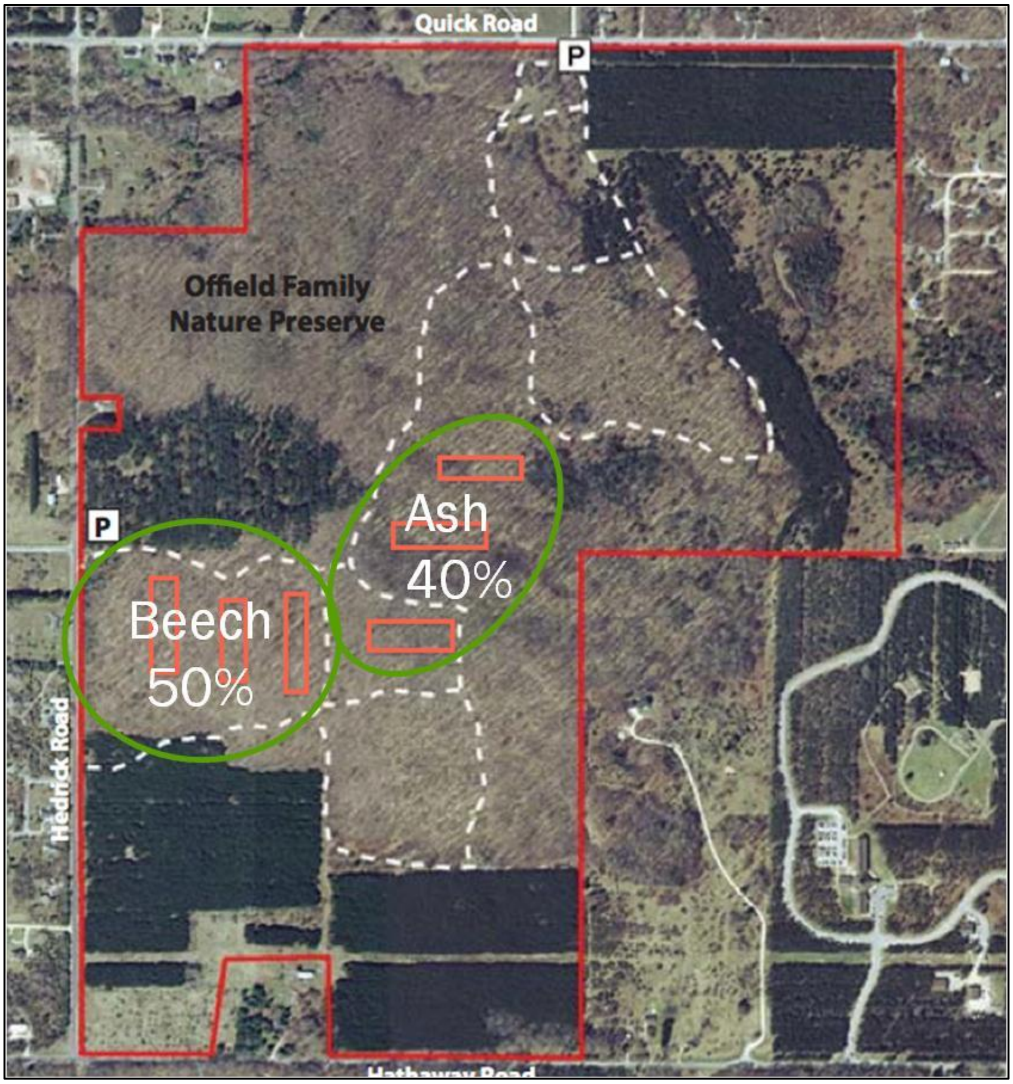

Figure 1. Map of Offield Preserve illustrating locations of sample areas and transects.

Materials and Methods

Field data collection

In order to collect the data detailed in this paper, we sampled two stand areas within the Offield Preserve. Transects were located in stands that had relatively high dominance of ash or beech based on an earlier site-level survey. Three of these transects were located in an area with 50% beech dominance and three of them were located in an area with 40% ash dominance (Figure 1). Transect starting locations were located at random distances along trails running through selected stands. Transects were 50m in length and 20m wide ($500m^2$) and were divided into ten $50m^2$ subplots (Figure 2). All trees within the plot area were mapped and had diameter at breast height (1.37m; dbh) measured – trees were defined as having dbh ≥10cm. For each tree crown classes (dominant, codominant, intermediate, overtopped, suppressed) were recorded as defined in Smith et al. (1997). Saplings were classified as any stem >1.37m in height with a dbh of less than 10cm. We recorded two classes of saplings: 0-5cm and 5-10cm dbh. All stems in both size classes were tallied by species in each of the $50m^2$ subplots. Data was also collected for the herbaceous layer. We estimated cover for all species within each $50m^2$ subplot.

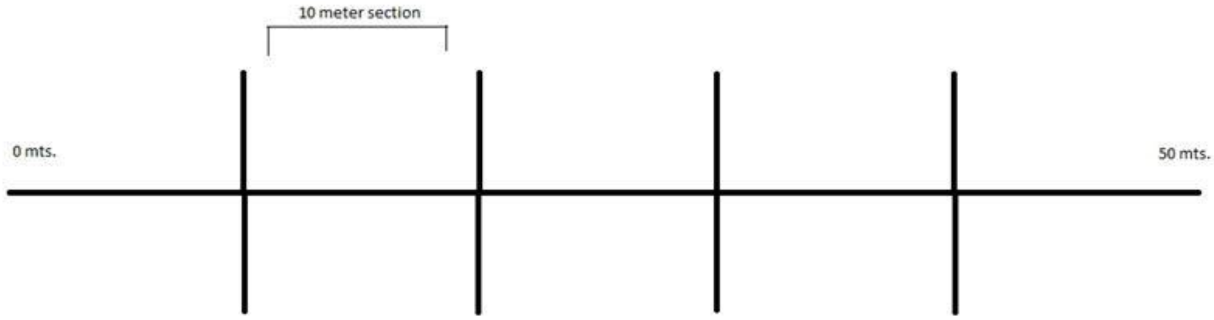

Figure 2. Transect sampling design. Subplot is area indicated as "10 meter section".

