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Savanna Restoration Using Fire Benefits Birds Utilizing Dead Trees, Up to a Point

MARK A. DAVIS[1] AND ANDREW MILLER
Department of Biology, Macalester College, Saint Paul, Minnesota 55105

ABSTRACT.—The decline of savanna habitat in the upper Midwest has resulted in a decline of savanna and grassland birds. Many savanna restoration efforts involve the re- introduction of fire, a method which kills fire-sensitive trees, often leaving them standing as snags. The purpose of this study was to assess how the number of snags (standing dead trees) is associated with the breeding bird community and to document how the number of snags at a site varied over a 23 y period of restoration by fire. The effect of snags on bird communities was studied by establishing bird census plots along a wide range of snag abundances. To determine for what purposes birds utilized snags, observers documented all visits during an hour-long period for pairs of a dead and live tree. Change in the abundance of snags over time was documented over 23 y in a 16 ha grid. We found both bird species richness and abundance were positively associated with the number of snags and that birds used dead trees for mating and reproductive purposes more than live trees. We found the introduction of fire for restoration purposes initially resulted in an increase in the number of snags, but repeated fires eventually caused the number of snags to decline substantially. If a primary goal of savanna restoration is to enhance breeding bird community, our results show how burn regimes can be managed to maximize the number of dead tree snags for as long as possible.

INTRODUCTION

Oak savanna was once common throughout much of the Midwest. Such habitats either largely have been destroyed to make room for human activities, such as agriculture and urban development, or have aged into later stages of succession—oak woodlands and forests, through the suppression of fire (Nuzzo, 1986). Various studies have shown this loss of habitat has resulted in the decline of several savanna and grassland bird species (Herkert, 1994; Peterjohn and Sauer, 1994; Sample and Mossman, 1994; Davis *et al.*, 2000; Au *et al.*, 2008; Thompson *et al.*, 2012).

In recent decades efforts have been made to restore Midwestern savanna ecosystems that have succeeded to woodlands and forests (Axelrod and Irving, 1978; Peterson and Reich, 2001). These restoration efforts commonly involve fire (Irving, 1970; Faber-Langendoen and Davis, 1995). Typically, such restoration efforts focus on the vegetation (Peterson and Reich, 2001) and do not account for the fact restored ecosystems are important habitats for many animal groups, for example the breeding bird community (Morrison, 1995). Although some research has been conducted to understand the effects of savanna restoration on the resident bird species (Robinson, 1994; Davis *et al.*, 2000; Grundel and Pavlovic, 2007; Au *et al.*, 2008; Thompson *et al.*, 2012), the role played by snags (standing dead trees) in influencing the savanna bird community (Johnston, 2007) has not been as widely studied as it has in western forests (Bergstrom, 1977; Scott, 1978; Scott and Whelan, 1978; Bagne *et al.*, 2008). While snag dynamics have been studied over multiple years in some western forest studies (Morrison and Raphael, 1993; Bagne *et al.*,2008), a detailed annual accounting of change in the number of snags as restoration by fire continues over decades has not been reported for any site.

[1] Corresponding Author: Telephone: (651) 696–6442, e-mail: davis@macalester.edu

The purpose of this study was to document how the abundance of snags at a particular site changed over 23 y of savanna restoration by fire and to document changes in the savanna breeding bird community along a gradient of snag abundance. We also wanted to record the ways birds use snags and live trees (*e.g.*, for foraging, perching, calling, nesting). Finally, we hoped to provide ecosystem managers with information that could help them restore savannas in a way that would enhance the bird community, specifically increasing overall species richness and abundance of birds that utilize snags, including some uncommon or threatened species, such as the Red-headed Woodpecker (*Melanerpes erythrocephalus*) and the Lark Sparrow (*Chondestes grammacus*).

