Insect Damage to Wind-Thrown and Standing Live Black Cherry Resulting From Delayed Salvage After a Major Abiotic Disturbance

Marc F. DiGirolomo, Douglas C. Allen, Stephen V. Stehman, Susan L. Stout, and Jan Wiedenbeck

ABSTRACT

Severe windstorms that swept through three counties in northwestern Pennsylvania on July 21 and 22, 2003, caused extensive blowdown in many northern hardwood stands containing an extensive component of black cherry, *Prunus serotina* Ehrh. Although many species were affected by the storm, black cherry is the most valuable timber species in the region. A number of factors prevented salvage until 3 years after the storm. The purposes of this study were to identify the wood-boring insects that attacked damaged cherry and to estimate the value lost due to delayed salvage. The long-horned beetle *Saperda imitans* Felt and Joutel (Coleoptera: Cerambycidae) and the ambrosia beetle *Xyleborinus saxeseni* (Ratz.) (Coleoptera: Curculionidae: Scolytinae) were the most abundant wood borers reared from wind-thrown cherry. We also monitored both changes in the population of the bark beetle *Phoeotribus liminaris* (Ratz.) and the damage it caused to live residual cherry. Based on the average depth of *S. imitans* galleries and associated stain, the estimated grade loss of a 25-cm (10 in.) cherry log (large end) after slab removal was approximately 27% and for a 102-cm (40 in.) log it was 3.6%. Wood borer galleries occurred throughout the first 5.2 m (17 ft) of the butt log as well as in the upper bole and larger branches. The density of ambrosia beetle galleries on wind-thrown trees was highest on trees with dying and dead epicormics than on trees with live epicormics and higher on trees suspended off the ground. Catches of *X. saxeseni* in ethanol-baited, Lindgren funnel traps increased significantly from 2005 to 2006 as did numbers of *P. liminaris* and the gum spot damage these insects did to residual live cherry in 2005 compared with that in 2004. Results of this study indicate that the extent of insect damage after this abiotic disturbance was influenced by the time of year the damage occurred relative to the temporal activity of the insects involved and emphasizes the importance of swift salvage.

Keywords: black cherry, wood-boring insects, timber salvage, *Saperda imitans*, *Xyleborinus saxiseni*, *Phloeotribus liminaris*, storm damage

Severe wind is a large-scale disturbance that may significantly alter the ecology and economic potential of forests in North America (Oliver and Larson 1990). Wind-thrown trees not salvaged on a timely basis may set the stage for additional hazards such as fire and increased risks for outbreaks of inner-bark and wood-boring insects (Stathers et al. 1994). Ecologically, these insects comprise one of the key elements responsible for initiating the decomposition and general reduction of woody debris after a large-scale abiotic disturbance (Schowalter 1996). If salvage is not timely, however, their activities can reduce the quality of logs recovered from damaged stands (Wickman 1965, Gardiner 1975, Nevill and Whitehead 1996), and they may threaten residual trees as well (Barry et al. 1993, Eriksson et al. 2005).

On July 21, 2003, a violent windstorm passed through the Allegheny National Forest in northwestern Pennsylvania, causing extensive wind-throw. The main swath of the storm event covered 525,000 ha of forest throughout the Allegheny Plateau, approximately 5,000 ha of which were moderately to severely damaged (Evans et al. 2007). A variety of factors delayed salvage of damaged trees for three growing seasons. Preliminary inspection of the 688-ha Kane Experimental Forest, part of the Allegheny National Forest, in 2004 revealed that stems and crowns of downed black cherry on the 138 ha affected by the storm (J.W. Hazel, USDA Northeast Area State and Private Forestry, pers. comm., Morgantown, WV, Oct. 16, 2003) were being invaded by populations of a long-horned beetle, *Saperda imitans* Felt and Joutel (Coleoptera: Cerambycidae), two species of ambrosia beetles, and the peach bark beetle, *Phloeotribus liminaris* (Harris) (Coleoptera: Curculionidae: Scolytinae).

The depth of galleries made by *S. imitans* and their distribution throughout the first 5.2 m of cherry boles indicated that this insect had potential to lower the grade and reduce the volume of wood processed from infested logs (DiGirolomo et al. 2011). Its larval stages feed in the phloem beneath the bark of black cherry (*Prunus*

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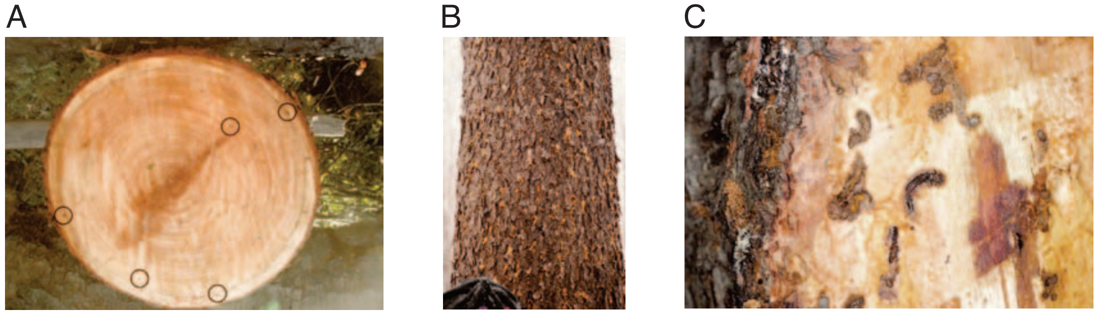