Finally, we recorded information on tree canopy extent to evaluate potential gap area upon removal of ash and beech trees from the forest. Canopy area was estimated by measuring canopy extension (distance of furthest foliage from the stem) in the four cardinal directions (N, S, E, W) and applying the formula for area of an ellipse. All ash and beech trees within the transect area were measured and any trees of these species with canopy adjacent to the trees in the transect were also measured – the process was then continued until no additional susceptible trees were found to be adjacent to those already measured (the gap "blob" method). Total gap area was then calculated based on the sum of the areas of all the adjacent canopies. To assess the impact of potential removal of understory trees of other species in areas with ash and beech canopy trees the proportion of the potential gap that had subcanopy cover of other tree species was also estimated.

Data analysis

The following variables were calculated from the data: overstory composition (stems/ha and basal area/ha) overall and by crown class, understory composition (stems/ha in two size classes), and total gap area by transect. Transect-level gap area was compared between beech and ash areas using Analysis of Variance (ANOVA). Forest structure was an important component of our analysis of this system, so bisects were prepared for representative transects of both the ash and beech sites. These bisects are a visual representation of the forest structure and can show a lot about species composition and vertical structure of the forest. Tree heights were estimated from crown class averages.

Results and Discussion

Forest composition

Overall density and structure did not differ much among transects, but the proportion of overstory and understory stems that were likely to be susceptible to disease impacts was much greater in Transect 1 (ash stand) and Transects 2 & 4 (beech stand) respectively (Table 1).

Table 1. Characteristics of forest communities in transect sample.

Transect	*Group*	*Canopy BA M^2ha^{-1}*	*Canopy Density (stems/ha)*	*Understory Density (stems/ha)*	*Sapling Density 0-5cm*	*Sapling Density 5-10cm*	*% Canopy Susceptible*	*% Understory Susceptible*
1	Ash	33.1	480	160			68.3	0.0
2	Beech	25.3	420	180	2880	400	24.5	48.0
3	Beech	36.8	420	140	5800	160	25.8	23.3
4	Beech	29.5	360	100	5540	160	35.5	50.5
5	Ash	26.4	600	280	940	240	22.6	17.2
6	Ash	26.0	620	60	2960	620	14.5	0.0

Overstory basal area in all transects was dominated by maple species, with a significant component of ash and beech in the community in the areas selected to sample those species (Figs. 3 & 4). Beech dominated the smaller sapling size class in both the ash and beech stands and the larger size class in the beech stands, while sugar maple dominated the larger size class in the ash stands (Fig. 5). The surveys of herbaceous indicator species in the understory suggest that the stands lie on generally highly productive mesic sites (Kotar et al. 2002).

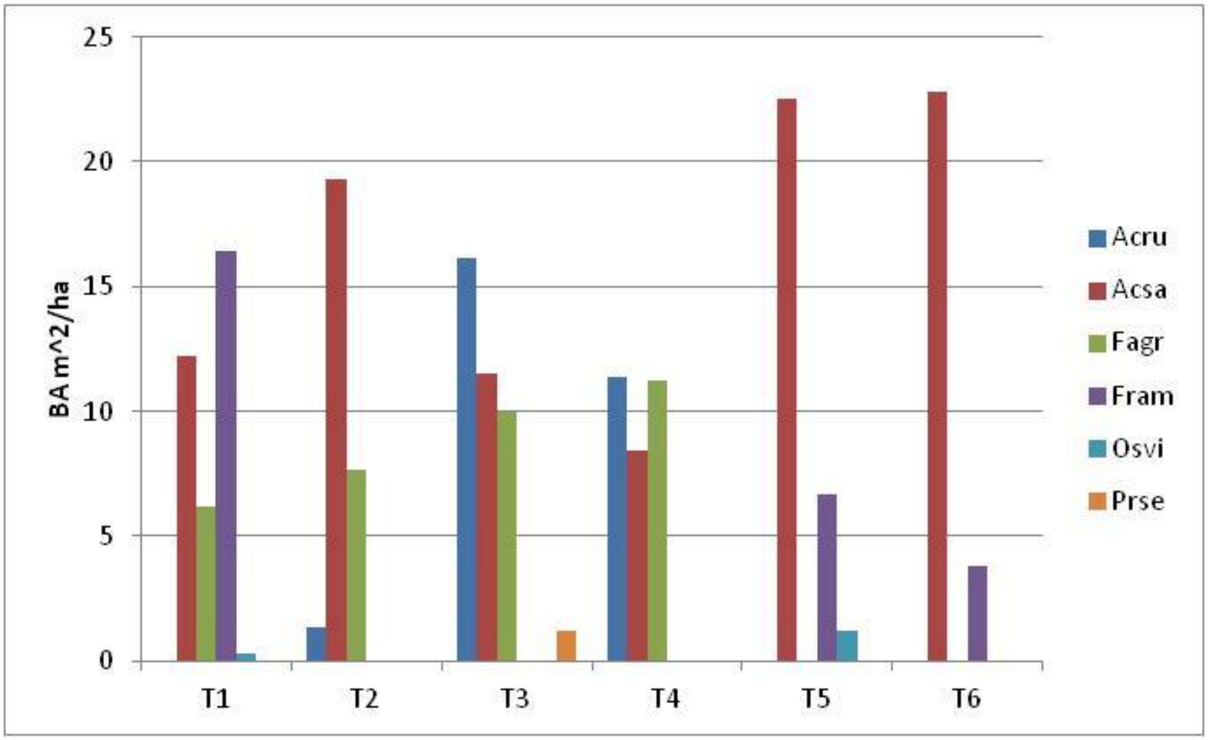

Figure 3. Overstory composition in basal area per hectare for each transect.

