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Emergence of Buprestidae, Cerambycidae, and Scolytinae (Coleoptera) from Mountain Pine Beetle-Killed and Fire-Killed Ponderosa Pines in the Black Hills, South Dakota, USA

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Abstract

Wood borers (Coleoptera: Cerambycidae and Buprestidae) and bark beetles (Coleoptera: Curculionidae) infest ponderosa pines, *Pinus ponderosa* P. Lawson and C. Lawson, killed by mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, and fire. No data is available comparing wood borer and bark beetle densities or species guilds associated with MPB-killed or fire-killed trees from the Black Hills of South Dakota, USA. We compared species assemblages of wood borers (Cerambycidae and Buprestidae) and bark beetles (*Dendroctonus* spp. and *Ips* spp. (Coleoptera: Curculionidae)) emerging from bolts collected from trees that had been killed by MPB or fire one or two years prior to harvesting. Significantly more wood borers emerged from bolts of fire-killed trees than from bolts of MPB-killed trees. Wood borer density in fire-killed trees was 13.8 per m^2, compared to 4.4 per m^2 in MPB-killed trees. Six wood borer species, *Acanthocinus obliquus* (LeConte), *Buprestis consularis* Gory, *Chrysobothris* sp., *Melanophila acuminata* (De Geer), *Monochamus clamator* LeConte, and *Phaenops gentilis* (LeConte), emerged from fire-killed tree bolts. Four species of wood borers, *A. obliquus, Rhagium inquisitor* (L.), *Tetropium cinnamopterum* Kirby, and *Xylotrechus longitarsis* Casey, emerged from MPB-killed tree bolts. *Acanthocinus obliquus* was the only species that emerged from both MPB-killed and fire-killed tree bolts. The bark beetles *D. ponderosae*, *Dendroctonus valens* LeConte, *Ips knausi* Swaine, and *Ips pini* (Say) emerged from one-year-old, MPB-killed trees, while *I. pini* was the only species that emerged from a fire-killed tree.

Key Words: wood borers, bark beetles, metallic wood-boring beetles, longhorn beetles, *Dendroctonus ponderosae*

In Memory of Sheryl L. Costello.
Student and colleague but above all friend.
She passed 3 July 2011, while passionately
enjoying adventure in the outdoors.

Many coniferous wood borers in the Buprestidae (metallic wood-boring beetles) and Cerambycidae (longhorn beetles) and Curculionidae: Scolytinae (bark beetles) attack trees that are stressed or dying from agents such as diseases, bark beetles, or fire. Different species arrive at different times after a tree is stressed or killed, likely due to changes in chemical composition of chemical volatiles such as ethanol and monoterpenes produced by trees, that influence host selection (Linsley 1961; Ikeda *et al*. 1980; Kelsey and Joseph 2003) or synchronization between beetle seasonal activity and tree condition. Once a suitable host is selected, oviposition occurs and larvae feed under the bark on the phloem, outer xylem (sapwood), or both and sometimes tunnel deep into the xylem.

Large populations of wood-boring beetles and bark beetles are often present in forests recently burned, and several studies have demonstrated the attraction of wood borers to fire-injured or killed trees (Gardiner 1957; Zhang *et al*. 1993; Ryan and Amman 1994; Schutz *et al*. 1999; Suckling *et al*. 2001). For example, insects in the genus *Melanophila* Eschscholtz (Buprestidae) are found immediately invading trees after a wildland fire. *Melanophila* spp. possess specific heat-sensing organs on their metathorax that can detect infrared radiation (Schmitz and Bleckmann 1998). It appears that several wood borers have adapted to locate suitable host trees by sensing heat resulting from fires. Wood borers are also associated with trees infested or killed by bark beetles. For instance, passive window pane traps placed on trees attacked by southern pine beetle, *Dendroctonus frontalis* Zimmermann, collected more cerambycids than non-attacked trees (Dodds and Stephen 2002).

While it is known that wood borers infest ponderosa pines, *Pinus ponderosa* P. Lawson and C. Lawson (Pinaceae), killed by either mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, or by fire, data is lacking on whether species composition emergence differs between MPB-killed and fire-killed trees. The objective of this study was to compare wood borer and *Dendroctonus* spp. and *Ips* spp. bark beetles assemblages emerging from MPB-killed and fire-killed ponderosa pine trees one and two years after tree mortality.