Figure 1. A. Overwintering niches produced by peach bark beetle adults. The outer bark has been removed to expose the inner bark and phloem. This burrowing activity leaves coffee-colored spots on the surface of the sapwood, B. Peach bark beetle-produced gum spots on the bark of a heavily infested black cherry tree. C. Gum spots and stain that have been incorporated into growth rings. This discoloration degrades the value of black cherry lumber and veneer. (Photo courtesy of USDA Forest Service, Northern Research Station, Princeton, WV.)

serotina Ehrh.) and fully grown larvae overwinter at the end of a gallery they excavate in the sapwood and outer heartwood.

Ambrosia beetles enter directly into the wood, creating a myriad of small diameter galleries that may penetrate for several centimeters. Both larvae and adults feed exclusively on a symbiotic fungus adults introduce into the galleries during the process of egg laying (Wood 1982). Stain associated with growth of this fungus and the presence of these galleries can be major sources of degrade in lumber and veneer of both coniferous (e.g., Orbay et al. 1994) and broad-leaved trees (Solomon 1995).

Peach bark beetle breeds in freshly produced cherry slash and stressed or recently killed cherry. Damage to live black cherry trees occurs when adults emerge from brood material in spring and burrow into the phloem of healthy cherry (Figure 1C) to overwinter (Kulman 1964). Tree health is usually not compromised unless the density of overwintering beetles is extremely high (25–41 galleries/1,000 m^2 of bark surface; Rexrode 1982) (Figure 1B). The resulting coffee-colored stains and gum deposits, however, can be significant defects in factory grade sawlogs and potential veneer logs once the affected growth ring is assimilated into the tree bole (Figure 1A) (Rexrode and Smith 1990, Cassens 2004).

The purposes of this study were to identify the species complex; to describe the temporal occurrence and to determine the relative abundance of wood-boring insects infesting the boles of wind-thrown black cherry, a major component of these Allegheny hardwood stands; to describe the host condition associated with their activity; and to estimate the extent of insect-caused degrade resulting from delayed salvage. Black cherry is among the highest valued timber species throughout much of the northeastern United States, and in the Allegheny hardwood stands it is typically more valuable than the same species grown in other regions (Penn State University 2005, Wiedenbeck et al. 2004). This premium value is especially evident in the veneer industry because cherry logs from this region are less prone to gum spot defects and the wood is a lighter pink than cherry grown elsewhere (Cassens 2004).

Methods

Study Site

The Kane Experimental Forest is located in Elk County, Pennsylvania, on the eastern side of the Allegheny National Forest. Elevations within the forest vary from 550 to 640 m, and overall topography is mostly flat and gently sloping. Black cherry, sugar maple (*Acer saccharum* Marsh., and red maple (*Acer rubrum* L.) account for 65–95% of the basal area in these stands. Many other hardwood species and eastern hemlock are common associates (Marquis 1980). The storm affected a high proportion of black cherry, which reflects the fact that black cherry is more susceptible to wind-throw than other Allegheny hardwoods (Canham et al. 2001), because it is shallow rooted and the relatively small crowns of dominant and codominant individuals tend to extend above the general canopy in mixed stands (Marquis 1990).

Monitoring the Seasonal Activity of Ambrosia Beetles and Peach Bark Beetle

Five 12-unit Lindgren funnel traps (Phero Tech, Delta, BC, Canada) were placed approximately 20 m apart along each of two transects in each of three areas (30 traps total) within the windblown section in 2004–2005. In addition, a control transect was located in each area ≥40 m from the closest blow down. Traps remained in the field from Apr. 22 through Oct. 19, 2004, and from Apr. 22 through Aug. 16, 2005. The same trap positions were used each year; however, time constraints in 2006 required that trapping intensity be reduced to a single control in one area and two transects at one of the wind-damaged sites. Trapping in 2006 occurred from May 5 through Aug. 21. Salvage at all sites did not occur until the winter of 2006–2007. The three areas selected were similar in composition and extent of damage. This design provided multiple opportunities to monitor the response of peach bark beetle and ambrosia beetles to wind-thrown black cherry. Transects were the experimental units.

Traps were baited with black plastic pouches containing 125.5 ml of UHR ethanol (Phero Tech) with a release rate of 0.35 g/day. These lures were replaced once in mid-summer and were checked weekly to ensure that they did not empty prematurely and the plastic container remained soft and flexible. Whenever a pouch felt stiff and parchment-like, most likely as a consequence of overexposure to direct sunlight, it was replaced regardless of age. We assumed that this change in texture affected permeability and, consequently, the release rate. Approximately 2–3 cm of diluted ethylene glycol were placed in the container at the base of each trap to prevent decomposition of trapped insects. Trap contents were collected weekly in paper paint strainers and each strainer was placed in a plastic sandwich bag containing a few millimeters of 80% ethyl alcohol and stored in a refrigerator. The population of peach bark beetle was monitored during all 3 years, but ambrosia beetles were collected only during 2005 and 2006. Individuals were preserved in 80%

ethanol. Trap catches from damaged and control areas were combined to determine temporal patterns of beetle activity.