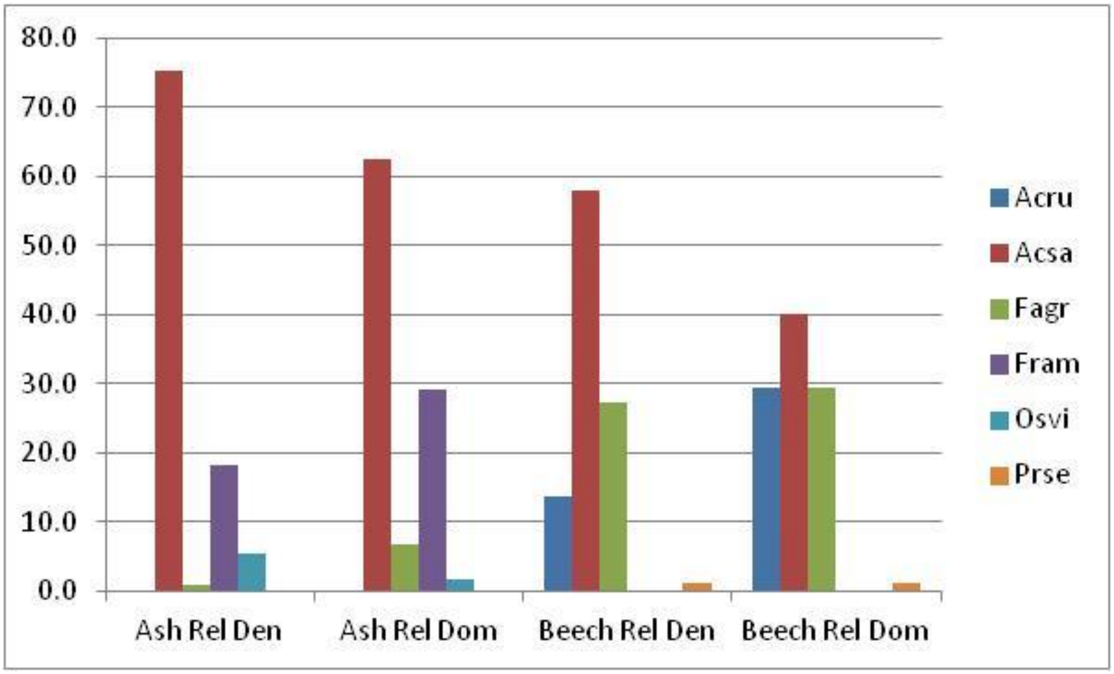

Figure 4. Overall composition overstory in ash and beech stands (averaged across all transects) in terms of relative density (proportion of total stems) and relative dominance (proportion of basal area).

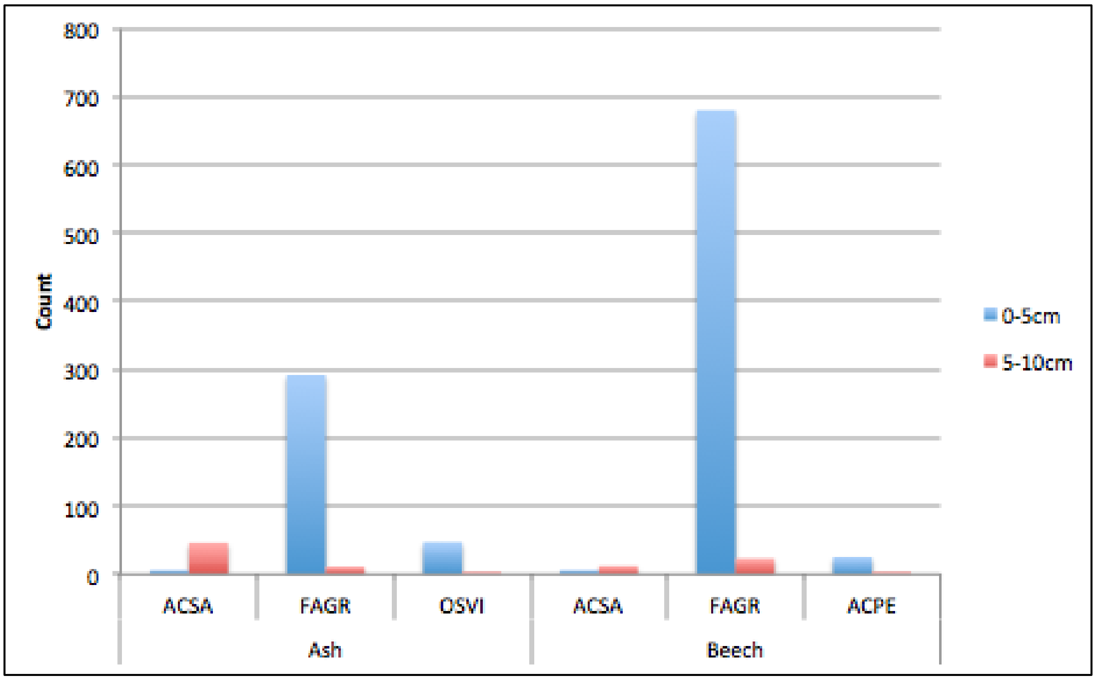

Figure 5. Understory composition in ash and beech stands (averaged across transects) shown as total stem count by species and size class.

Potential gap area

Estimated potential gap sizes in the beech-dominated stand tended to be larger than those in the ash areas (Table 2). This effect was not statistically significant based on ANOVA (Actual Gap – F = 0.72, p = 0.41; Potential Gap – F = 1.79, p = 0.21), but we believe that the difference in gap sizes could be important biologically and from a management perspective (Figs. 6 & 7). The difference in potential gap area is likely related to the higher tendency for dominance by beech in northern hardwood forests. Ash was a minor, occasional component of the canopy, rather than a ubiquitous canopy dominant, thus the gaps created by this species will tend to be smaller.