METHODS

Study site.—Field observations were conducted at the Cedar Creek Ecosystem Science Reserve (CCESR) located in east-central Minnesota (45°24′09.30″N, 93°12′09.27″W). CCESR lies between the tallgrass prairie biome to the west and the deciduous forest biome to the east (Tester, 1989). Oak savanna was among the dominant vegetation types in the Cedar Creek area prior to settlement by Europeans (Grigal *et al.*, 1974). In 1964 a program of prescribed burns was initiated at CCESR to restore and maintain oak savanna and woodland vegetation and to study the effects of fire on vegetation (Irving, 1970). Most of the trees in the burn units are oaks (*Quercus macrocarpa* and *Quercus ellipsoidalis*). Other less common species include *Populus tremuloides*, *Prunus serotina*, and *Acer rubrum,* along with other even rarer fire sensitive species.

Change in the abundance of snags over time was documented in a 16 ha grid (GLADES – Grid for Landscape Analysis and DEmographic Study; Davis *et al.*, 2005) in which the status of all tree stems greater than 2 cm diameter at breast height (dbh; more than 11,000 stems) was monitored annually from 1995–2017. The grid, which had not been burned for more than 25 y prior to 1987, contains three burn units (BU). BU 1 (6.17 ha) was burned 14 times from 1987 to 2017; BU 2 (6.03 ha) remained unburned until 1992 and was burned eight times from 1992 to 2017; and BU 3 (3.25 ha) remained unburned through 1999 and was burned eight times from 2000 to 2017. Two corners of the grid (0.55 ha) are outside any of the three burn units.

Data collection.—The effect of snags on bird communities was studied in 1999 by establishing sixteen 50 m radius (0.79 ha) plots throughout the Cedar Creek burn units. The plots were selected to provide a wide range in the relative abundance of snags to live trees (near zero to 2.5). Each plot was visited four times between the hours of 0600 and 0930 during the month of June (1999), and resident birds in the plots were identified by sight and/or calls during 15 min point count censuses. In each plot four vegetation attributes were recorded including number of snags, ratio of snags to live trees, basal area of live trees, canopy extent of live and dead trees, and ratio of snag canopy to live canopy. To determine the extent to which the birds utilized snags and live trees and for what purposes, observers documented all visits during a single hour-long period for 14 pairs of a dead and nearby (<30 m) live tree of comparable size (similar dbh, height, and canopy extent; only dead trees with substantial remaining dead canopy were included in this part of the study). Observations were conducted early in the morning (0600–0930) in June 1999. While birds in dead trees were more observable than those in live trees, we are confident that hour-long observation periods were sufficient to document all the birds in both trees. Change in the abundance of snags over time was documented over 23 y in the 16 ha grid (1995–2017). Snags of two sizes are reported here, 10–24.9 cm dbh and 25 cm dbh and greater. Only trees lacking any living branches were considered snags in this study.

