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SHORT COMMUNICATION

Impacts of prescribed fire on saproxylic beetles in loblolly pine logs

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Abstract. 1. Studies addressing the immediate impacts of fire on forest arthropod communities and their implications for conservation are few, particularly for species within dead wood. To investigate the effects of fire on saproxylic beetles (Coleoptera), we randomly assigned large-diameter loblolly pine (*Pinus taeda* L.) logs to a forest scheduled for a prescribed burn (i.e. a low-intensity surface fire) or to an adjacent unburned forest in Georgia, USA.

2. Beginning 5 days after the fire, the logs were placed in rearing bags to capture emerging beetles. In total, 3457 individuals from 80 taxa were collected.

3. While more than twice as many individuals were collected from unburned logs than from burned logs, none of the 21 most abundant (i.e. ≥10 individuals) taxa, with the exception of *Dioedus punctatus* LeConte (Tenebrionidae), was absent from burned logs. Furthermore, similar total numbers of species were collected from unburned (62) and burned (60) logs.

4. *Diplocoelus rudis* (LeConte), *Cathartosilvanus imbellis* (LeConte) and *Endeitoma dentata* (Horn) were considerably more common in burned logs, suggesting rapid colonisation following the fire.

5. There were no differences in community composition between treatments based on analyses of similarities (ANOSIM) using presence–absence data. Community composition, however, did differ between treatments based on ANOSIM using log-transformed abundance data, but only for logs taken from a tree largely covered by bark, suggesting that the subcortical fauna is more strongly impacted.

6. These results indicate that saproxylic beetles within large-diameter loblolly pine logs can, for the most part, tolerate low-intensity fires and need not recolonise burned sites.

Key words. Coarse woody debris, dispersal, disturbance, fire adapted, forest management, heat tolerance, pyrophilous, xylobiont.

Introduction

Fire has various immediate, short-term and long-term impacts on forest arthropod communities. The most obvious immediate impact is direct mortality, but the extent to which arthropods are eliminated from burned substrates is not clear. While several studies have shown that most ground-dwelling invertebrates subjected to fires are eliminated unless adequately insulated by the soil (Paquin & Coderre, 1997; Wikars & Schimmel, 2001), similar efforts are lacking for arthropods in dead wood. In contrast, many studies have followed changes in arthropod communities following fires. Although most of these focused on the flying or ground-dwelling fauna (Heyward & Tissot, 1936; Buffington, 1967; Abbott, 1984; Holliday, 1991; Muona & Rutanen, 1994; Buddle *et al*., 2000; Niwa & Peck, 2002; Hanula & Wade, 2003; Saint-Germain *et al*., 2004a; Toivanen & Kotiaho, 2007a,b; Hyvärinen *et al*., 2009; Hanula *et al*., 2009), several targeted arthropods in dead wood (Wikars, 2002; Gibb *et al*., 2006; Johansson *et al*., 2006, 2007a,b) or in fire-killed (Gardiner, 1957;

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Ross, 1960; Saint-Germain *et al*., 2004b) or fire-damaged (Furniss, 1965; Dixon *et al*., 1982) trees.

The severity, frequency and seasonality of fires vary widely among forests (Bond & Keeley, 2005) and arthropod communities adapt accordingly. In frequently burned forests, many species are pyrophilous, meaning they depend on burned substrates or are strongly favored by conditions created by fire, such as increased sun exposure (Evans, 1966; Jonsell *et al*., 1998; Wikars, 2002). Moreover, many species inhabiting such forests are highly mobile and capable of avoiding flames while others are relatively heat-tolerant (Paquin & Coderre, 1997; Wikars & Schimmel, 2001). Although strong dispersal abilities may also be important to recolonise burned sites following a fire, the degree to which recolonisation is necessary depends on the extent to which arthropods are eliminated by fire. This question may have important conservation implications, especially for the saproxylic (i.e. dependent on dead or dying wood) fauna which has become highly threatened in many developed countries (Siitonen, 2001; Grove, 2002). Saproxylic species with poor dispersal abilities are among the most threatened (Nilsson & Baranowski, 1997; Ranius, 2006). If fires largely eliminate arthropods from dead wood, thereby selecting for strong dispersal abilities, saproxylic communities in regularly burned forests may be more resilient to changes in the abundance, variety and connectivity of resources than those in more stable habitats. This possibility was raised by Ulyshen and Hanula (2009b) who found large-scale manipulations of dead wood to have little effect on saproxylic beetles or ground-dwelling arthropods in managed loblolly pine (*Pinus taeda* L.) forests of the southeastern United States.