Table 2. Characteristics of potential EAB/BBD gaps sampled by transects

Transect	*Group*	*Gap #*	*Potential Max Gap Area*	*Susceptible Midstory*	*Actual Gap Area*
1	Ash	1	476.2	30	142.9
2	Beech	1	278.7	70	195.1
2	Beech	2	128.7	80	102.9
3	Beech	1	2232.1	90	2008.9
3	Beech	2	505.8	75	379.3
4	Beech	1	390.8	70	273.6
4	Beech	2	114.4	50	57.2
5	Ash	1	587.4	10	58.7
5	Ash	2	263.9	10	26.4
5	Ash	3	40.8	40	16.3
6	Ash	1	67.1	10	6.7

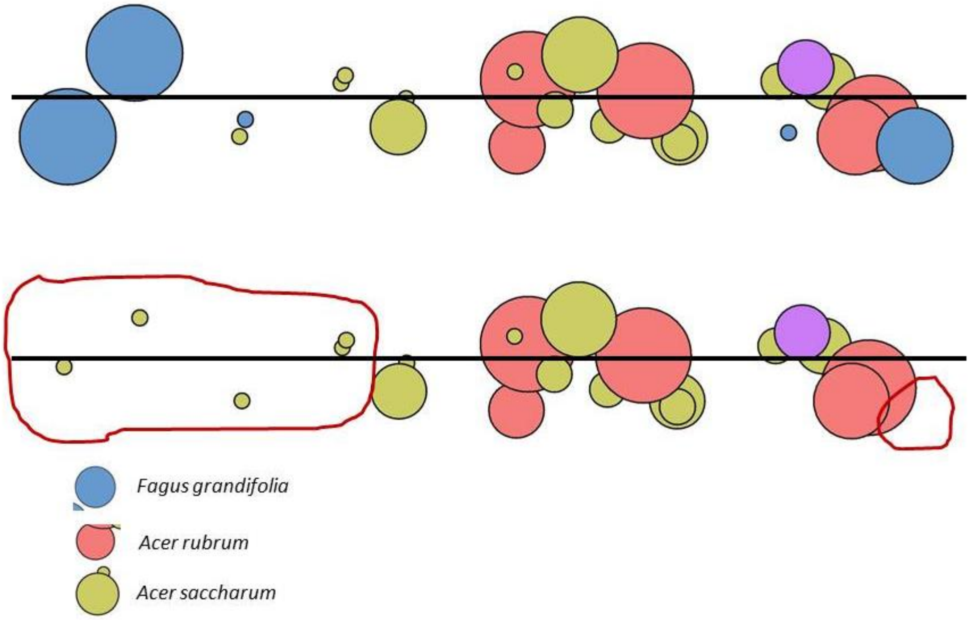

Figure 6. Stem/canopy map for Transect 3 (in beech stand) showing position of all stems and relative size of tree canopies. Upper image represents current (pre-disturbance) condition; lower image represents likely post-disturbance condition. In lower image, red outline represents potential gap area.

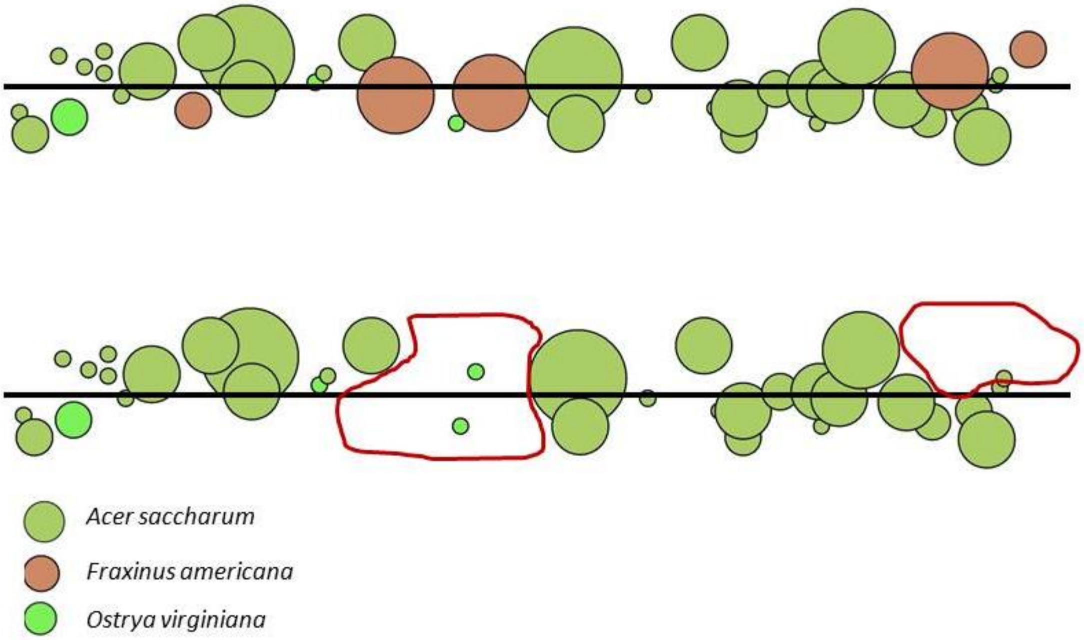

Figure 7. Stem/canopy map for Transect 5 (in ash stand) showing position of all stems and relative size of tree canopies. Upper image represents current (pre-disturbance) condition; lower image represents likely post-disturbance condition. In lower image, red outline represents potential gap area.

Forest structure

As seen in Fig. 8, the example beech transect had a high dominance of beech in the upper canopy with a fairly heterogeneous mid-story of beech, sugar maple, and red maple. To construct what the forest might look like after beech bark disease, the beeches were removed from the bisect (Fig. 9). Following beech removal, there is a very large canopy opening created ($2000m^2$; Figs. 6 & 9). This large gap will likely facilitate the canopy accession of some of the mid-story sugar maples. Due to the large gap area in this transect (and corresponding high light availability), there is the potential for the establishment of new regeneration of mid-tolerant species. However, the sapling composition of this area was highly dominated by beech (Fig. 5). Therefore, any new regeneration is likely to be outcompeted by advance regeneration of beech, and by sprouts arising from dead canopy beeches. If no management action is taken, the gap area will be largely dominated by dense thickets of beech saplings, which will likely die from the effects of BBD as they reach maturity.

