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YELLOW-BELLIED SAPSUCKERS (*SPHYRAPICUS VARIUS*) ALTER SAP WELL LOCATIONS IN RESPONSE TO EXPERIMENTALLY INDUCED TREE DAMAGE

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ABSTRACT.—Yellow-bellied Sapsuckers (*Sphyrapicus varius*) regularly use paper birch (*Betula papyrifera*) as a source of sap during the breeding season and may position their sap wells on the tree in order to maximize sap extraction. Sap flow can be affected by tree damage, and altering sap well locations in response to such damage could enhance sapsucker foraging efficiency. We sought to determine if sapsuckers selectively drilled sap wells on damaged (experimentally girdled) paper birch trees over non-damaged healthy trees and, if so, whether the locations of the drill sites varied in response to this damage. Sapsuckers drilled holes on a significantly larger proportion of girdled trees than control trees (healthy trees on adjacent plots), and the holes were lower on girdled trees in comparison with control trees. These differences occurred even though control and girdled trees were of similar size (diameter) and had similar numbers of sap wells per tree. Yellow-bellied Sapsuckers appear to alter their foraging behavior in response to tree damage, and thus factors affecting such damage could indirectly influence the foraging ecology of this species. *Received 28 April 2015. Accepted 28 January 2016.*

Key words: foraging behavior, sap wells, woodpeckers, Yellow-bellied Sapsuckers.

The Yellow-bellied Sapsucker (*Sphyrapicus varius*) plays a significant keystone role in ecological communities, because other species including insects, birds, and mammals make use of the sapsuckers' nesting sites and foraging sap wells (Kilham 1971, Erskine and McLaren 1972, Miller and Nero 1983, Rissler et al. 1995, Walters et al. 2002, Tozer et al. 2012). With respect to use of the sap wells, other species can supplement their diets with sap or with insects attracted to the sap, or they may use the sap as a primary food source (Walters et al. 2002). It is estimated that sap comprises up to 20% of the Yellow-bellied Sapsuckers' annual diet (Short 1982), and the quality of the sap resources may influence annual reproductive success and demography (Tozer et al. 2011). Yellow-bellied Sapsuckers create both phloem and xylem wells on a tree and can drill hundreds of wells in a given breeding season (Tate 1973; Eberhardt 1994, 2000).

Yellow-bellied Sapsuckers preferentially create sap wells on specific tree species, which during the spring and summer include paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), juneberry (*Amelanchier* sp.), big-tooth aspen (*Populus grandidentata*), and trembing aspen (*Populus tremuloides*; Eberhardt 1994, 2000; Savignac and Machtans 2006; Tozer et al. 2011; reviewed in Walters et al. 2002). During the breeding season, Yellow-bellied Sapsuckers regularly focus their feeding on species of birch (Nappi et al. 2015) and often drill their sap wells above scarred tissue of trees, including old sap wells (Kilham 1964, Eberhardt 2000, Mancusco et al. 2014), or near the bases of tree crowns (Erdmann and Oberg 1974). Eberhardt (1994, 2000) found sap wells from Yellow-bellied Sapsuckers were on average 7.13 m from the ground, usually within 1 m of a branch, and the majority (85%) of wells were located above previous scarred wounds on the tree. It is thought that the sapsuckers prefer to drill holes near scarred tissue because of the pooling sap that occurs there with increased sugar content (Kilham 1964). Sapsuckers regularly peck sap wells in rows, presumably because this configuration induces the pooling effect and thus increases the productivity of future sap wells on the same tree.

In this study, we sought to determine if experimental damage to birch trees would influence where sapsuckers drilled their sap wells. We made use of paper birch trees artificially killed in 2008 by completely girdling the phloem of the main bole, as part of the Forest Accelerated Succession Experiment site (FASET) at the University of Michigan Biological Station (Nave et al. 2011). We asked whether the proportion of trees with sap wells, the number of sap wells, and the height of those sap wells differed between the

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damaged and undamaged trees. Forests will be adversely affected by global climate change and other human-induced changes to ecosystems. In addition to the many direct effects that such changes will have on ecosystems, resultant damage to trees may further affect the foraging ecology of bird species that depend on those trees.

