NOTES

WOODPECKER FORAGE AVAILABILITY IN HABITAT DISTURBANCES OF THE BLACK HILLS—Habitat disturbance events are critical to ecological systems in which some bird species have become specialized. The vegetation community, reduced competition, ability to avoid predators, nest site characteristics, and forage opportunities within a disturbed ecosystem are all aspects that make it desirable for selection by particular species (Svärdson 1949, Cody 1981, Martin 1998). Specifically, avian species rely on the forest conditions created by fire, insects, and disease (Brawn et al. 2001, Hunter et al. 2001, Devictor et al. 2008). In the Black Hills National Forest (BHNF) of South Dakota, two major types of natural disturbances include wildfires and mountain pine beetle (*Dendroctonus ponderosae*; MPB) infestations. Dead trees (snags) created by these disturbances attract a suite of insects and wildlife species. Bark beetles (Family: Curculionidae, Scolytinae) and wood borer beetles (Families: Buprestidae and Cerambycidae) are of particular importance to black-backed woodpeckers (*Picoides arcticus*; BBWO) because they feed almost exclusively on the larvae of these insects (Beal 1911, Murphy and Lehnhausen 1998, Hutto 2006, Bonnot et al. 2008, Bonnot et al. 2009). Black-backed woodpeckers are of key interest to resource management agencies due to their habitat specialization needs and the management activities like wildfire salvage logging and pre-thinning that occur in these disturbance areas (Hutto 1995, 2006). These management activities potentially reduce nest site and food availability for BBWOs and, as a result, they were recently petitioned for protection under the Endangered Species Act (Hanson et al. 2012). Following a fire event or insect infestation, the relative probability of using trees affected by the disturbance increases over surrounding healthy trees (Rota 2013). As a result, we were interested in understanding the food that is available to the woodpeckers following these forest disturbances.

Adult wood borers in the BHNF are typically active from May through September with peak activity and egg-laying occurring in July (Costello et al. 2008). After hatching (9–14 days), wood borer larvae feed within tree phloem but then excavate into the xylem to overwinter (Wilson 1962) from 1 to 2 years and sometimes longer before pupating and emerging as adults. Mountain pine beetle (*Dendroctonus ponderosae*; MPB) and pine engraver beetle (*Ips pini*; Ips) are bark beetle species that spend the egg, larval, and pupal stages within the bark and phloem of the host tree. Mountain pine beetles generally have a univoltine life cycle and are actively laying eggs from late June through August (primarily in Aug in the BHNF) with eggs hatching within 10–14 days (Blackman 1931, Knight 1959, Furniss and Carolin 1977, Gibson et al. 2009). The larvae then feed within the phloem in distinct larval galleries where they overwinter and ultimately pupate. Pine engraver beetles have 1–5 generations per year (life cycle similar as MPB) depending on locality and length of season throughout its range (Furniss and Carolin 1977), with the first flight of some of the adults generally occurring in April and activity slowing in late May (Kegley et al. 1997). This information about life history indicates that wood borer and MPB larvae are available within two weeks of egg laying and remain in larval form throughout the year, giving woodpeckers essentially a year round food supply.

The objectives of our study were to examine the availability of wood borer and bark beetle (MPB and Ips collectively) larvae, a primary food source for BBWOs, associated with snags from wildfires and MPB infestations, respectively. We wanted to determine how these food resources varied with season of fire, severity of fire, time since initial MPB infestation, and height of tree bole. Our hypotheses were as follows: greater numbers of wood borer larvae in early season wildfires than late season wildfires, greater numbers of wood borer larvae in high severity than moderate severity, greater numbers of bark beetle larvae in green hit MPB infestations than red hit, and greater numbers of beetle larvae on lower sections of the tree bole.

The wildfire and MPB disturbance sites were typical of the BHNF with ponderosa pine (*Pinus ponderosa*) dominating the stands and white spruce (*Picea glauca*), paper birch (*Betula papyrifera*), and quaking aspen (*Populus tremuloides*) occurring infrequently outside of the stands we studied (Hoffman and Alexander 1987). We opportunistically sampled two wildfires in 2012; the Dakota fire (UTM 13 T 0623650 E, 4870764 N) occurred 26 June 2012 and burned ~139 ha and the Kinney fire (UTM 13 T 0578896 E, 4862292 N) occurred on 4 September 2012 and burned ~607 ha (elevation 1,580 m and 1,900 m, respectively). We also identified two sites infested by MPBs in the summer of 2012, one near Sheridan Lake (UTM 13 T 0622336 E, 4868605 N) and another near Deerfield Reservoir (UTM 13 T 0597698 E, 4875039 N) with elevations 1,480 m and 1,845 m above mean sea level, respectively.