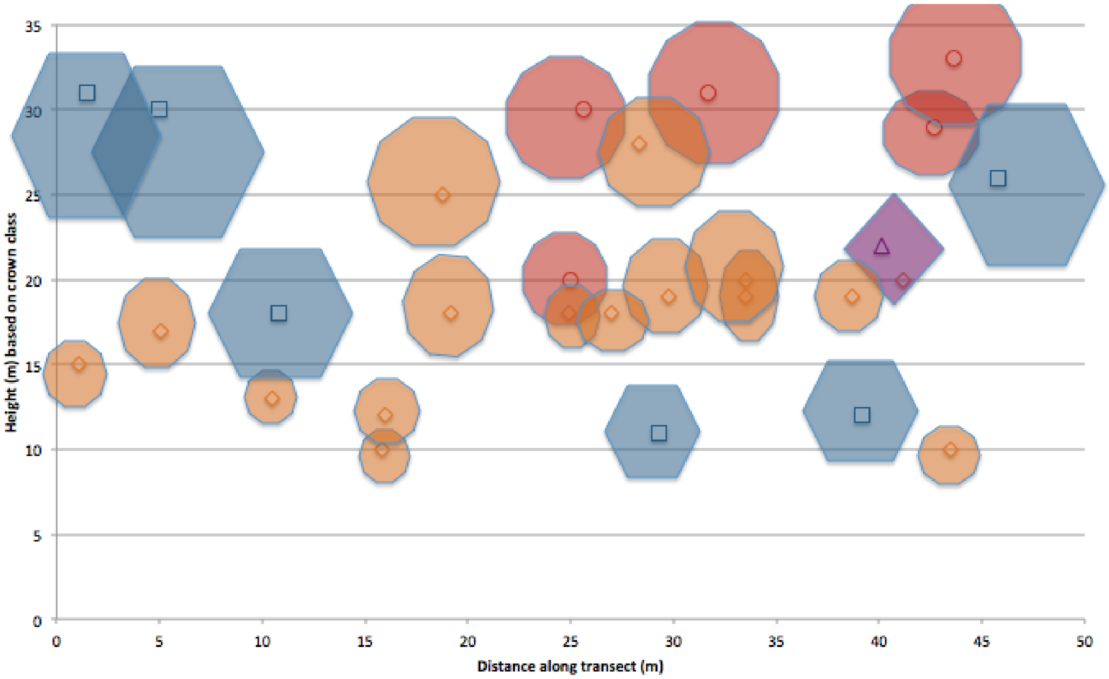

Figure 8. Canopy bisect for Transect 3 (in beech stand) showing position and relative size of tree canopies in current (pre-disturbance) condition.

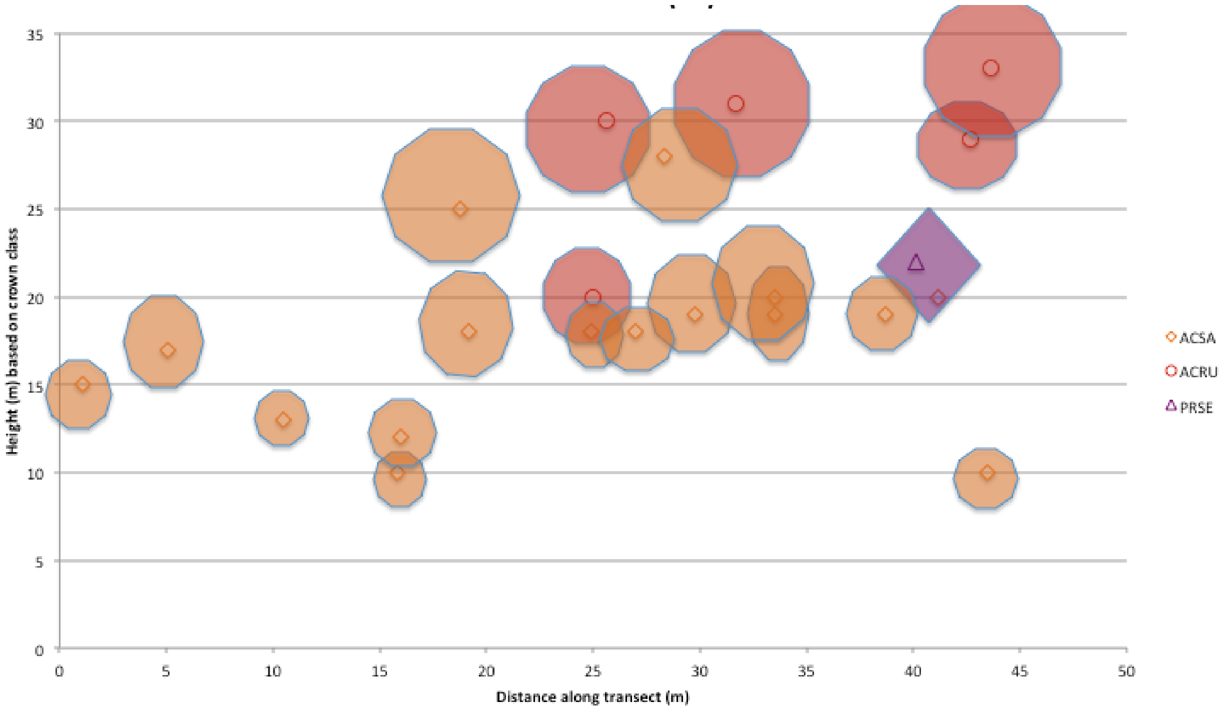

Figure 9. Canopy bisect for Transect 3 (in beech stand) showing position and relative size of tree canopies in likely immediate post-disturbance condition.