Monitoring Gum Spots on Undamaged Black Cherry

The number of fresh gum spots produced in 2004 and 2006 was determined for each of 10 dominant or codominant black cherry trees adjacent to each of the transects. Sample trees were spaced 20 m apart and parallel to each transect. The same location on the bole of each tree was sampled both years. To standardize the bole area inspected, a 30-cm tall band was outlined on each tree with the bottom of the band at 1.4 m above the ground. This location was selected because it occurs at a height that facilitates accurate counting and gum spot numbers here represent the maximum density of overwintering peach bark beetle on the tree bole (Hanavan et al. 2013). Tree diameter was measured at breast height (1.4 m), and gum spots were counted and classified as soft, hard, or black. These categories correspond to a gum spot's age, soft being the most recently formed. Soft gum spots were identified by gently pressing a pencil tip against the gum to see whether a depression was formed. A hard (old) gum spot will not depress but rather crumbles. In addition, sooty mold often coats old gum and eventually will break it down. Surface area was determined by converting tree diameter at 1.4 m to circumference (cm) and multiplying by 30 cm. Gum spot density was expressed as the number/m^2 of bark surface to standardize data for differences in tree diameter.

Density of Wood Borer Galleries in Wind-Thrown Black Cherry

Twenty-three galleries of the most common ambrosia beetle, *Xyleborinus saxeseni* (Ratzburg), and 233 galleries of the most abundant cerambycid, *S. imitans*, reared from sections of 10 wind-thrown black cherry trees were excavated during the summers of 2006 and 2007. Maximum depth of gallery penetration (length) and depth of staining were measured to the nearest 0.5 mm.

In addition, a band of bark 30-cm tall was removed from four bole sections on each of 68 wind-thrown black cherry trees. The first band began 25 cm from the base of the tree or above the root swell if applicable, and the base of each subsequent band was located 1.25 m above the top of the previous band. These samples provided an estimate of beetle density and distribution throughout the first 5.2 m of each tree bole. This usually is the most valuable part of a tree in terms of both lumber and veneer. The number of ambrosia beetle entrance/exit holes was counted in each sample (band), and density is expressed as the number of holes/m^2 of bark surface. The diameter of each log was measured 1.4 m above the root collar and at the middle of each band. The 68-tree sample was stratified by tree position relative to the ground (in contact with the ground or suspended above the ground), the condition of epicormic sprouts (live, absent/dead, or dying), and three diameter classes (small [20–30 cm], medium [>30–40 cm], and large [>40 cm]). For these analyses, beetle density/m^2 for each tree was determined by averaging data from all four 30-cm bands.

Volume of Wood Affected by Insect Galleries

American units are the standard in the US forest industry; therefore, all calculations of log size and volume for this aspect of the study are expressed in American units. The total volume of a hypothetical 16-ft (~4.9 m) log ranging from 12.5 in. (32 cm) to 50 in. (126 cm) in diameter at the large end was determined using Smalian's formula (Wiant et al. 1996). This method averages the cross-sectional areas of the large and small ends of each log and multiplies this by log length. Large end diameters were estimated using Girard form class 80 to account for taper (Mesavage and Girard 1946) whenever the lower bole of a tree rested on the ground and direct measurement was not possible. Smalian's formula was then reapplied after the diameter of both ends of a log was reduced by twice the depth of the average depth of gallery penetration to arrive at salvageable volume; that is, the volume of the cylinder within a log that would be clear of gallery defects. The difference between total volume (using actual diameter) and salvageable volume is the estimate of volume lost as a result of wood borer activity.

A small portion of a potential veneer log is lost when the log is debarked before processing. Slab removal to square a log before sawing also reduces the volume recovered. In the absence of a mill study, it was not possible to determine total volume that would be lost due to debarking and slab removal. Using the average of two estimates of slab volume in relation to log volume (Abebe and Holm 2003), we determined that approximately 5% of log volume is removed during this initial processing when logs are converted into lumber. This percentage was applied to the total volumes to obtain the volume of wood removed in the slabs. Slab volume was then subtracted from the volume affected by beetle activity, resulting in the net volume obtainable in the absence of beetle-caused defects.