Material and Methods

Ten MPB-killed and ten fire-killed (100% foliage consumption) ponderosa pine trees were cut on 15–16 May 2004 in the Black Hills, SD. MPB-killed trees were removed from Bear Mountain (13 T 0598918, 4855319), an area with several years of previous beetle-caused mortality; these trees had been killed either one year (four trees) or two years (six trees) prior to cutting. One-year beetle-killed trees were faders (turning in color from green to red-orange) yet with all foliage still present, while two-year beetle-killed trees still had some red foliage still attached. Five fire-killed trees were cut from the Red Point Fire (13 T 0579238, 4828821) and five trees cut from the Battle Creek Fire (13 T 0608116, 4891085), located 29 km to the southeast and 32 km east, respectively, of the Bear Mountain site. The Red Point fire burned 24–30 July 2003 and the Battle Creek fire burned from 15–25 August 2002, providing trees that had been killed one and two years prior to cutting, respectively, similar to our sample of MPB-killed trees. Average height (± SE) of MPB-killed and fire-killed trees sampled was 15.4 ± 0.9 m and 13.7 ± 0.7 m, respectively. Average diameter (± SE) at breast height of MPB-killed and fire-killed trees sampled was 25.5 ± 0.9 cm and 25.0 ± 0.6 cm, respectively.

One 0.75-m bolt section was cut from each tree at 1.37 m above the forest floor. In order to fit bolts in rearing cages, the diameter could be no greater than 30 cm. The ends of each bolt were covered with paraffin wax to reduce desiccation. Bolts were placed in 77×30×32-cm plastic box rearing cages with 10×10-cm screen vents. While it is possible that some small bark beetles may have escaped the rearing cages, we did not notice this when cages were checked. Cages were placed in a shade cloth-covered greenhouse and kept at 20 ± 2°C. Cages were checked for emerging insects every two weeks from 11 June through 27 August 2004, then monthly until January 2006, and periodically after that until 30 March 2007. Voucher specimens are deposited in the insect collection at the Rocky Mountain Research Station, Fort Collins, CO.

Like most western coniferous forests, the Black Hills exhibit a diversity of forest structure. However, pure ponderosa pine forest, from which our study trees were collected, is the dominant type in the Black Hills, comprising 85% of the forest land area. Ponderosa pine comprises 76% of all trees, with 84% being less than 23 cm dbh and 16% being 23 cm or greater. Mean tree diameter sizes follow a typical diameter distribution dominated by small trees (Deblander 2002). Epidemic populations of MPB have been causing extensive ponderosa pine mortality across the Black Hills (USDA Forest Service 2011) and a number of large fires have also occurred (Costello *et al*. 2008, 2011). These major disturbances have resulted in large populations of wood borers across the Black Hills landscape. Similar stand structures and extensive wood borer populations across the landscape suggest that our study sites were likely exposed to similar insect populations in abundance and diversity. In addition, as trees collected from the different sites were of comparable dbh and height, they were likely suitable hosts for similar wood borer guilds.

We fit the data to a negative binomial distribution. Differences in the number of insects emerging from one- and two-year MPB-killed and one- and two-year fire-killed tree bolts were examined with a t-test (SAS/STAT®). To compare the number of insects emerging from fire-killed tree bolts with the number of insects emerging from MPB-killed tree bolts across years since mortality, we used an orthogonal contrast. To compare insect emergence by killing agent and time since mortality, we used a Tukey-Kramer multiple comparisons test. Means are accompanied by their standard error. Data analysis was generated using SAS software (SAS Institute Inc., Cary, NC).

Results

A total of 143 wood borers were collected from our study logs during the three-year monitoring period, including 16 metallic wood-boring beetles and 127 longhorn beetles. In addition, 507 bark beetles were collected. More wood borers, including all metallic wood borers, emerged from fire-killed tree bolts (16 buprestids and 94 cerambycids) than from MPB-killed tree bolts (0 buprestids, 33 cerambcyids). For the duration of the study, there were significantly ($P<0.01$) more beetles emerging

Table 1. Species and number of Buprestidae, Cerambycidae, *Dendroctonus* spp., and *Ips* spp. collected from *Pinus ponderosae* bolts in emergence cages, from trees killed by *Dendroctonus ponderosae* (MPB) or by fire, 11 June 2004 to 30 March 2007.