The ash stand had several prominent structural differences from the beech sites we investigated (Fig. 10). Namely, ash and sugar maple shared dominancy in the upper canopy. The mid-story was almost exclusively sugar maple. The main difference however, was that the gaps likely to be formed by ash removal were much smaller than those in the beech stand (Figs. 7 & 11). Such small gaps will likely be captured by the sugar maples that dominate the understory. Even in the event of larger gap formation, sugar maple comprises most of the larger, more competitive saplings, which will be most likely to access the canopy (Fig. 5). Therefore gap formation in this stand is likely to result in a forest almost exclusively composed of sugar maple. Thus after the EAB invasion, current ash-dominated areas are likely to become near monocultures of sugar maple if this part of the forest is not actively managed.

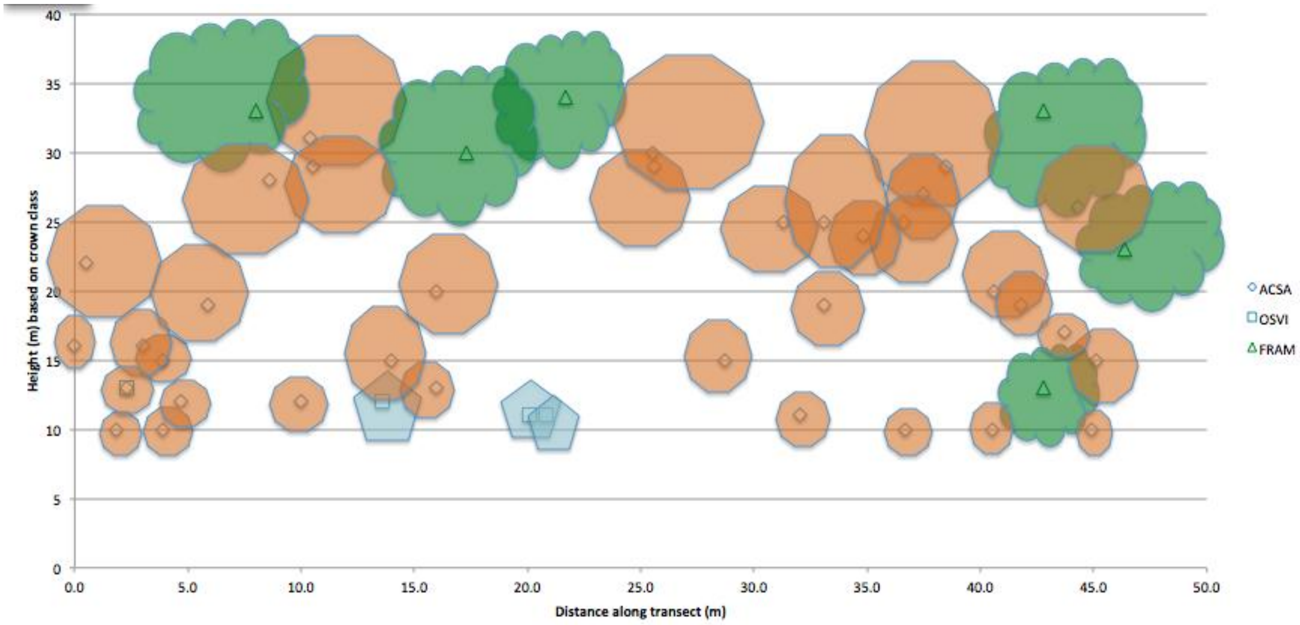

Figure 10. Canopy bisect for Transect 5 (in ash stand) showing position and relative size of tree canopies in current (pre-disturbance) condition.

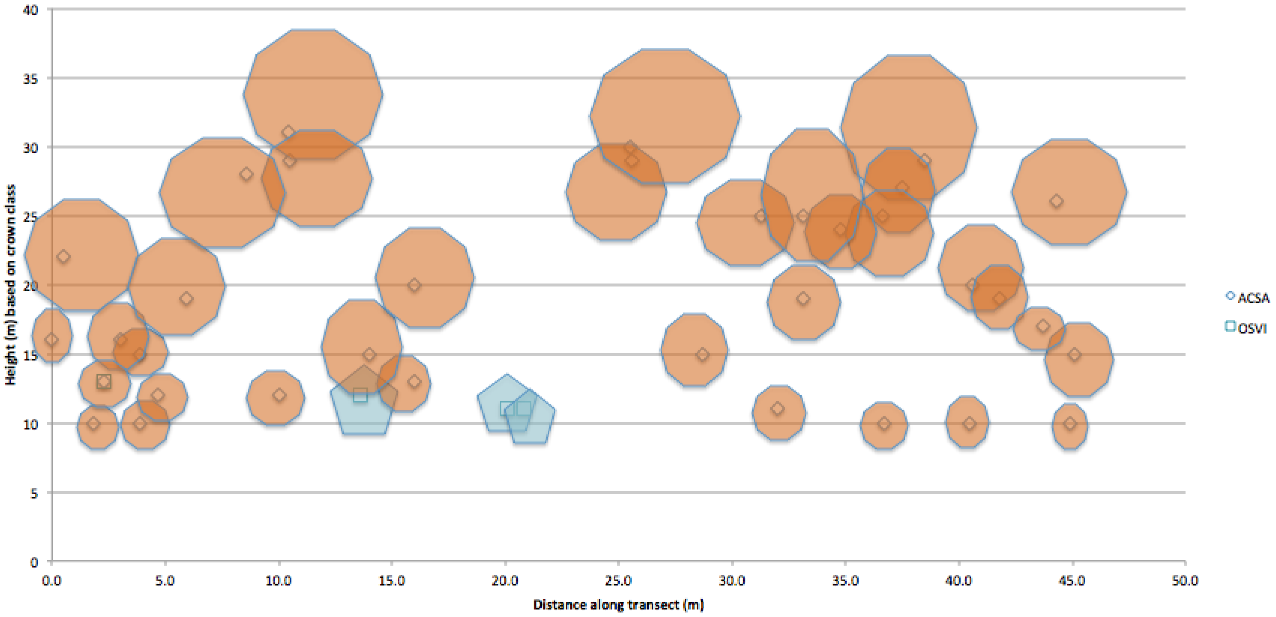

Figure 11. Canopy bisect for Transect 5 (in ash stand) showing position and relative size of tree canopies in likely immediate post-disturbance condition.