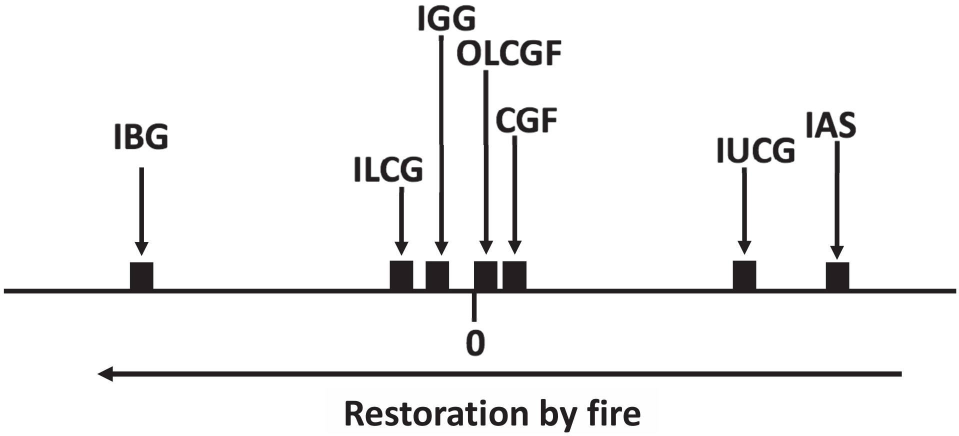

FIG. 1.—Distribution of the seven guilds along the first axis of the correspondence analysis. Moving from right to left along the axis, *i.e.,* as restoration proceeds, the dead to live canopy ratio and burn frequency increase while live tree basal area decreases. Specific axis values for each guild are: IBG (Insectivorous Bark Gleaner) = –0.578, ILCG (Insectivorous Lower Canopy Gleaner) = –0.101, IGG (Insectivorous Ground Gleaner) = –0.074, OLCGF (Omnivorous Lower Canopy and Ground Forager) = 0.035, OGF (Omnivorous Ground Forager) = 0.044, IUCG (Insectivorous Upper Canopy Gleaner) = 0.408, IAS (Insectivorous Air Sallier) = 0.59

Data analysis.—The distribution of species along the restoration (fire frequency) gradient was analyzed using correspondence analysis. In addition the individual species were grouped into one of seven foraging guilds, a three-part classification system based on primary food type, foraging substrate, and foraging technique (de Graaf *et al.*, 1985) and a separate correspondence analysis was conducted on the guilds. First axis coordinates of the 16-point count sites were compared (simple regression analysis) with each of the four vegetation attributes recorded and showed that the first axis of the correspondence analysis represented a restoration gradient. Consequently, the number of birds of individual species and guilds in the respective sites were compared (simple regression analysis) with the first axis coordinates of the 16 sites to determine if they were distributed predictably along the restoration gradient. In addition changes in the overall bird abundance and species richness along the 16-site restoration gradient were analyzed using linear regression. Differences between number of species recorded in the paired dead and live tree observations were analyzed using a paired *t*-test, and a chi-square test was used to evaluate the extent to which birds used the dead and live trees for different purposes, *e.g.*, related to reproduction (singing, nesting) or foraging.

RESULTS

As burn frequency and the ratio of dead to live canopy extent increased and as basal area of live trees decreased (*i.e.*, as savanna restoration progressed) there was a guild shift from Insectivorous Air Salliers to Insectivorous Bark Gleaners (Fig. 1). Overall, bird density and species richness rose with the increased relative abundance of snags (Fig. 2). Four of the guilds correlated positively with one or more measurements of snag abundance. (Table 2). No guilds declined with increased snag abundance. Thirteen bird species corresponded

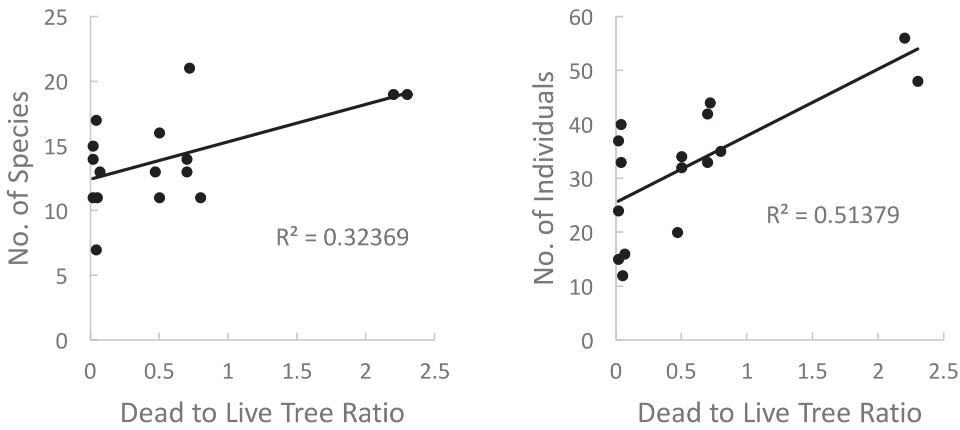

FIG. 2.—Species richness (left, P = 0.023) and density (right, P = 0.002) of birds recorded in the sixteen 50 m radius observation plots shown as a function of dead to live tree ratio