In November 2012, we performed a general survey of both fires for anecdotal evidence of wood borers, bark beetles, and woodpecker activity. Beetle surveys included peeling bark from burned trees and examining the bark surface for entrance holes and egg niches. If bark beetles or wood borers had infested the tree then bark was loosely attached and the phloem was mostly consumed by foraging larvae, as indicated by the presence of frass which is made up of plant fragments and beetle excrement. We surveyed woodpecker activity by looking for drill holes that penetrated the bark. Trees (ponderosa pine) in the Dakota fire exhibited extensive phloem consumption with loosely attached bark and exhibited foraging evidence from woodpeckers. In contrast, ponderosa pine trees in the Kinney fire had intact phloem and bark and did not exhibit evidence of wood borer or bark beetle activity. Woodpecker foraging activity was sporadic in isolated areas. To evaluate potential food resources for BBWOs, we sampled and quantified beetle larvae abundance following the first opportunity for bark beetles or wood borers to breed in snags. All trees selected for measurements were ponderosa pine between 22.86-cm and 27.94-cm diameter at breast height, the typical size of trees utilized by foraging BBWOs in the BHNF (Rota et al. 2014). For all treatments, we felled snags from the wildfire and MPB sites and removed, labeled, and placed in garbage bags, three sections (1.22 m – 1.83 m, 3.66 m – 4.27 m, 6.10 m – 6.71 m) from each snag for transport to a lab. The three height sections sampled represent the main portion of the trunks below the canopy as a previous study found the mean height of snags in the BHNF to be 5.8 m (SD = 3.6; Spiering and Knight 2005) .

In December 2012, we returned to the Dakota fire and felled 14 dead trees (snags) in each of two fire severity classes; moderate (canopy dead, but not consumed by fire) and high (canopy consumed by fire and void of needles; Rota et al. 2014). Because the Kinney fire occurred during the time of year where beetles are dormant, we selected 14 moderate severity trees and 14 high severity trees in May 2013 and began monthly beetle and woodpecker activity surveys of the selected trees to assess if the site would be suitable for sampling after the next beetle season. In late June of our Kinney fire survey, we observed wood borer egg niches and large numbers of adult wood borer beetles engaged in egg-laying activities on the bark of tree boles. This activity continued into late July and was followed with an increase in woodpecker activity. We continued the monthly surveys in the Kinney fire until we felled the selected trees in November 2013 (n = 28). At each of the MPB sites in January 2013, we felled seven likely infested trees (indicated by presence of pitch tubes on the tree bole) for a total of 14 which still had green canopy and are referred to as green hits (Rota et al. 2014). During November 2013, we felled seven additional snags from each MPB infested site with a reddish-brown canopy which we referred to as red hits (n = 14; Rota et al. 2014). Our sample size reflected the availability of time and resources that we were able to allocate to collecting and subsequently processing field data.

We unwrapped the bagged sections, recorded the diameter of each log section and tabulated woodpecker activity by counting the number of drill holes (Villard and Beninger 1993, Murphy and Lehnhausen 1998, Shea et al. 2002). We peeled the bark and tabulated wood borer larvae, wood borer larvae entrance holes into the xylem, and bark beetle larvae. Bark beetle larvae were so numerous in the green hit MPB sections that we subsampled a 15.24-cm band around the middle of each section and extrapolated counts to the entire section to provide a total count.

We accounted for beetle larvae potentially removed by woodpecker foraging by assigning woodpecker drill holes to either wood borer larvae or bark beetle larvae based on the proportion of each larvae type that occurred beneath the bark. Generally, in burned areas, woodpecker drill holes were allocated to wood borers, and in bark beetle areas, they were allocated to bark beetles. We assumed each woodpecker drill hole was one larvae removed. Only 11% of log sections in the burned sites contained larvae from both wood borers and bark beetles and among those sections, 78% of woodpecker drill holes were allocated to wood borers based on the abundance of each larvae type beneath the bark.