The objective of this project was to investigate the immediate impacts of a prescribed fire on saproxylic beetles in a loblolly pine forest in the southeastern United States. Prescribed fires are regularly implemented in managed pine forests throughout this region to mimic the frequent (i.e. every 2–8 years) low-intensity surface burns to which these ecosystems are adapted (Outcalt, 2008). We hypothesised that fire would eliminate many species and drastically reduce the abundance of others, thereby necessitating recolonisation of burned sites.

Methods

This project took place in a 40- to 50-year-old managed loblolly pine-dominated forest within B.F. Grant Forest, Putnam County, Georgia, USA (33°21.1, −83°29.3). In April 2009, 10 short logs, 0.5 m in length, were removed from each of the three downed loblolly pine trees. The trees differed in diameter and bark area as follows, as calculated from the 10 logs removed from each: tree 1 (0.20 ± 0.01 m and 0.07 ± 0.04 m^2), tree 2 (0.33 ± 0.00 m and 0.31 ± 0.04 m^2) and tree 3 (0.33 ± 0.00 m and 0.02 ± 0.01 m^2). Bark area was calculated for each log by multiplying its surface area by the percentage of its surface covered by bark (a visual estimate). Exactly, how long each tree had been dead at the time of sampling is not known, but trees 1 and 2 were relatively young (~1 to 2 years) with large amounts of bark remaining, whereas tree 3 was older (~3 to 4 years) with very little bark remaining. Trees 1 and 2 belonged to FIA decay class 1, whereas tree 3 to decay class 2 (Woodall & Williams, 2005). Half of the logs from each tree were randomly chosen to be placed in a forest scheduled for a prescribed fire. The remaining logs were placed in an adjacent unburned forest. One week before the prescribed fire, three transects, spaced 15 m apart, were established in the forest to be burned, each receiving five randomly selected logs spaced 15 m apart. The fire burned relatively evenly across the forest floor and none of the logs escaped the fire (Fig. 1). Five days after the fire, the logs from both the burned and unburned forest, 30 in total, were transferred from the field to the laboratory where each log was placed in an individual rearing bag (for methodology, see Ulyshen & Hanula, 2009a). After allowing 5 months for emergence, beetles were identified to species when possible, otherwise to morphospecies. Voucher specimens of the most common (≥10 individuals) taxa have been deposited in the Georgia Museum of Natural History, Athens, Georgia, USA.

As only three trees were used in this project, each differing in diameter and age, statistical tests could not be used to compare the abundance and species richness of beetles between treatments. Analyses of similarities (ANOSIM), however, were performed separately for each tree using PAST (Hammer *et al*., 2001) to determine the extent to which the burn treatment affected community composition. These analyses were performed on both presence–absence data (Jaccard distance measure) and $\log(x + 1)$-transformed abundance data (Bray–Curtis distance measure) with 10 000 permutations.

Results and discussion

In total, 3457 adult individuals from 80 taxa were collected. Logs taken from tree 2 yielded more individuals and taxa (2676 and 59) than those taken from tree 1 (434 and 25) or tree 3 (347 and 44). Although over twice as many individuals overall were collected from unburned logs (2349) than from burned logs (1108), none of the 21 most abundant (i.e. ≥10 individuals) taxa, with the exception of *Dioedus punctatus* LeConte (Tenebrionidae), was absent from burned logs (Table 1). Furthermore, about the

Fig. 1. A log following the prescribed burn.

Table 1. Most common (≥10 individuals) beetle taxa collected, in decreasing order of abundance, from loblolly pine logs that were or were not subjected to a prescribed burn.