TABLE 1.—This table shows the different foraging guilds that were represented in this study, and examples of each. Guild scheme is from de Graaf *et al.* (1985)

Guild name	Examples
Insectivorous Bark Gleaner (IBG)	Red-headed Woodpecker *Melanerpes erythrocephalus* White-breasted Nuthatch *Sitta carolinensis*
Insectivorous Lower Canopy Gleaner (ILCG)	Black-capped Chickadee *Poecile atricapillus* House Wren *Troglodytes aedon*
Insectivorous Ground Gleaner (IGG)	American Robin *Turdus migratorius* Ovenbird *Seiurus aurocapillus*
Omnivorous Lower Canopy and Ground Forager (OLCGF)	Gray Catbird *Dumetella carolinensis* Brown Thrasher *Cinclocerthia ruficauda*
Omnivorous Ground Forager (OGF)	Field Sparrow *Spizella passerina* Eastern Towhee *Pipilo erythrophthalmus*
Insectivorous Upper Canopy Gleaner (IUCG)	Blue-gray Gnatcatcher *Polioptila caerulea* Red-eyed Vireo *Vireo olivaceus*
Insectivorous Air Sallier (IAS)	Great-crested Flycatcher *Myiarchus tyrannulus* Eastern Wood-Pewee *Contopus virens*

TABLE 2.—Shown are foraging guilds and species that increased or decreased in association with one or more measurements of snag abundance. Four of the seven guilds observed in the study and thirteen of the thirty-seven species observed corresponded positively with one or more measurements of snag abundance. The numbers in parentheses after the guilds and species represent the vegetative variable to which they corresponded: 1 = snag density; 2 = snag to live tree ratio; 3 = percent dead canopy; 4 = dead to live canopy ratio. Increasing and decreasing trends were based on regression analyses (see Methods) using a significance value of $P < 0.10$

Guilds	Species
Increasing	Increasing
Insectivorous Ground Gleaners (1,2)	American Goldfinch (2) *Carduelis tristis*
Insectivorous Air Salliers (2)	American Robin (2,4) *Turdus migratorius*
Omniorous Lower Canopy and Ground Foragers (2,3,4)	Black-capped chickadee (3,4) *Poecile atricapillus*
Insectivorous Bark Gleaners (4)	Blue Jay (4) *Cyanocitta cristata*
Decreasing	Brown Thrasher (2,4) *Cinclocerthia ruficauda*
None	Northern Flicker (1,2) *Colaptes auratus*
	Cedar Waxwing (1,2) *Bombycilla cedrorum*
	Downy Woodpecker (3) *Picoides pubescens*
	Gray Catbird (3) *Dumetella carolinensis*
	Lark Sparrow (2) *Chondestes grammacus*
	Mourning Dove (1,2,3,4) *Zenaida macroura*
	Red-headed Woodpecker (4) *Melanerpes erythrocephalus*
	Scarlet Tanager (3) *Piranga olivacea*
	Decreasing
	Eastern Wood-Pewee (1,3) *Contopus virens*

positively with snag abundance (Table 2), including the Red-headed Woodpecker and the Lark Sparrow, two species that have been declining in abundance in Minnesota for several decades (Sauer et al., 2014). Only one species, Eastern Wood-Pewee (*Contopus virens)* showed a negative relationship with an increase in snag abundance (Table 2). During observations of individual dead and live trees, more bird species were seen, on average, on dead trees ($P = 0.066$, Fig. 3). Birds spent more time foraging on live trees than dead ones and more time engaging in reproductive behavior (nesting, displaying/singing) on dead trees (Fig 4).