The likely future trajectories of both stands are likely to result in lower diversity and less resilience to future outbreaks and other stressors, such as those associated with climate change. Monoculture-type stands are more likely to be highly affected by pest outbreaks, and the sugar maple-dominated stands produced by these disturbances could be highly susceptible to the invasive Asian Longhorned Beetle (Dodds & Orwig 2011). Stands dominated by beech saplings and sprouts may spend a long interval in a shrubby/small tree phase before eventually transitioning to sugar maple dominance with the continued decline of the beech populations (Houston 1975; Ostrofsky & McCormack 1986). This transition phase (commonly known as "beech-hell" in the northeastern US) would have low aesthetic value and provide little in terms of diversity, carbon storage, and other ecosystem services. Both the sugar maple monoculture and "beech-hell" stand types would also have much lower value as wildlife habitat for most species, because of the loss of structure, diversity, and food production.

Management Implications

Highly productive soils in northern Michigan have a tendency towards dominance of sugar maple and beech (Barnes & Wagner Jr 1981). The northern hardwood forests of the Offield Preserve are no exception to this pattern and the introduction of EAB and BBD into the system is likely to increase the dominance of sugar maple within this forest type. Without some management, the post-disturbance forest is likely to transition to a condition of extreme sugar maple dominance in the overstory and shared dominance of sugar maple and beech-sprouts in the understory. These post-disturbance stands would be highly susceptible to the impacts of ALB and would likely have lower resilience to such an infestation than a more diverse forest (Dodds & Orwig 2011). In order to increase the potential resistance of the ecosystem to future disturbances and climatic changes, some degree of management intervention may be necessary.

In order to inform the possible future management of the Offield Preserve and other forests in the region facing similar changes, we outline three possible courses of action in response to the impacts of BBD and EAB. These management plans involve varying degrees of manipulation and were developed to best match the Little Traverse Conservancy's mission of conservation and ecological land stewardship. The three options are as follows:

1. No manipulation – natural or artificial regeneration
2. Post-disturbance understory/canopy management
3. Pre-emptive harvest and understory management

No manipulation – natural or artificial regeneration

One course of action would be to allow EAB and BBD to run their course in the current stand and make the changes to stand structure and composition that we have forecasted. Allowing the forest to regenerate naturally is the least intensive management strategy and would require no input of effort from the LTC. This course of action could be seen as being the most "ecologically sound" from a certain perspective. This strategy would limit any potential negative impacts of harvesting and would rely on the "natural" disturbance of the pest outbreak to alter the ecosystem. This strategy would retain significant levels of biological legacies, such as standing dead snags and coarse woody debris on the forest floor. Biological legacies create essential habitat for wildlife, as well as keeping nutrients within the system (Hunter 1999). This strategy would also allow the LTC to monitor the forest for resistance to the outbreaks. Possible genetic resistance could help repopulate the forest with trees that would not be affected by these pests and help maintain a component of these species in the landscape. However, there is very little evidence for genetic resistance to either EAB or BBD (Evans et al. 2005; Poland & McCullough 2006). An additional problem associated with this management strategy is that our data suggest the forest will likely develop into a monoculture of sugar maple and beech saplings. Such a change would have serious consequences for the resilience of the ecosystem to future changes.

A strategy of supplementing natural regeneration with some planting into the gaps created by the EAB and BBD disturbance could help promote diversity in the post-disturbance stand while limiting harvesting impacts. The pest outbreaks will reduce canopy density and could result in light levels high enough to promote seedling establishment. However, natural regeneration requires an existing seed source and is often sporadic and depends on the confluence of environmental conditions and good seed production. Some species that could be successful in BBD and EAB created gaps are present in the forest and would therefore have an existing seed source. However, some of the species that would be potential targets for promoting diversity are rare or absent from all or part of the Offield northern hardwood forest. Planting could be used to introduce these species into the areas affected by the disturbance.

The data presented here could be useful in determining what species would be most appropriate for planting (Table 3). The larger gaps created by BBD could increase light levels enough to promote mid-tolerant species such as yellow birch (*Betula alleghaniensis)*, eastern white pine (*Pinus strobus),* and northern red oak (*Quercus rubra)*(Burns & Honkala 1990). However, these species would probably require gap expansion through canopy/subcanopy tree removal to be successful in all but one of the potential gaps that we measured (on Transect 3). The smaller gaps associated with EAB may not be suitable for such light-demanding species and may be more appropriate for shade tolerant species such as basswood (*Tilia Americana),* black cherry (*Prunus serotina),* or hemlock (Burns & Honkala 1990). Many of these species would also do well in highly productive soil (basswood, cherry, yellow birch), while the conifers (white pine and hemlock) may be more successful in pockets of lower-productivity soil (Kotar et al. 2002). However, all of these species are likely to be outcompeted by advance regeneration of maples and beeches, potentially making it necessary to remove maple and beech saplings. Many of these species can also be important to wildlife for food and habitat, especially oak, cherry, and basswood. Yellow birch and cherry are especially valuable lumber species that could eventually provide an economic benefit to the landowner as well (Burns & Honkala 1990).