METHODS

This study was conducted from 7– 29 July 2014. The FASET site consists of 39 ha of northern temperate forest south of Douglas Lake on the property of the University of Michigan Biological Station in northern Michigan. This experimental site is part of a larger, ~140-ha temperate forest, that is ~90 years of age and composed of paper birch, red maple, big-tooth aspen, northern red oak (*Quercus rubra*), white birch (*Betula papyrifera*), eastern white pine (*Pinus strobus*), trembling aspen (*Populus tremuloides*), sugar maple (*Acer saccharum*), and American beech (*Fagus grandifolia*; Pearsall 1995, Gough et al. 2007, Nave et al. 2011). Within the FASET site, all paper birch and big-tooth aspen trees were mechanically girdled in the summer of 2008 in order to study succession in future forest conditions that may exist because of effects of climate change (Nave et al. 2011, 2013) or disturbance because of a pest outbreak. We used the forest within the FASET site as our experimental area and the surrounding forest as our control. The forest is homogenous, and composition of the forest inside and outside of the FASET site did not differ (Pearsall 1995). The girdling of trees inside the FASET site certainly affected the birch and aspen trees, but otherwise there was no evidence that the girdling operation itself affected the forest except through the eventual death of the trees.

Our goals were to determine if sapsuckers drilled more sap wells in the girdled trees within the experimental site in comparison to un-girdled trees in the control area and whether the sapsuckers altered the height of their sap wells on the bole of trees in each area. To test this, we ran transect lines both within and outside the FASET site. We ran eight transects in total, four within (experimental) and four outside FASET (control). The location and direction of each experimental transect was randomly selected, and then control transects were selected with the same directionality and as close as possible to the experimental transects but outside of the FASET site. In all cases, the control transects were within 250 m of the experimental transects. Transects were 200 m in length, except two that were limited to 146 m, one in the experimental and one in the control area because they reached Douglas Lake at the northern limit of the study area.

Along transect lines, we examined each paper birch tree within 10 m of either side of the transect line and gave each tree a unique number (1 to 106). For each tree, we recorded height (m), diameter at breast height (DBH; cm), the presence and number of sap wells, the height of the lowest sap well, and the height of the girdling (in the FASET site). When possible, the exact number of sapsucker sap wells on the tree was counted. However, when sap wells were high above the forest floor, the number of sap wells could only be estimated. To avoid potential bias, all of the sap well counts in our study were rounded to the nearest 10. All height measurements, such as heights of sap wells and of trees, were made using tape measure or a manual clinometer, and DBH measurements were made with a standard DBH tape.

The majority of girdled birch trees showed signs of damage from animals such as other woodpeckers, insects, or small mammals; however, despite this additional damage, sap wells were obvious and easily discriminated from other types of tree damage. To be characterized as a sapsucker sap well, the damaged area had to consist of holes that were in rows, were usually circular with smooth edges and smaller than a centimeter in diameter, and were spaced less than a centimeter apart. Any holes, even if they were in vertical or horizontal rows, that were larger than 1 cm, had jagged edges, or were spaced >1 cm apart were not classified as sap wells. We used these criteria based on descriptions of sap wells in Ostry and Nicholls (1976) and Eberhardt (2000) and also to be conservative given the fact that the girdled trees had been dead for 2–3 years when we conducted our study and could have been utilized by many different species.

Results are presented as mean $\pm$ SD. Depending on the data being analyzed, a combination of parametric statistical tests (*t*-test, ANOVA, regression) and non-parametric statistical tests (Chi-square) were utilized.

RESULTS

We examined a total of 106 standing paper birch: 71 in the control site and 35 in the FASET site. The average DBH of the birch trees did not differ between the experimental and control sites (21.84 ± 4.82 cm and 20.04 ± 6.45 cm, respectively, $t_{104} = -1.462$, $P = 0.15$) but tree height did (experimental = 10.50 ± 4.15 m, control = 12.69 ± 5.59 m; $t_{104} = 2.056$, $P = 0.042$). This difference in tree height was almost certainly the result of the fact that most of the birch trees in the experimental plots were 'topped' with the uppermost parts of the tree having broken off after death of the tree. In the experimental plots, 22 of the 35 trees (60.0%) were topped, whereas in the control plots this was the condition for only 23 of the 71 (32.4%) trees ($\chi^2 = 3.386$, $P = 0.033$).

The percentage of paper birch containing sap wells was significantly higher in the experimental plots than in the control plots (46% and 23% respectively; $\chi^2 = 5.0$, $n = 106$, $P = 0.015$). However, there was no significant difference between the experimental and control sites in sap well counts per tree, whether we considered all birch trees (experimental = 21.63 ± 38.60; control = 13.89 ± 35.69, $t_{104} = -0.995$, $P = 0.32$) or just those trees that had sap wells (experimental = 47.31 ± 39.89; control = 61.62 ± 61.77, $t_{30} = 0.779$, $P = 0.44$).

The mean height of the lowest sap well was significantly lower in the FASET plots than in the control plots: 1.42 ± 1.22 m and 7.32 ± 5.05 m, respectively ($t_{30} = 5.544$, $P < 0.0001$). When we considered the 16 trees in the experimental plot that had sap wells, the height of the lowest sap wells above the girdling was 0.45 ± 1.27 m, but on 11 of the 16 trees, the lowest sap well was within 2 cm, and always above, the girdling.