In the entire portion of the grid that was burned (15.45 ha), small snags (10–24.9 cm dbh) exhibited a stable abundance from 1995 through 2001, approximately 975 stems (63 snags per ha, Fig 5). In 2002 the number of small snags began a mostly steady decline, with the

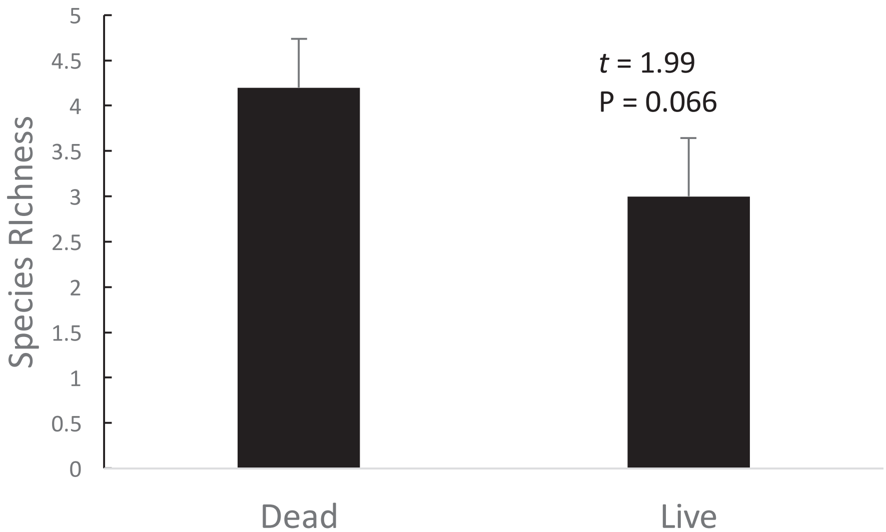

FIG. 3.—Number of species recorded at the fourteen pairs of observation trees (one live and one dead). Standard errors presented

number in 2017 (364, 24 snags per ha) being 37% of the abundance in the late nineties (Fig. 5). Large snags (> 25 cm dbh) showed a similar stable abundance in the early years (1995–2000) of approximately 125 snags (8 snags per ha, Fig 5). Beginning in 2001 the number of large snags steadily increased in abundance, peaking at 409 in 2007 (26 snags per ha) and then steadily declined through 2017 when there were 244 large snags (16 snags per ha, Fig. 5). The total number of snags 10 cm or greater in 1995 was 1070 (69 snags per ha). The total

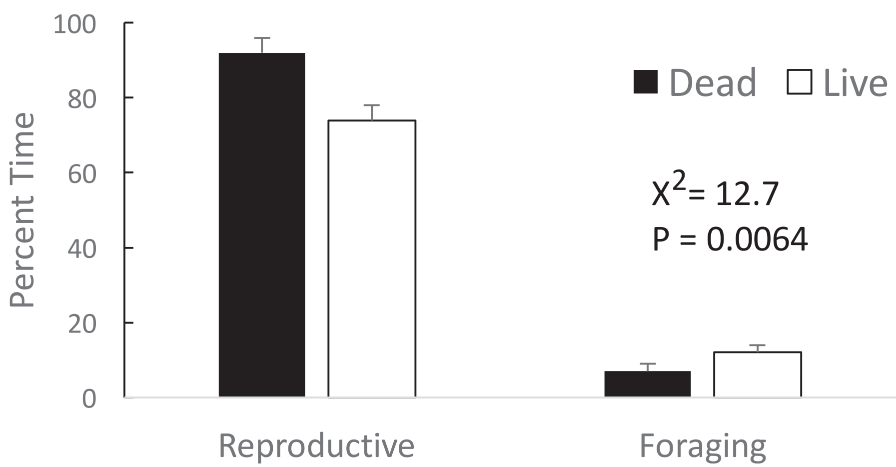

FIG. 4.—The percent time birds engaged in reproductive and foraging behavior on dead and live trees. Standard errors presented