Table 3. Potential species for planting with recommendations, characteristics, and requirements

Common name	Scientific name	Site	Shade tolerance	Uses
Basswood	*Tilia Americana*	High	Tolerant	Honey
Black cherry	*Prunus serotina*	Medium-high	Tolerant	Food, Lumber
Red oak	*Quercus rubra*	Low-medium	Intolerant	Food, Habitat
White pine	*Pinus strobus*	Low-medium	Intolerant	Habitat
Yellow birch	*Betula alleghaniensis*	Medium	Intermediate	Lumber

Allowing the disturbance to run its course and relying on natural or artificial regeneration to create a diverse future canopy may be the easiest and least disruptive course of action, but the likelihood of this course leading to a forest that is diverse and resilient to future disruptions may be somewhat low. One effect of the BBD/EAB disturbance will be a response in the understory of existing sugar maple and beech advance regeneration and beech sprouts. Sugar maple was dominant in the understory of the ash stands (especially among the larger stems) and beech was highly dominant in the understory of the beech stands (and these small stems will not be killed by BBD). It is likely that these regeneration pools will be highly competitive with any newly established natural or artificial regeneration given the head start in size and/or resources that these individuals will have. For this reason relying on the BBD/EAB disturbance to diversify the forest is unlikely to be successful.

Post-disturbance understory/canopy management

A management plan that includes some degree of post-disturbance management may be beneficial to the development of a diverse regeneration layer. An understory thinning aimed at reducing the dominance of sugar maple and beech would be likely to aid the growth and competitive status of natural and planted seedlings of other species. This management could be tailored to the specific conditions left following the progression of the outbreaks. Dying beeches could be treated with herbicide to limit the development of a beech-sprout layer (Ostrofsky & McCormack 1986). An understory thinning-only option would be relatively low in intensity and harvesting impacts and could be used to establish shade-tolerant species or release advance regeneration of these species where they are present.

Some removals of canopy or subcanopy sugar maple trees (in addition to understory saplings) could also be employed to help increase light levels for mid-tolerant species such as yellow birch, white pine, and red oak. These removals could be targeted in such a way as to expand the gaps created by BBD/EAB. The intensity of management therefore would need to be tailored to both the severity of the disease impacts (i.e., how large the gaps are) and the species that are the focus of the management. If the managers are not prepared to remove larger canopy and subcanopy trees it may not be possible to manage for mid-tolerant species in some areas. However, large gaps created by BBD (such as that on Transect 3) may be ideal for mid-tolerant species if understory thinning is implemented to allow them access to the heightened light levels.

Another facet of post-disturbance management that could be implemented would be salvage of EAB/BBD killed trees. This would have the negative effect of removing snag and coarse woody debris biological legacies from the forest, but could provide some economic relief to offset the required investment in understory thinning of non-merchantable trees. The trees that are removed could be sold to lumber mills and distributors. Ash is a valuable wood and is used for many purposes, such as furniture and baseball bats, while beech is much less valuable (Barnes & Wagner Jr 1981). Only ash would have any real value as timber and therefore any salvage in BBD affected stands would not be of much benefit economically. Salvaging in EAB affected stands may be more likely to provide some economic benefit, but the large quantities of ash entering the market with EAB may negate any such value (Pugh et al. 2011). These factors and the high ecological value of retaining snags and coarse wood probably make the prospect of salvage harvesting a less desirable option.

Pre-emptive harvest and understory management

Another possible strategy would focus on pre-emptive harvesting of ash and beech trees that are likely to be killed by the EAB/BBD disturbance. Such a treatment could manipulate how the disturbance moves through the forest and could provide economic benefits to the Little Traverse Conservancy. Although this strategy would have some economic benefit, it would suffer from the same drawbacks as salvage harvesting (low timber value for beech and poor market for ash – but no beetle damage to wood). This strategy would also have the same ecological drawbacks – lack of biological legacies with the added loss of the mast in the intervening years before complete removal and lower chance of identifying resistant trees. However, such a strategy could have some important management benefits. One benefit would be the ability to control the size and timing of the gaps created by the disturbance, which would make planning for establishment of a diverse pool of tree seedlings much easier and likely more effective. This strategy would also allow for pre-establishment of seedlings with precise knowledge of when and to what degree these seedlings would be released by gap formation. Such pre-planting would probably increase the likelihood of the seedlings being successful because they would be able to become established on the site prior to the disturbance that would release them. Pre-planting could be used in the other management scenarios, but not knowing the timing of gap formation would make the timing of planting difficult and could lead to high mortality rates of seedlings if gap formation was delayed. Removing susceptible trees from the community could help to slow the speed at which the disturbance moves through the forest or possibly avoid the entry of the pest entirely. Such a strategy could be especially useful in the case of BBD, where a few smooth-barked trees could be retained. These trees may be more likely to survive an outbreak, and could benefit from lower population pressure from surrounding dying/diseased trees. Such a strategy is less likely to be important for EAB, which has a wide dispersal range and no known physical markers of resistance.

Another strong argument against pre-emptive harvesting is the uncertainty of the spread and development of the pest outbreaks. In the case of BBD, not all areas have been equally hardhit and it is possible that the Offield site may not have 100% mortality. In the case of EAB, biological control agents may slow or halt the spread and destruction of the pests in the near future (Bauer et al. 2010). A parasitoid wasp has been identified as a possible control agent for EAB and trials are being conducted to evaluate the efficacy and potential ecological impact of this control measure.

Recommendation/Conclusion

The imminent introduction of Beech Bark Disease and Emerald Ash Borer to the Offield Preserve is likely to produce a northern hardwood forest component that is lower in tree diversity and less resilient to future stressors such as subsequent pest outbreaks and climate changes. We would recommend that the LTC consider including elements of Management Scenarios 1 & 2 into the management planning process for the Offield Family Nature Preserve. Planting of selected tree seedlings/saplings into areas affected (or soon to be affected) by EAB/BBD could be very useful for increasing species diversity and resilience of the northern hardwood forests of the site. These efforts are most likely to be successful if they are implemented in conjunction with clearing of saplings of sugar maple and beech. Clearing would be most effective if implemented both directly at the time of planting (and with stump herbicide application) as well as a few years following planting to control beech sprouts. In addition to clearing of understory competitors, the more mid-tolerant to intolerant species that we have identified would benefit greatly from targeted removals of canopy/subcanopy trees to increase gap size and light availability, especially in the ash-dominated areas of the site.

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