Statistical Analyses

With a few exceptions, nonparametric statistical methods were used to assess statistical significance. The Wilcoxon test was applied to the differences for paired analyses (e.g., using a transect as the "pairing" attribute) to compare the number of peach bark beetles caught/trap/week in 2004 and 2005 and to compare mean gum spot density/m^2 in 2004 and 2006. The Kruskal-Wallis test was used for comparisons involving three independent tree conditions or groups (e.g., differences in the density of ambrosia beetle holes for wind-thrown black cherry with live, absent/dead, or dying epicormic branches) and two positions (trees on the ground and off the ground). To compare the density of ambrosia beetle holes for each pair of band heights, the difference in the number of holes/m^2 was computed for each tree and the Wilcoxon test (Minitab 2007) was applied to these differences. Because six pairs of band heights were compared (all possible pairs of the four heights), P values were adjusted using the Bonferroni method applied to the six comparisons. The α level (probability of a type I error) for the family of comparisons was set at 0.05. Annual differences in the average number of *Anisandrus sayi* (Hopk.) and *Xyloterinus politus* (Say) caught/trap/week were compared using two-sample pooled t-tests (sample variances for the groups compared were similar). Simple linear regression was used to assess the relationship between the density of ambrosia beetle holes and the diameter of the tree at breast height.

Results

Seasonal Activity of Ambrosia Beetles and Peach Bark Beetle and Changes in Gum Spot Density on Residual Black Cherry

The mean number of peach bark beetles caught/trap/week in wind-damaged areas was low (1.4 ± 0.5) in 2004 (Table 1) the summer after the storm but increased to 10.4 ± 4.4 in 2005 ($P = 0.04$, Wilcoxon test of differences paired by transects for 2005 compared with 2004). The mean number caught/trap remained high (8.5 ± 1.7) in 2006 but with only two transects in the damaged

Table 1. Average number of peach bark beetles captured/trap/transect for 2004–2006 and number of gum spots/m² of bark surface area on 10 black cherry trees adjacent to each of nine transects in 2004 and 2006: Kane Experimental Forest (Kane, PA).

	2004			2006	
Transect no.	Gum spots/m²	PBB/trap/wk	2005: PBB/trap/wk	Gum spots/m²	PBB/trap/wk
1	0.3 (0.3)	2	13.2	205.2 (37.9)	
2	0.3 (0.3)	4	28.4	141.5 (259.)	
3	0	00.8	3	183.6 (51.5)	
4	0.3 (0.3)	0.4	15.6	38.5 (11.8)	6.8
5	0	0.2	0.4	6.0 (9.1)	10.2
6	0.3 (0.3)	1	1.6	36.7 (20.0)	
Mean	0.2 (0.1)	1.4 (0.6)	10.4 (4.4)	120.3 (44.3)	8.5 (1.7)
Controls					
7	0.2 (0.2)	0.4	1.8	1.5 (1.1)	
8	0.6 (0.4)	0.4	2.0	33.5 (17.9)	8.2
9	1.8 (1.4)	3.8	1.0	1.2 (0.6)	
Mean	0.9 (0.5)	1.5 (1.1)	1.6 (0.3)	12 (10.7)	

Numbers in parentheses are ±SE. PBB, peach bark beetle.

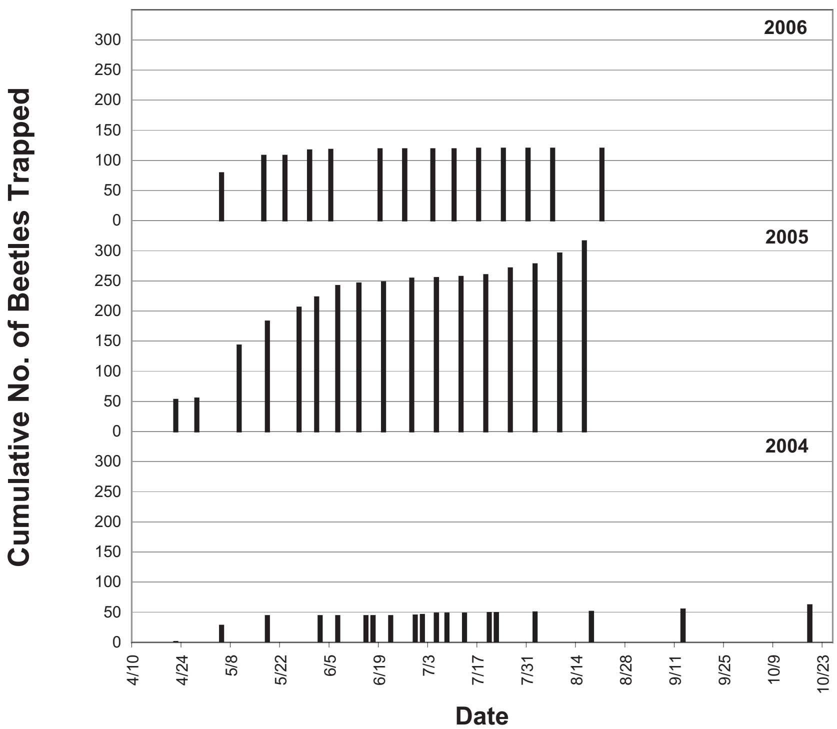

Figure 2. Cumulative number of peach bark beetles captured in Lindgren funnel traps for 3 years at the Kane Experimental Forest (Kane, PA).

areas, a statistical test comparing 2006 to 2004 is not meaningful. In contrast to the transects in wind-thrown areas, the mean number of beetles caught/trap in the control areas did not increase between 2004 (1.5 ± 1.1) and 2005 (1.6 ± 0.3) ($P = 0.99$, Wilcoxon test of paired differences). Beetle density was similar in wind-thrown and control areas in 2004 and 2006 but was almost seven times higher in damaged areas in 2005 (Table 1.) A majority of these beetles were caught during late May and through the first week of June (Figure 2). A relatively small number appeared later than this in 2004 and 2005.