Family	Species	Burned	Unburned	Total
Curculionidae	*Cossonus* spp.	547	1130	1677
Curculionidae	*Stenoscelis andersoni* Buchanan	118	609	727
Curculionidae	*Rhyncolus* spp.	71	82	153
Zopheridae	*Pycnomerus haematodes* (Fabricius)	47	106	153
Ciidae	spp.	21	100	121
Oedemeridae	*Oxycopis thoracica* (Fabricius)	23	60	83
Cerylonidae	*Philothermus glabriculus* LeConte	32	32	64
Carabidae	*Mioptachys flavicauda* Say	22	30	52
Biphyllidae	*Diplocoelus rudis* (LeConte)	44	7	51
Elateridae	*Drapetes quadripustulatus* Bonvouloir	17	21	38
Carabidae	*Tachyta nana inornata* (Say)	13	12	25
Silvanidae	*Cathartosilvanus imbellis* (LeConte)	22	1	23
Staphylindae	Tachyporinae spp.	6	15	21
Cerambycidae	*Xylotrechus sagittatus* (Germar)	7	8	15
Colydiidae	*Endeitoma dentata* (Horn)	14	1	15
Tenebrionidae	*Hymenorus* spp.	11	2	13
Cerambycidae	*Trigonarthris minnesotana* (Casey)	5	6	11
Tenebrionidae	*Dioedus punctatus* LeConte	0	11	11
Elateridae	*Lacon impressicollis* (Say)	4	7	11
Aderidae	*Pseudariotus notatus* (LeConte)	4	6	10
Tenebrionidae	*Platydema flavipes* (Fabricius)	9	1	10

same number of taxa overall were collected from unburned (62) and burned (60) logs. Based on ANOSIM, using presence–absence data, the burn treatment had no significant effect on community composition for tree 1 ($R = 0.22$, $P = 0.10$), tree 2 ($R = 0.09$, $P = 0.21$) or tree 3 ($R = -0.15$, $P = 0.83$). While there were also no significant differences in community composition using $\log(x + 1)$-transformed abundance data for trees 1 ($R = 0.11$, $P = 0.24$) and 3 ($R = -0.11$, $P = 0.77$), there was a difference for tree 2 ($R = 0.28$, $P = 0.02$). This difference may be attributed to the fact that the log sections removed from tree 2 had much more bark than those removed from trees 1 and 3 considering that beetles living within the subcortical space would likely be more exposed and vulnerable to fires than those living within the wood. A more intensive sampling effort will be needed to properly test this idea.

The results from this study suggest that the frequent low-intensity surface burns typical of southeastern pine forests have little immediate impact on the community composition of saproxylic beetles in large-diameter loblolly pine logs. We must therefore reject our hypothesis that saproxylic beetles need to recolonise sites following fires. In fact, because short sections of wood removed from downed trees were used in this study, saproxylic beetles within intact logs are likely even less affected (i.e. more sheltered) by fire. It should be mentioned, however, that because the logs were removed 5 days after the burn, some colonisation may have already occurred, particularly given that Wikars and Schimmel (2001) documented colonisation of burned soil by fire-favored species in < 24 h. Several species [e.g. *Diplocoelus rudis* (LeConte), *Cathartosilvanus imbellis* (LeConte) and *Endeitoma dentata* (Horn)] were considerably more common in burned logs than unburned logs (Table 1). While these results may represent rapid colonisation by fire-favored species, further research is needed in southeastern pine forests to determine which species are indeed pyrophilous.

That saproxylic beetles were not eliminated from burned wood in this study is perhaps not surprising considering the fire was relatively low-intensity. These organisms would no doubt be more strongly impacted by the high-intensity fires characteristic of other forest types. The extent to which saproxylic beetles in frequently burned forests are more heat-tolerant than those in more stable habitats is not known. This seems likely, however, particularly for species in southeastern pine forests, and other forests with relatively open canopies, as these organisms must also cope with the temperature extremes associated with sun exposure (Craighead, 1920; Graham, 1924). It would be interesting to test whether saproxylic beetles in logs taken from closed-canopy and rarely burned forests are more susceptible to fire.

Although fire did not immediately eliminate species from wood, it may affect habitats and resources such that some species are repelled by and others attracted to burned wood. For example, in Sweden, Wikars (2002) compared the succession of beetles and other insects in burned and unburned birch and spruce logs for 2 years following a fire (sampling began 1 year after the fire). Most of the taxa negatively affected by the fire were bark beetles (perhaps due to the drying effects of fire or to the possibility that fungal species promoted by fire may hamper growth of bark beetle fungal symbionts), being nearly 10 times less frequent in burned logs than in unburned logs (Wikars, 2002). In contrast, all taxa positively affected by fire were mycophagous, possibly benefiting from the fact that ascomycete fungi were more common in burned logs than in unburned logs. Therefore, while fire may not select for strong dispersal abilities by immediately eliminating arthropods from dead wood, it may nonetheless do so by affecting habitat quality.