We used generalized linear mixed models (PROC GLIMMIX, SAS 2012) with a negative binomial distribution accounting for response dispersion to test for differences in mean wood borer and MPB larvae occurrence in sections of snags based on the date the fire occurred, severity of burn, green or red hit MPB, and height from ground. A generalized chi-square statistic was calculated for each model to assess the residual dispersion estimate. Using PROC GLIMMIX, we analyzed data with dual Quasi-Newton optimization technique, log-link function, and residual pseudo-likelihood (PL) estimation. We treated wildfire date, wildfire severity, green or red hit MPB, and height from ground as fixed effects while the tree was treated as a random effect. We further evaluated significant differences in fixed effects using Tukey-Kramer multiple comparison adjustments ($\alpha < 0.05$; PROC GLIMMIX, SAS 2012).

Mean bark beetle occurrence was not different ($F_{1, 106}$ = 0.17, P = 0.68) between summer and fall wildfires or between moderate and high severity snags ($F_{1, 106}$ = 2.39, P = 0.13; Table 1), but greater occurrence was detected ($F_{2, 106}$ = 4.58, $P \leq 0.05$; Table 2) in the middle and upper section compared to the lower section of the tree bole. There were 17% more (t_{106} = –2.57, $P \leq 0.05$) wood borer occurrences on mean in the fall wildfire compared to the summer wildfire, but no differences ($F_{1, 106}$ = 0.32, P = 0.57; Table 1) were apparent between high severity and moderate severity snags. More wood borer larvae occurred in the lower section than the middle and upper sections (t_{106} = –2.83, $P \leq 0.05$; t_{106} = –2.69, $P \leq 0.05$, respectively; Table 2).

Mean bark beetle occurrence in green hit snags was 82% greater ($F_{1, 52}$ = 18.73, $P \leq 0.01$; Table 1) than red hit snags during the time of sampling and these were similar ($F_{2, 52}$ = 1.10, P = 0.34; Table 2) among heights. Wood borer occurrence was not different ($F_{1, 52}$ = 1.18, P = 0.28) at the time of sampling between green and red hits, but differed ($F_{2,52}$ = 3.82, P = 0.03; Table 2) among heights. Wood borer occurrence was greater (t_{52} = 2.72, P = 0.01; Table 2) in the lower section than the upper section of the tree bole.

Abundance of beetle larvae in summer and fall wildfires was of interest because recent research in the BHNF suggested that timing of a fire may play a role in use by BBWOs (Rota 2013, Rota et al. 2014). Following the Jasper fire (~35,000 ha, Aug 2000, UTM 13 T 0591144 E, 4852135 N), no BBWO nests were found the following breeding season (2001) and only a ‘small’ number of BBWOs were observed

Table 1. Least squares means for bark beetle (BB) and wood borer (WB) occurrences within mountain pine beetles (MPB) and wildfire disturbance types in the Black Hills of South Dakota, 2012–2013.

	MPB stage		Wildfire severity		Wildfire seasonality	
	Green[a]	Red[b]	Moderate[c]	High[d]	Summer[e]	Fall[f]
n[g]	42	42	84	84	84	84
BB (SE)	461.08* (172.31)	46.24 (17.46)	0.44 (0.16)	0.18 (0.08)	0.32 (0.12)	0.25 (0.11)
WB (SE)	0.48 (0.28)	1.13 (0.59)	42.75 (4.09)	46.14 (4.41)	37.32 (3.58)	52.86* (5.04)

[a] MPB infested trees with green canopy; [b] MPB infested trees with reddish brown canopy; [c] Canopy dead, but not consumed by fire; [d] Canopy consumed by fire and void of needles; [e] May–August; [f] September–December; [g] Number of logs sampled.
* Denotes a greater than significant difference ($P < 0.05$) from values without asterisk.

Table 2. Least squares means for bark beetle (BB) and wood borer (WB) occurrence in ponderosa pine tree sections measured in two disturbance types in the Black Hills of South Dakota, 2012–2013.