Ten ambrosia beetle genera were identified from funnel trap collections at the Kane Experimental Forest, seven of which occurred in low numbers or use conifers as hosts (*Dryocoetes*, *Trypodendron*, *Orthotomicus*, *Scolytus*, *Gnathotrichus*, *Hypocryphalus*, and *Monarthrum)*. Two species caught in relatively large numbers are known to infest broad-leaved trees (Solomon 1995), and the average

Table 2. Average number of the most abundant species of ambrosia beetles captured/Lindgren funnel trap/week for transects in wind-damaged areas of the Kane Experimental Forest (Kane, PA) in 2005 and 2006.

Species	2005[a]	2006[b]	*df*	*P*[c]
Anisandrus sayi (Hopk.)	13.8 (2.7)	30.0 (3.4)	6	0.02
Xyleborinus saxeseni (Ratz.)	5.0 (0.4)	17.1 (1.5)	2	0.001
Xyloterinus politus (Say)	0.9 (0.2)	3.9 (0.3)	5	0.001

Numbers in parentheses are ±SE.
[a] Five traps on each of nine transects.
[b] Five traps on each of three transects.
[c] *P* values from pooled two-sample *t*-tests.

number caught/trap/week for both increased significantly from 2005 to 2006 (Table 2). Cumulative trap catch for these species during each of 2 years indicated that adults of *A. sayi*, the most abundant ambrosia beetle captured, emerged throughout much of

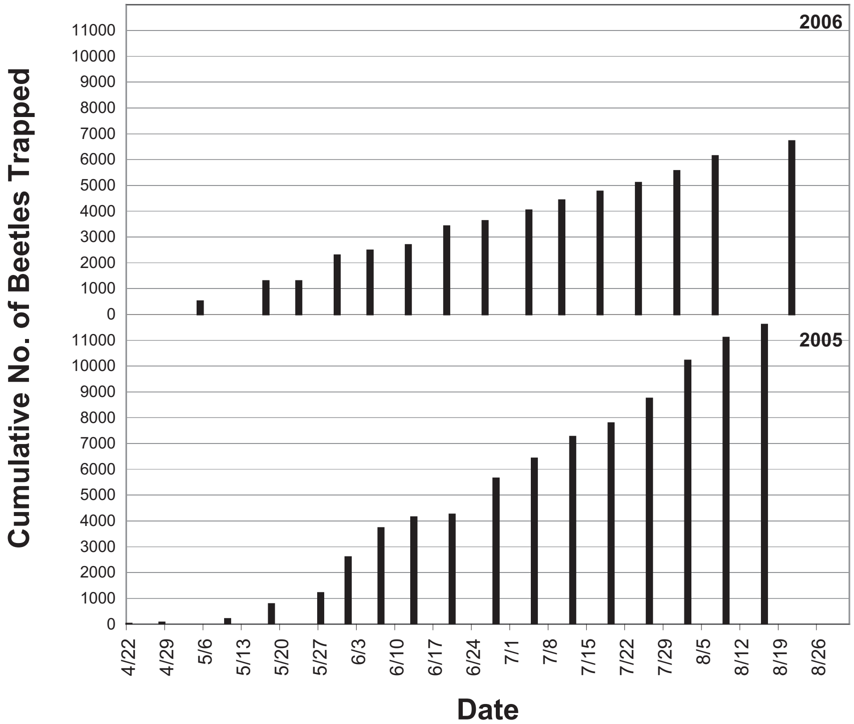

Figure 3. Cumulative number of *Anisandrus sayi* captured in ethanol-baited Lindgren funnel traps for 2 years at the Kane Experimental Forest (Kane, PA).