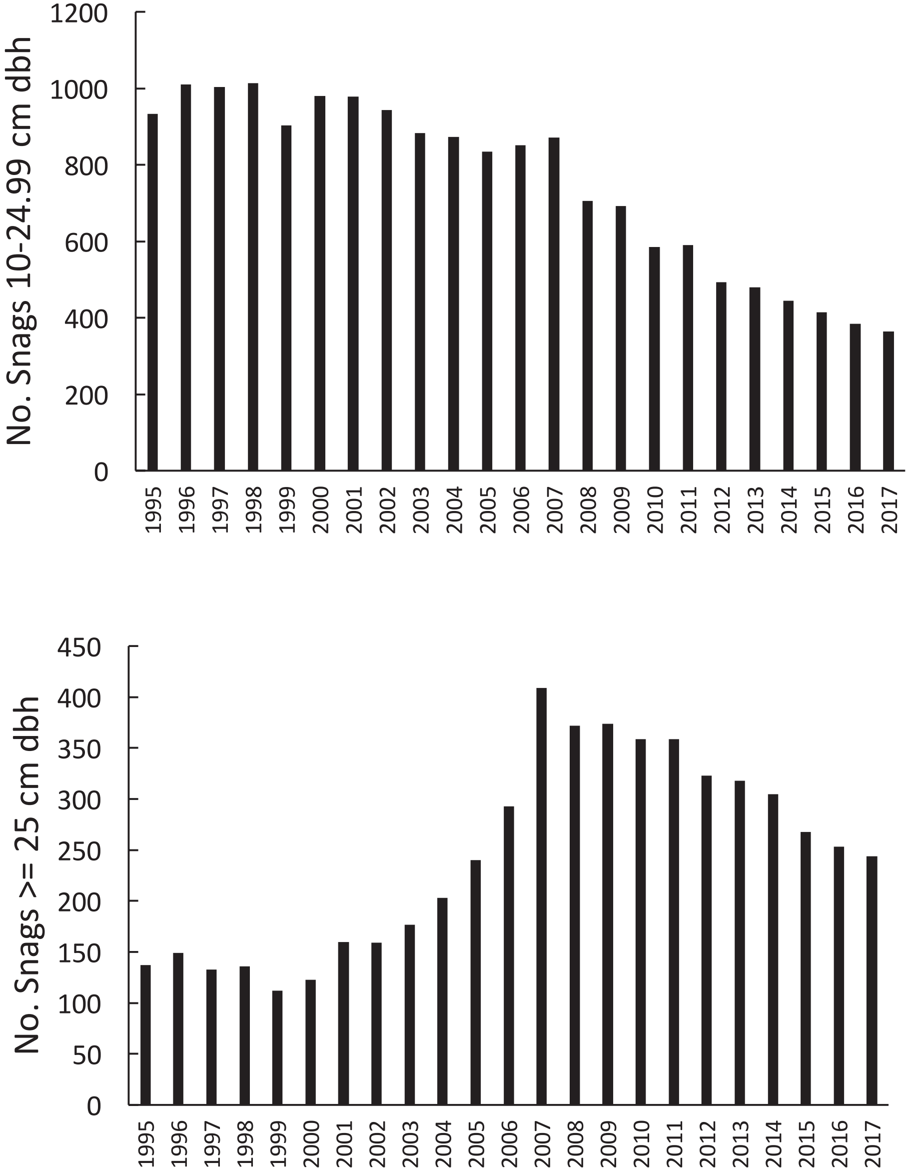

FIG. 5.—The number of snags 10–24.99 cm dbh (top) and the number of snags > 25 cm dbh (bottom) in each of the 23 y

number peaked in 2007 (1280 snags, 83 snags per ha), and in 2017 the total number had declined to 608 (39 snags per ha), more than a 50% reduction from the peak in 2007.