	Tree section		
Disturbance	Lower	Middle	Upper
MPB[b]			
n[d]	28	28	28
BB (SE)	154.97 (43.51)	157.37 (44.16)	127.65 (35.84)
WB (SE)	1.42*[a] (0.61)	0.76 (0.35)	0.38 (0.20)
Wildfire[c]			
n[d]	56	56	56
BB (SE)	0.11 (0.05)	0.49* (0.18)	0.43* (0.15)
WB (SE)	51.26* (4.15)	42.19 (3.43)	40.52 (3.30)

[a] Difference was between the lower and upper section; [b] MPB (mountain pine beetle) infestation; [c] Fire created habitat; [d] Number of logs sampled.
* Denotes a greater than significant difference ($P < 0.05$) from value(s) without asterisk.

foraging in the area (Vierling et al. 2008). This suggests that food availability was potentially limited the subsequent year following a late summer wildfire. Our two wildfire sites provided an opportunity to examine differences in beetle larvae occurrence in a wildfire that burned during the peak of beetle breeding activity with one that occurred after the peak flight period, when adults are not actively laying eggs. Research comparing three fires at 1, 2, and 3 years post fire (Costello et al. 2011) indicated wood borer incidence was similar between different age fires. We hypothesized that wood borer occurrences would not be similar, but lower in the late fire compared to the early fire because burned trees had likely desiccated before the beginning of the breeding season the following summer. Our data suggests otherwise and we acknowledge the timing of these particular two wildfires, along with elevation and reservoir populations near the fires, may have influenced our results. We noted that wood borers began infesting trees in early June during our Kinney fire monthly surveys. Consequently, the Dakota fire (mid-Jun) did not have a full season to attract wood borers before we sampled, while the Kinney (fall) fire was available for wood borers throughout their seasonal activity. High wood borer breeding and egg laying activity starting in late June to August and subsequent BBWO feeding was observed (B. Dickerson and A. Ambourn, personal observation) in the Kinney fire, suggesting that late season wildfires produce high quality forage opportunities for woodpeckers in the first season after a late season wildfire.

Mountain pine beetles have a one year life cycle in the Black Hills and do not re-infest trees (Reid 1962, Furniss and Carolin 1977). As expected, few bark beetles occurred in the second year MPB study areas. The few second year bark beetle larvae that we did observe (Table 1) were mostly *Ips* spp., a secondary bark beetle often found in conjunction with MPB and one that commonly infests the upper part of the tree (Furniss and Carolin 1977). Of particular interest to this study was quantifying wood borer presence in a MPB disturbance. Mountain pine beetle brood sampling from 2013 in the BHNF showed that 79% of all trees sampled also contained wood borer larvae (K. Allen and A. Ambourn, unpublished data). Costello et al. (2013) also found significantly more wood borers in MPB infested trees that were one year old, suggesting that wood borers infest trees soon after MPB outbreaks. Wood borers were not common in either MPB study site even though wood borers and bark beetles are known to simultaneously feed in the phloem of weakened trees (Furniss and Carolin 1977, Dodds et al. 2001). As a result, the lack of wood borers in our MPB study sites was unexpected. Perhaps localized factors such as nearby reservoir wood borer populations or size of MPB outbreak influenced our findings.

Combining various measures of presence for beetle species has been previously reported (Zhang et al. 1993, Powell et al. 2002, Costello et al. 2011). We assumed that a given woodpecker drill hole through the bark represented one beetle larvae extracted. Indeed, BBWOs are known to feed primarily by drilling below the outer bark layers (Hoyt and Hannon 2002, Tremblay et al. 2010). This assumption and others likely resulted in overestimations of beetle larvae occurrence in our data. However, including woodpecker drilling activity provides an estimate of forage that may have otherwise been unaccounted for, and is applicable when inferring foraging results to woodpecker use.

Our results should aid forest managers in making informed decisions regarding salvage and sanitation of timber following wildfire and MPB disturbances, relative to timing and forage availability used by BBWOs, a locally sensitive species (South Dakota Game, Fish and Parks 2006) recently petitioned for protection under the Endangered Species Act (Hanson et al. 2012). Due to the rapid deterioration of fire and beetle killed trees in the Black Hills, these forest management activities are constrained to a few months following disturbances. We recommend excluding at least 200 ha from management activities in larger disturbances (>400 ha). The larger disturbances will likely have only a small percentage (≤25%) of the area affected by harvest activities which leads us to speculate it will have little impact on woodpeckers. Smaller disturbances (<200 ha), particularly when uncommon and scattered on the landscape or distant from large disturbances in space and time, may need to be evaluated on a case by case basis as potential habitat for woodpeckers and possibly excluded from management activities altogether to provide suitable foraging and nesting habitat.

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