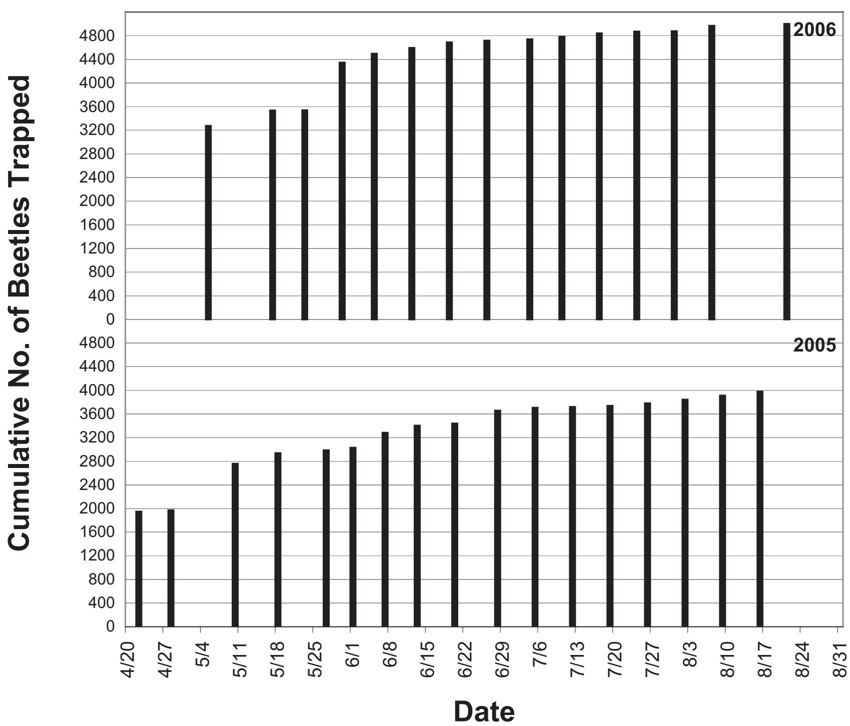

Figure 4. Cumulative number of *Xyleborinus saxeseni* captured in ethanol-baited Lindgren funnel traps for 2 years at the Kane Experimental Forest (Kane, PA).

the trapping season (Figure 3), and a majority of the adults of both *X. saxeseni* (Figure 4) and *X. politus* (Figure 5) were captured by mid-June. The former was the second most common scolytine captured in these Allegheny hardwood stands after the storm, and it was the most abundant ambrosia beetle reared from wind-thrown black cherry.

The number of gum spots/m^2 on standing, overstory black cherry trees in wind-thrown areas increased significantly ($P = 0.04$, Wilcoxon test of paired differences) from 2004 (mean= 0.2 ± 0.6 gum spots/m^2) to 2006 (mean = 101.9 ± 34.8 gum spots/m^2). Gum spot density for the three control transects remained low both years ($P = 0.42$, Wilcoxon test of paired differences) (Table 1).

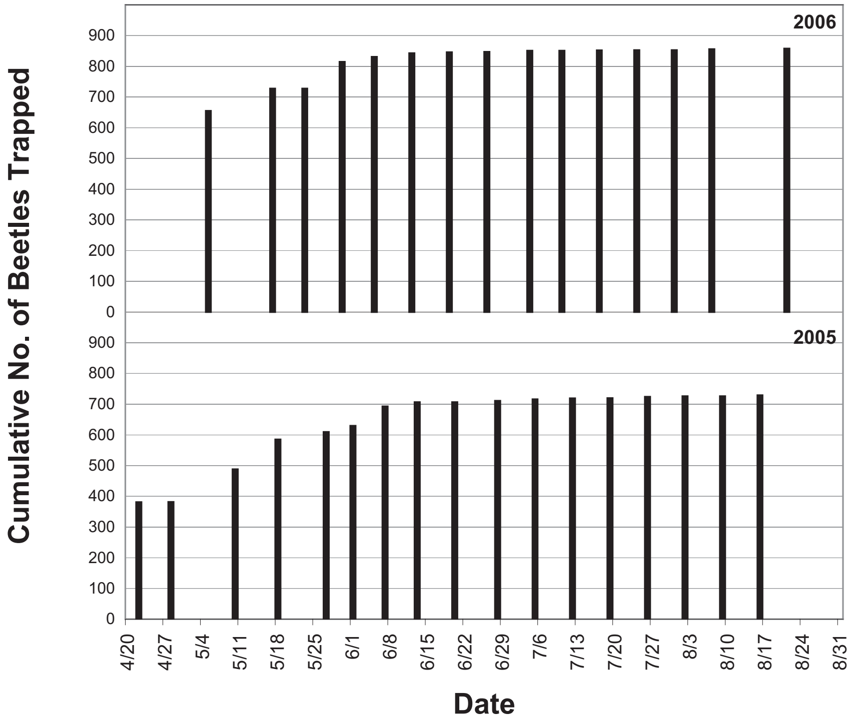

Figure 5. Cumulative number of *Xyloterinus politus* captured in ethanol-baited Lindgren funnel traps for 2 years at the Kane Experimental Forest (Kane, PA).

Density of Ambrosia Beetle Entrance/Emergence Holes in Wind-Thrown Black Cherry

The mean density of ambrosia beetle entrance holes for all bands on the 68 wind-thrown black cherry trees examined at the Kane Experimental Forest was 3.45 ± 0.8/m^2 of bark. Although ambrosia beetles occurred throughout the boles of infested trees, density on band 1 (1.83 ± 0.72 [mean ± SE]) and density on band 2 (2.06 ± 0.71) were significantly lower ($P = 0.006$) than the mean density on band 4 (Wilcoxon paired test of differences). Mean density on band 2 was significantly lower ($P = 0.02$) than the mean density on band 3 (4.08 ± 1.09). Other pairwise comparisons of bands not mentioned were not significantly different.