	MPB-killed		Fire-killed	
Species	1-year-old	2-year-old	1-year-old	2-year-old
Buprestidae				
Buprestis consularis Gory	0	0	0	1
Chrysobothris sp.	0	0	0	1
Melanophila acuminata (De Geer)	0	0	4	0
Phaenops gentilis (LeConte)	0	0	0	10
Cerambycidae				
Acanthocinus obliquus (LeConte)	0	3	18	8
Monochamus clamator LeConte, males	0	0	22	14
Monochamus clamator LeConte, females	0	0	23	9
Rhagium inquisitor (L.)	1	0	0	0
Tetropium cinnamopterum Kirby	0	5	0	0
Xylotrechus longitarsis Casey	0	24	0	0
Scolytinae				
Dendroctonus ponderosae Hopkins	265	0	0	0
Dendroctonus valens LeConte	1	0	0	0
Ips knausi Swaine	25	0	0	0
Ips pini (Say)	37	0	179	0

from fire-killed tree bolts (mean = 11.0±2.0) compared to MPB-killed trees (mean = 3.3±1.6).

Six wood borer species, *Buprestis consularis* Gory, *Chrysobothris* sp., *Melanophila acuminata* (De Geer), *Phaenops gentilis* (LeConte), *Acanthocinus obliquus* (LeConte), and *Monochamus clamator* LeConte, emerged from fire-killed tree bolts, with *M. clamator* the most common (Table 1). Wood borers emerged from every log obtained from fire-killed trees. Individual fire-killed tree bolts had between two and 19 wood borers emerging per bolt and their densities ranged from 2.8 to 23.6 per m^2 of bark surface. The average number of wood borers emerging from tree bolts from the one-year-old fire compared to the two-year-old fire (13.4±2.8 and 8.6±2.6, respectively) were not significantly different (t-value = 0.97, $P = 0.77$).

Four species of wood borers, *A. obliquus, Rhagium inquisitor* (L.), *Tetropium cinnamopterum* Kirby, and *Xylotrechus longitarsis* Casey, emerged from MPB-killed tree bolts (Table 1), but only one specimen and species (*R. inquisitor*) emerged from one-year-old MPB-killed tree bolts. Beetle-killed tree bolts had from zero to 14 wood borers emerged with densities ranging from zero to 19.9 per m^2. Wood borers emerged from seven out of the ten MPB-killed tree bolts. Wood borer emergences from the one- and two-year- old MPB-killed trees (0.3±0.3 and 5.3±2.3), respectively) were significantly different from each other (t-value = −2.78, $P < 0.06$).

The only species to emerge from both fire-killed tree bolts and MPB-killed tree bolts was *A. obliquus*. The remainder of the species, five for fire-killed tree bolts and three for MPB-killed tree bolts, only emerged from their respective tree type. When numbers of wood borers that emerged from bolts were compared across all four treatments (*i.e.*, damage type + years since death), there was no difference among the one- and two-year fire-killed tree bolts and two-year MPB-killed tree bolts, but emergence from fire-killed tree bolts was different from emergence from one-year MPB-killed tree bolts (F-value = 5.01, df = 16, $P < 0.01$) (Fig. 1).

The bark beetles *D. ponderosae, Dendroctonus valens* LeConte, *Ips knausi* Swaine, and *Ips pini* (Say) were collected only from one-year-old MPB-killed tree bolts (Table 1). No *Dendroctonus* spp. were collected from any fire-killed tree bolts. One bolt section from the one-year-old fire had 179 *I. pini* emerge.

Discussion

In ponderosa pine in the Black Hills of South Dakota, bolts from fire-killed trees produced more wood borer species and individuals per m^2 surface area than did bolts from trees that had been killed by the mountain pine beetle. Wood borers emerging from fire-killed tree bolts comprised 77% of all wood borers compared to 23% emerging from MPB-killed tree bolts. The mean number of wood borers per m^2 surface area emerging from one-year-old fire-killed tree bolts was 13.4 which is consistent with wood borer incidence reported by Costello *et al*. (2011) from one-year-old fire-killed trees with complete foliage scorch ($23/m^2$)

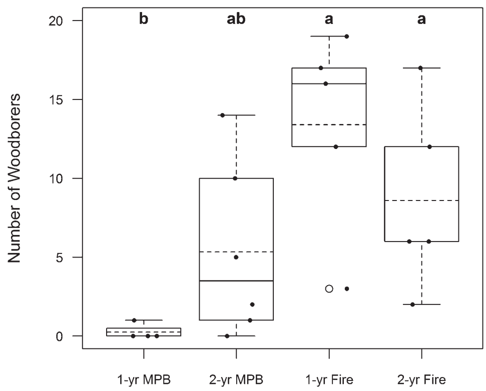

Fig. 1. Box plot showing the number of wood borers collected from bolts of one-year-old mountain pine beetle (MPB)-killed trees (n = 4), two-year- old MPB-killed trees (n = 6), one-year-old fire-killed trees (n = 5), and two-year-old fire-killed trees (n = 5). Letters above the bars represent means which if followed by the same letter are not significantly different ($p \leq 0.05$, Tukey-Kramer multiple comparisons test). The solid and dashed lines within the box represent the median and the mean, respectively. Box ends represent the first and third quartiles. The lower and upper horizontal lines above and below the box are at the last points less than 1.5 times the interquartile range from the first and third quartiles. Points represent the actual data, and the circle for the 1-yr fire indicates that the point next to it is an outlier.