The results from this preliminary project are limited, speaking only to the beetle communities inhabiting relatively large-diameter loblolly pine logs taken from three individual trees in a single-managed forest. Future work should consider a wider range of forest types, management histories, tree species, wood diameters, decay classes, fire intensities, wood postures, seasons, etc. Two questions are of particular interest. First, although many saproxylic beetles, including many red-listed species, have been shown to be strongly associated with fires in boreal forests (e.g. Jonsell *et al*., 1998; Saint-Germain *et al*., 2004b; Hyvärinen *et al*., 2006), the extent to which saproxylic beetles in other regions require fire is not known. Second, it is not known whether saproxylic beetles in regularly burned forests are generally stronger dispersers and are therefore more resilient to manipulations of dead wood than those in more stable habitats.

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References

Abbott, I. (1984) Changes in the abundance and activity of certain soil and litter fauna in the Jarrah Forest of Western Australia after a moderate intensity fire. *Australian Journal of Soil Research*, **22**, 463–469.

Bond, W.J. & Keeley, J.E. (2005) Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology and Evolution*, **20**, 387–394.

Buddle, C.M., Spence, J.R. & Langor, D.W. (2000) Succession of boreal forest spider assemblages following wildfire and harvesting. *Ecography*, **23**, 424–436.

Buffington, J.D. (1967) Soil arthropod populations of the New Jersey pine barrens as affected by fire. *Annals of the Entomological Society of America*, **60**, 530–535.

Craighead, F.C. (1920) Direct sunlight as a factor in forest insect control. *Proceedings of the Entomological Society of Washington*, **22**, 106–108.

Dixon, W.N., Corneil, J.A., Wilkinson, R.C. & Foltz, J.L. (1982) Using stem char to predict mortality and insect infestation of fire-damaged slash pines. *Southern Journal of Applied Forestry*, **6**, 85–88.

Evans, W.G. (1966) Perception of infrared radiation from forest fires by *Melanophila acuminata* DeGeer (Buprestidae, Coleoptera). *Ecology*, **47**, 1061–1065.

Furniss, M.M. (1965) Bark beetle attack in southern Idaho. *Journal of Forestry*, **63**, 8–11.

Gardiner, L.M. (1957) Deterioration of fire-killed pine in Ontario and the causal wood-boring beetles. *Canadian Entomologist*, **89**, 241–263.

Gibb, H., Pettersson, R.B., Hjältén, J., Hilszczański, J., Ball, J.P., Johansson, T., Atlegrim, O. & Danell, K. (2006) Conservation-oriented forestry and early successional saproxylic beetles: responses of functional groups to manipulated dead wood substrates. *Biological Conservation*, **129**, 437–450.

Graham, S.A. (1924) Temperature as a limiting factor in the life of subcortical insects. *Journal of Economic Entomology*, **17**, 377–383.

Grove, S.J. (2002) Saproxylic insect ecology and the sustainable management of forests. *Annual Review of Ecology and Systematics*, **33**, 1–23.

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. (2001) PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, **4**, 9.

Hanula, J.L. & Wade, D.D. (2003) Influence of long-term dormant-season burning and fire exclusion on ground-dwelling arthropod populations in longleaf pine flatwoods ecosystems. *Forest Ecology and Management*, **175**, 163–184.

Hanula, J.L., Wade, D.D., O'Brien, J. & Loeb, S.C. (2009) Ground-dwelling arthropod association with coarse woody debris following long-term dormant season prescribed burning in the longleaf pine flatwoods of north Florida. *Florida Entomologist*, **92**, 229–242.

Heyward, F. & Tissot, A.N. (1936) Some changes in the soil fauna associated with forest fires in the longleaf pine region. *Ecology*, **17**, 659–666.

Holliday, N.J. (1991) Species responses of carabid beetles (Coleoptera: Carabidae) during post-fire regeneration of boreal forest. *Canadian Entomologist*, **123**, 1369–1389.

Hyvärinen, E., Kouki, J. & Martikainen, P. (2006) Fire and green-tree retention in conservation of red-listed and rare dead-wood-dependent beetles in Finnish boreal forests. *Conservation Biology*, **20**, 1711–1719.

Hyvärinen, E., Kouki, J. & Martikainen, P. (2009) Prescribed fires and retention trees help to conserve beetle diversity in managed boreal forests despite their transient negative effects on some beetle groups. *Insect Conservation and Diversity*, **2**, 93–105.