For epicormic branches, the density of entrance/emergence holes in wind-damaged black cherry differed among trees with live, absent/dead, and dying epicormic branches ($P = 0.006$, Kruskal-Wallis test). The mean density for trees with live epicormic branches was 0.7 ± 0.4 holes/m^2 ($n = 24$ trees), the mean density for trees with dead epicormic branches was 5.2 ± 1.4/m^2 ($n = 22$ trees), and the mean density for trees with dying epicormic branches was 4.7 ± 1.9/m^2 ($n = 22$ trees). The density of ambrosia beetle entrance/exit holes on wind-damaged trees with dead ($P = 0.002$) or dying ($P = 0.02$) epicormic branches differed from ambrosia beetle density on trees with live epicormic branches, but trees with dead or dying epicormic branches did not differ in density ($P = 0.42$) (Mann-Whitney tests). The density of ambrosia beetle entrance/emergence holes in trees that were resting on the ground (mean = 2.7 ± 1.3/m^2, $n = 32$ trees) was significantly ($P = 0.05$, Mann-Whitney test) lower than the density for trees suspended off the ground (4.1 ± 1.0/m^2, $n = 36$ trees). The density of entrance/emergence holes showed no association with tree diameter ($P = 0.69$, $R^2 = 0.2$, simple linear regression), and density transformed to a logarithmic scale was also not associated with dbh of the tree.

Volume of Wood Affected by Wood-Boring Beetles

Average depth of *X. saxsensi* galleries was 16.6 ± 1.7 mm. The deepest average penetration of wood-boring insects (23.5 ± 0.5 mm, $n = 228$) in wind-thrown black cherry was caused by the long-horned beetle *S. imitans* (DiGirolomo et al. 2011). This is the figure used to estimate damage for a range of log sizes. The log volume affected by this damage was 27% for a 12.5-in. diameter (large end) log and 3.6% for a 50-in. diameter log.

The total volume of cherry logs salvaged from the Allegheny National Forest after the 2003 windstorm was 9,106 million board feet (MBF), valued at $ 3.1 million, a salvage value of $342 MBF (S.L. Stout, USDA Forest Service, Northern Research Station, pers. comm., Irvine, PA, Nov. 8, 2006). No information on the actual value loss due to beetle damage after the salvage operation at the Kane Experimental Forest was available. The value received, however, was substantially lower than the average value of $1,575 MBF reported for black cherry in the Allegheny region during winter 2003–2004 (New York State 2003, p. 8). Many variables influence the value received for sawlogs, and certainly in this case the difficulties associated with the need to work in wind damage stands and perceived defects because of delayed salvage substantially reduced stumpage value.

Discussion

The July storm was accompanied by severe thunderstorms, downbursts, and an F1 tornado. This system was described as a mesoscale convective vortex that produced a series of spiral-like bands, which gave rise to violent downbursts of intense wind (J.W. Hazel, USDA Northeast Area State and Private Forestry, pers. comm., Morgantown, WV, Oct. 16, 2003). Approximately 9.3 cm of rain fell in a 24-hour period (USDA Forest Service 2010) saturating the soil and presumably resulting in reduced soil cohesion and shear strength of root systems (Schaetzl et al. 1989). Patches of trees in exposed topographic locations, in areas of excessive moisture (Evans et al. 2007), and in dominant/codominant crown positions were especially vulnerable to blowdown. Small, relatively root-firm black cherry trees snapped below the crown. Cherry with infirm root systems were partially blown over (incomplete fall), were incompletely uprooted (hinge type of root tear), or were completely felled leaving a vertical root plate (for illustrations, see Ulanova 2000). The type of blowdown influenced the likelihood of epicormic branching, which in turn reflected host suitability and susceptibility to wood-boring insects.

The temporal activity of both adult ambrosia beetles and adult peach bark beetle at the Kane Experimental Forest relative to the timing of the windstorm event also determined, in part, the extent of damage to both wind-thrown and healthy black cherry trees. Peach bark beetle adults emerged and moved to brood material (e.g., black cherry slash, stressed trees, and dying branches) by late May in 2004 and 2006, and the major portion of this movement occurred by the end of the first week in June during 2005. In 2004 and 2005, a second smaller emergence occurred beginning in mid-July. A small amount of adult activity extended into mid-October during 2004. Several circumstances and elements of peach bark beetle biology explain this delayed emergence. First, climatic events produce variability in both the time of bark beetle oviposition and the rate of larval development (Bentz et al. 1991). Second, after emergence from the overwintering galleries in the spring, peach bark beetle adults may either reenter the tree from which they emerged or seek an adjacent tree to feed before searching for appropriate brood material (Gossard 1913). In addition, some females may excavate a second brood gallery during a single growing season (Rexrode 1982), and this generation will complete development later in the season.

Gum spot density and associated damage to the residual stand as a result of overwintering galleries in 2006 was significantly higher ($P = 0.02$) than in 2004 (Table 1), most likely because brood material associated with wind-throw was created in late July 2003, 5–6 weeks after the peak of adult emergence. Brood material created after late summer, especially for trees whose root systems remained partially buried in the soil, which was common with the wind-throw at the Kane Experimental Forest, probably remained suitable for breeding the following summer (Rexrode and Smith 1990). Although we did not quantify the abundance of gum in 2005, when final measurements were made in 2006 1-year-old gum was evident on some trees. The mere presence of gum on cherry bark or associated internally with growth rings can remove an otherwise suitable log from veneer grade (Wiedenbeck et al. 2004).