or consumption ($17/m^2$). The numbers reported by Costello *et al.* (2011) included egg niches, larvae, and borer perforations in the xylem which may have resulted in somewhat higher numbers. The greater abundance in fire-killed trees can have important implications for wildlife species that feed on wood borers. Wood borer larvae make up a large proportion of the diet of woodpeckers, such as the black-backed, *Picoides arcticus* Swainson, and the three-toed, *Picoides tridactylus* (L.), in the Black Hills (Beal 1911; Pechacek and Kristin 2004). Several studies have quantified a post-fire increase in these woodpecker species (Taylor and Barmore 1980; Murphy and Lehnausen 1998; Hoyt and Hannon 2002; Saab *et al.* 2007). The greater numbers of wood borers available in fire-killed trees is likely a driving factor in the previously noted observations of increasing woodpecker densities in post-fire areas.

During this experiment, we collected four longhorn beetle species associated with MPB-killed ponderosa pine trees and three longhorn beetle and three metallic wood boring beetle species from the fire-killed trees. The diversity represented by the number of species is comparable with other studies that have examined wood borer diversity emerging from bark beetle-killed trees and from fire-killed trees, although species assemblages were different. During experiments in which wood borers were reared from approximately 400 bolts of loblolly pine, *Pinus taeda* L., killed by the southern pine beetle, *D. frontalis*, six longhorn beetle species were collected (Overgaard 1968; Moser *et al.* 1971). Saint-Germain *et al.* (2004) reported five species of longhorn beetles and two species of metallic wood boring beetles emerging from 84 logs of fire-killed black spruce, *Picea mariana* (Mill.) B.S.P. (Pinaceae), in Ontario, Canada. A larger sample size in our study may have resulted in an increase in species diversity.

Three of the four species emerging from MPB-killed tree bolts in our study were unique to these trees. Similarly, five of the six species emerging from fire-killed tree bolts were unique to these trees. Only one species, *A. obliquus*, emerged from both MPB-killed and fire-killed tree bolts. Flight data from the Black Hills indicate that different wood borer species fly during different periods of the summer (Costello *et al.* 2008). The observed diversity and species composition could be a reflection of the timing of MPB attacks or fire as it relates to time of insect flight or differential host condition preference by the insect, or both. For example, Ross (1960) indicated that the number of wood borers attacking a fire-injured white spruce, *Picea glauca* (Moench) Vos, tree depends on the level of bole damage.

No MPBs emerged from the fire-killed tree bolts, although MPB outbreaks were abundant near the fires. Our results agree with other studies that demonstrated no preference of MPB to attack fire-damaged ponderosa pine or lodgepole pine, *Pinus contorta* var. *latifolia* Engelm. (Elkin and Reid 2004; Six and Skov 2009). Less than 5% of fire-injured lodgepole pines were attacked by MPB after the 1988 Greater Yellowstone Area fires (Ryan and Amman 1994; Rasmussen *et al.* 1996). However, recent studies in California found that fire damage increased MPB-caused tree mortality of ponderosa pine (Fettig *et al.* 2008, 2010a, 2010b). The relationship between fire damage and MPB attack has not been examined in the Black Hills of South Dakota and Wyoming.

Our results represent the guild of wood borers that attacked the dead trees one and two years post-mortality. Both MPB-killed and fire-killed trees may subsequently be attacked by wood borers past the stage at which we collected our sample bolts as the trees continue to deteriorate. It is possible that some species of wood borers may not have been able to complete development and emerge from the sample logs due to the environment created by the rearing boxes. The examination of long term emergence of insects from tree sections of dead trees is laborious and resource-demanding, particularly in space utilization. We acknowledge that various factors likely influenced our findings. Our sampling was limited due to space constraints, and there are potentially confounding effects associated with year and location of fire-killed trees. Nevertheless, several interesting observations are notable. Wood borer emergence from fire-killed trees was higher than from MPB-killed trees, and the species composition was different between the two types of dead trees. Factors that may contribute to these differences are unknown, and further investigation could yield useful information for managers in strategies to optimize food availability for insectivorous fauna and elucidate the relationships between species diversity in MPB-killed and fire-killed trees.

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