The pattern of increase in snags with the introduction of fire followed by eventual decline in snags as prescribed burns continue can be seen best in the snag data from BU 3, the burn unit that did not experience any restoration by fire until 2000 (Fig. 6). The number of snags

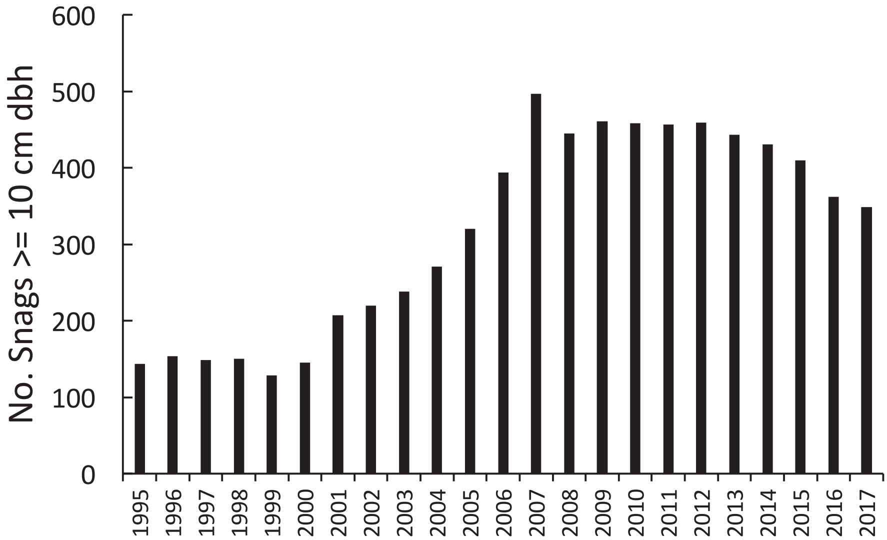

FIG. 6.—The number of snags (> 10 cm dbh) in Burn Unit 3 during each of the 23 y. Fire was introduced in 2000

began to increase rapidly once fire was introduced in 2000, peaking in 2007. However, as frequent restoration fires continued, the number of snags in BU 3 began to consistently decline. By 2017 the number of snags in BU 3 had declined by 30%.

DISCUSSION

The changes in the bird community along the savanna restoration gradient are consistent with other studies (Davis *et al.*, 2000; Grundel and Pavlovic, 2007; Au *et al.*, 2008; Thompson *et al.*, 2012). In particular the positive relationship between the abundance of snags in the savanna and several avian guilds and individual bird species supports similar findings (Johnston, 2007). Cavity nesters are primary users of snags, but the observational studies showed snags are also used frequently as perches, whether or not the species actually nests in a cavity. Perched birds often engaged in territorial and mating displays, mostly calling.

The significant finding from the grid, in which trees were monitored annually, is the abundance of snags varied substantially but predictably during the 23 y of restoration by fire. Specifically, repeated fires initially increase the number of snags but eventually caused a decline in snag number. This pattern was due to the change in the relative numbers of live and dead trees and their fates from one year to the next. When restoration by fire begins, there are many live trees and comparatively few snags. During the early years of restoration at this site, the number of snags that fell to the ground was less than the number of live trees that were killed by fire, many of which remain standing as snags. Therefore, the number of snags initially increases with the introduction of fire. However, as restoration by fire continues, not only does the number of live trees decline, but the remaining live trees are the more fire-resistant ones, either due to their adaptations, *e.g.*, thicker bark in *Quercus macrocarpa*, or due to their location, *e.g.*, sheltered by a wetland. Therefore, the number of live trees that are killed by subsequent fires declines. At the same time, as snags are weakened by repeated fires and decay, the frequency with which they fall increases. When