Similarly, the pattern of adult activity displayed by *X. saxeseni* indicates why damage to wind-thrown black cherry by this ambrosia beetle was limited during the year of the storm. Ambrosia beetles were not retained from ethanol-baited traps until 2005 so we do not know what the relative abundance of this insect was during the previous year. Large numbers were captured for each of 2 years after the storm (Figure 5), and in 2005 92% and in 2006 94% of them were captured by the last week in June. In view of the fact that the storm occurred in late July 2003, it is probable that a majority of the beetle population that year was not able to use wind-thrown cherry for reproduction. This species has a wide distribution (Wood 1982) and is exotic to North America (Mattson et al. 1994). It is one of the most abundant species of ambrosia beetle captured in eastern broad-leaved forests (e.g., Oliver and Mannion 2001, Coyle et al. 2005). It has several generations per year in the southeastern United States (Solomon 1995) and a single generation per year in Tennessee (Oliver and Mannion 2001). As in the case of peach bark beetle, however, a small number of adults periodically emerge in mid-summer through early winter (Oliver and Mannion 2001).

As mentioned above, the average depth of its galleries and accompanying stain in wind-thrown black cherry was approximately 1 cm, but occasionally galleries penetrated as deep as 4 cm and may reach a depth of 7 cm in some hosts (Solomon 1995). The potential for value loss in black cherry destined for veneer is substantial. The impact of ambrosia beetle damage to wind-thrown logs used for lumber, however, probably would have been minimal for 1 year after a storm, because most of this insect damage would be eliminated when slabs are removed during processing.

Of the three most abundant species of ambrosia beetles with broad-leaved hosts that were trapped at the Kane Experimental Forest, only *X. saxeseni* was reared from wind-thrown black cherry. It has been recovered from a variety of tree species known as "stone fruits," but this is the first record specifically identifying *P. serotina* as a host. Both *X. politus* and *A. sayi* are known to breed in several species of eastern hardwoods (Solomon 1995). The most abundant ambrosia beetle trapped in 2005 and 2006 was *A. sayi*. The number of beetles/trap/week significantly increased in 2006 compared with that in 2005. Bright (1968) noted eight genera of broad-leaved trees as hosts for this species. It was most commonly reared from subcanopy *A. saccharum* Marsh. and *A. rubrum* L. in Michigan (Hazen and Roeper 1980). Both of these species at the Kane Experimental Forest, especially the latter on very wet sites, were involved in the blowdown.

Emergence of *S. imitans* in northwestern Pennsylvania began in late May and peeked by mid to late June (DiGirolomo et al. 2011). Our study did not address adult longevity for this insect, but work on three other species in the genus indicated adult longevity averaged 40–50 days (Brooks 1915, 1920, Peterson 1947). It seems probable, therefore, that by late July or early August 2003 some wind-thrown black cherry was infested by *S. imitans*, although we did not see much evidence of borer damage that year. Wind-thrown black cherry continued to provide a suitable habitat for the beetle in 2004–2005, especially trees that remained off the ground with epicormic branches that died recently (i.e., possessed dry leaves) or were dying (foliage present but wilting) (DiGirolomo et al. 2011).

Veneer-quality logs are a rare find in eastern hardwood forests where $<1\%$ of the resource meets qualifications (Alderman et al. 2010). If the wind-thrown black cherry at the Kane Experimental Forest had been salvaged immediately after the event of July 2003, however, it is likely that some of the logs would have qualified for veneer. Many conditions must be satisfied before this standard can be met (Wiedenbeck et al. 2004). It is probable that damage by wood-boring insects would not have been a major issue that year. A majority of damage to residual cherry by peach bark beetles and physical damage and stain in boles of wind-thrown trees caused by *S. imitans* would not have occurred until 2004.

Most forest owners are aware that damaged or stressed trees will eventually deteriorate due to the combined activity of fungi and insects. What often is not considered in the decision of whether or when to salvage, however, is the timing of the disturbance event relative to the biology of organisms that are likely to attack tree species of interest, the type of disturbance event, and the ultimate product or products to be derived from them.

Management Recommendations

In the situation, we investigated many wind-thrown black cherries that were not completely up-rooted and remained alive for 1–2 years as evidenced by the abundance of epicormic branches. This provided a continuing resource necessary to maintain high populations of wood-inhabiting insects. *S. imitans* did not heavily infest this material until 2–3 years later (DiGirolomo et al. 2011). Adults of *X. saxeseni* were not sorted from trap catches in 2004. Like peach bark beetle, however, this species could not fully respond to the wind-thrown brood material until 2004 because emergence in 2003 peaked before the storm. Delaying salvage for 6–7 months would have made little difference in terms of the extent of insect-caused degrade to residual or wind-thrown cherry, and this damage would have been minimal thereafter if salvage had taken place before spring 2004. Timely salvage will minimize damage by *S. imitans* and make it possible to recover maximum economic value from wind-thrown black cherry. Sanitation could have been accomplished in 2003 by salvaging logs that year and, at the same time, by reducing slash to small pieces to accelerate drying. Slash with dry inner bark is not a good habitat for peach bark beetle.

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