There was a significant positive relationship between tree height and sap well height for trees in the control site (ANOVA, $F_{1,14} = 66.89$, $R^2 = 0.827$, $P < 0.0001$). However, trees in the experimental site showed no such relationship ($F_{1,14} = 0.911$, $R^2 = 0.061$, $P = 0.36$).

DISCUSSION

Yellow-bellied Sapsuckers are a keystone species in the communities where they occur, because in both their nesting and foraging habits, they modify the habitat in ways that other, diverse species utilize or depend on (Kilham 1971, Erskine and McLaren 1972, Miller and Nero 1983, Rissler et al. 1995, Walters et al. 2002, Tozer et al. 2012). The foraging ecology of this species is diverse and varies seasonally across the year (Tate 1973, Long 2011), but the species is best known for their foraging habits during the spring and summer when they drill sap wells in the bark of various tree species (Savignac and Machtans 2006, Tozer et al. 2011). It is well known from previous work that the birds will often create sap wells near wounds in the tree (Kilham 1964; Eberhardt 1994, 2000), presumably because sap accumulates near such wounds. Making use of a large-scale environmental experiment at University of Michigan Biological Station in which all of the birch and aspen trees were girdled (Nave et al. 2011, 2013), in this study we asked whether Yellow-bellied Sapsuckers would drill more sap wells in girdled trees, and whether the number and height of sap wells would differ between girdled and non-girdled trees.

For two of the questions we posed, the answer is yes. Sapsuckers drilled sap wells on a significantly larger proportion of girdled birch trees and at significantly lower heights than they did on natural, un-girdled trees. For the third question, whether the birds would drill more holes in the girdled trees, the answer was no; experimental and control trees did not significantly differ in numbers of sap wells. But, before we discuss the specific results of our study, we should acknowledge the limitations of our work.

This study was conducted at a site where the trees were girdled in 2008. The trees at the FASET site died within 1–4 years of the girdling (L. E. Nave, pers. comm.), but our work took place in 2014. Thus, the trees we examined with respect to sap wells had been dead for at least 2 years, whereas the trees in the control areas were still living. Thus, one might expect that the living trees in the control transects might accumulate sap wells in comparison with the experimental trees, in which the drilling of sap wells would have stopped when the trees died. Nevertheless, this did not appear to be the case when we considered number of sap wells; experimental trees were similar to control trees.

Further, we did not directly observe the sapsuckers drill the sap wells. We quantified the effects of the birds' behaviors, not the actual foraging behavior. It is possible the same birds had territories encompassing parts of both the experimental and control areas. We cannot, therefore, speak directly to a preference for trees with or without damage, because we did not quantify relative abundance of trees of each type.

Nevertheless, and perhaps despite these limitations, the results of our sampling were clear with respect to where the birds drilled sap wells. A greater percentage of trees in the experimental (girdled) site had sap wells than in the control area. Additionally, the sap wells on trees in the experimental site were significantly lower than on trees in the control areas. In the experimental site, on 11 of the 16 trees with sap wells, the lowest well was within 2 cm of the girdling scar. It appears that the birds responded to the girdling of the trees in the experimental site by drilling sap wells close to the site of damage. This is experimental evidence confirming observations of the behavior of the species in natural areas (Eberhardt 1994, 2000).

In the control site, there was a significant positive relationship between sap well height and tree height. This result is to be expected for non-girdled trees, because sapsuckers will use branches as perch sites when creating sap wells (Eberhardt 2000) and often create wells near the crown of a tree (Erdmann and Oberg 1974). In the FASET site, however, there was no correlation between the tree height and the girdle height. This suggests that the girdle (or scarring) changed the sapsuckers' foraging behavior. If the sapsuckers were seeking out trees with damage, and they preferred to feed directly above such damage, the height of the tree should not matter (Eberhardt 2000).

Forests will be adversely affected by global climate change and other human-induced changes to ecosystems. In addition to direct effects of climate change, there may be significant indirect effects, for example an increase in forest pest outbreaks (Joyce et al. 2014). Our findings suggest that sapsuckers may alter their foraging behaviors in accordance with some forms of altered forest dynamics and provides the first experimental evidence that sapsucker foraging preferences are influenced by human-induced tree damage. Furthermore, because sap wells created by sapsuckers are used by other wildlife (Miller and Nero 1983, Rissler et al. 1995, Walters et al. 2002), the foraging behaviors of these other species might be altered too. Additional study is needed to examine the repercussions the alteration of sapsuckers feeding behavior may have on other animal species that rely on sapsucker sap wells.

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