Johansson, T., Gibb, H., Hilszczański, J., Pettersson, R.B., Hjältén, J., Atlegrim, O., Ball, J.P. & Danell, K. (2006) Conservation-oriented manipulations of coarse woody debris affect its value as habitat for spruce-infesting bark and ambrosia beetles (Coleoptera: Scolytinae) in northern Sweden. *Canadian Journal of Forest Research*, **36**, 174–185.

Johansson, T., Gibb, H., Hjältén, J., Pettersson, R.B., Hilszczański, J., Alinvi, O., Ball, J.P. & Danell, K. (2007a) The effects of substrate manipulations and forest management on predators of saproxylic beetles. *Forest Ecology and Management*, **242**, 518–529.

Johansson, T., Hjältén, J., Gibb, H., Hilszczański, J., Stenlid, J., Ball, J.P., Alinvi, O. & Danell, K. (2007b) Variable response of different functional groups of saproxylic beetles to substrate manipulation and forest management: implications for conservation strategies. *Forest Ecology and Management*, **242**, 496–510.

Jonsell, M., Weslien, J. & Ehnström, B. (1998) Substrate requirements of red-listed saproxylic invertebrates in Sweden. *Biodiversity and Conservation*, **7**, 749–764.

Muona, J. & Rutanen, I. (1994) The short-term impact of fire on the beetle fauna in boreal coniferous forest. *Annales Zoologici Fennici*, **31**, 109–121.

Nilsson, S.G. & Baranowski, R. (1997) Habitat predictability and the occurrence of wood beetles in old-growth beech forests. *Ecography*, **20**, 491–498.

Niwa, C.G. & Peck, R.W. (2002) Influence of prescribed fire on carabid beetle (Carabidae) and spider (Araneae) assemblages in forest litter in southwestern Oregon. *Environmental Entomology*, **31**, 785–796.

Outcalt, K.W. (2008) Lightning, fire and longleaf pine: using natural disturbance to guide management. *Forest Ecology and Management*, **255**, 3351–3359.

Paquin, P. & Coderre, D. (1997) Deforestation and fire impact on edaphic insect larvae and other macroarthropods. *Environmental Entomology*, **26**, 21–30.

Ranius, T. (2006) Measuring the dispersal of saproxylic insects: a key characteristic for their conservation. *Population Ecology*, **48**, 177–188.

Ross, D.A. (1960) Damage by long-horned wood borers in fire-killed spruce, central British Columbia. *Forestry Chronicle*, **36**, 355–360.

Saint-Germain, M., Drapeau, P. & Hébert, C. (2004a) Comparison of Coleoptera assemblages from a recently burned and unburned black spruce forests of northeastern North America. *Biological Conservation*, **118**, 583–592.

Saint-Germain, M., Drapeau, P. & Hébert, C. (2004b) Xylophagous insect species composition and patterns of substratum use on fire-killed black spruce in central Quebec. *Canadian Journal of Forest Research*, **34**, 677–685.

Siitonen, J. (2001) Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. *Ecological Bulletins*, **49**, 11–41.

Toivanen, T. & Kotiaho, J.S. (2007a) Mimicking natural disturbances of boreal forests: the effects of controlled burning and creating dead wood on beetle diversity. *Biodiversity and Conservation*, **16**, 3193–3211.

Toivanen, T. & Kotiaho, J.S. (2007b) Burning of logged sites to protect beetles in managed boreal forests. *Conservation Biology*, **21**, 1562–1572.

Ulyshen, M.D. & Hanula, J.L. (2009a) Habitat associations of saproxylic beetles in the southeastern United States: a comparison of forest types, tree species and wood postures. *Forest Ecology and Management*, **257**, 653–664.

Ulyshen, M.D. & Hanula, J.L. (2009b) Responses of arthropods to large-scale manipulations of dead wood in loblolly pine stands in the southeastern United States. *Environmental Entomology*, **38**, 1005–1012.

Wikars, L.-O. (2002) Dependence on fire in wood-living insects: an experiment with burned and unburned spruce and birch logs. *Journal of Insect Conservation*, **6**, 1–12.

Wikars, L.-O. & Schimmel, J. (2001) Immediate effects of fire-severity on soil invertebrates in cut and uncut pine forests. *Forest Ecology and Management*, **141**, 189–200.

Woodall, C. & Williams, M.S. (2005) *Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program*. General Technical Report NC-256. United States Department of Agriculture, Forest Service, North Central Research Station, St. Paul, Minnesota.

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