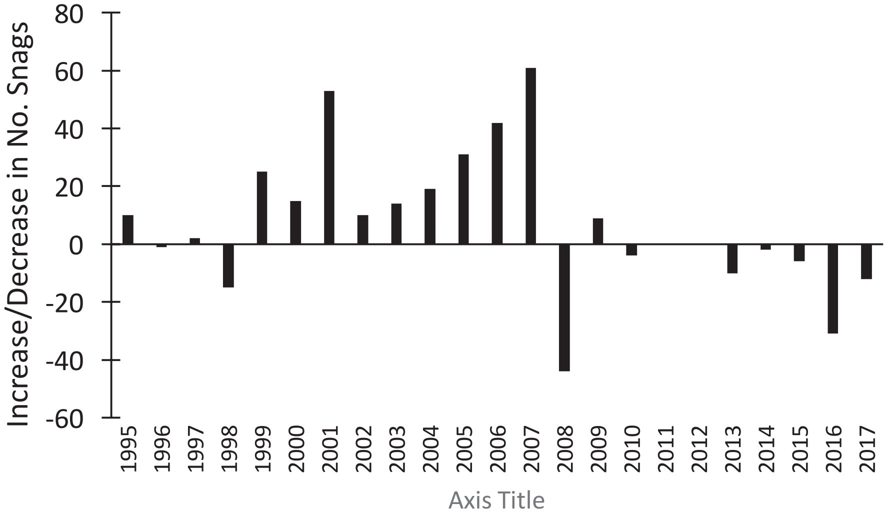

FIG. 7.—The increase or decrease in number of snags in Burn Unit 3 during each of the 23 y. Fire was introduced in 2000

the number of snags that fall exceeds the number of live trees that are killed and remain standing, the number of snags declines. Prior to the introduction of fire in BU 3 in 2000, there were annual oscillations in the direction of snag abundance change (Fig. 7). However, once fire was introduced, there was a steady increase in the number of snags through 2007. Following 2007 except for a small increase in snags in 2009, the number of snags steadily declined. It should be noted in several western forest studies prescribed fire did not result in high tree mortality and the production of more snags (Horton and Manning, 1998; Holden *et al.*, 2006; Bagne *et al.*, 2008), as was the case when prescribed fire was introduced in this study.

Other studies have shown features of the snags (*e.g.*, degree of decay, hardness of the wood, size of the snag, species of the tree) can be important in determining the use of the snag by cavity nesting birds (Raphael and White, 1984; Conner *et al.*, 1994; Farris *et al.*, 2002). While this study did not assess the effects of these snag features, the results of this and Johnston's (2007) study have shown simply increasing the number of standing dead trees (snags) in a savanna enhances the richness of the bird community, both with respect to feeding guilds and number of species, often including uncommon species or species on the decline, *e.g.*, the Red-headed Woodpecker and the Lark Sparrow in this study.

These results have restoration and management implications. If managers want to restore a savanna in a way that will enhance the breeding bird community, they will want to manage the environment in a way that maintains a high number of snags. What this study showed is restoration by fire at this site initially increases the number of snags. However, if the site continues to be burned frequently, the number of snags inevitably and substantially declines. Therefore, managers should consider recording the number of snags in their restoration site annually. Once the number of snags begins to decline, managers might consider halting the burns for a while or increasing the amount of time between burns to prolong the period of high snag abundance and prevent a rapid decline in dead tree numbers. Alternatively, if managers wanted to continue burning, they could take steps to minimize the effects of the fire on existing snags by removing vegetation surrounding snags and raking the surrounding soil to create targeted fire breaks (Kathryn Purcell, pers. comm.)

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LITERATURE CITED

AU, L., D. E. ANDERSON, AND M. A. DAVIS. 2008. Patterns in bird community structure related to restoration of Minnesota dry oak savannas across a prairie to oak woodland ecological gradient. *Nat. Areas. J.*, **28**:330–341.

AXELROD, A. N. AND F. D. IRVING. 1978. Some effects of prescribed fire at Cedar Creek Natural History Area. *J. Minnesota Acad. Sci.*, **44**:9–11.

BAGNE, K. E., PURCELL, K. L., AND ROTENBERRY, J. T. 2008. Prescribed fire, snag population dynamics, and avian nest selection. *Forest Ecol. Manage.*, **255**:99–105.

BERGSTROM, D. 1977. The legacy of the standing dead, p. 5–8. *In*: Forestry research: What's new in the West (July 1977). USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, CO.

CONNER, R. N., S. D. JONES, AND G. D. JONES. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. *Wils. Bull.*, **106**:242–257.

DAVIS, M. A., D. W. PETERSON, P. B. REICH, M. CROZIER, T. QUERY, E. MITCHELL, J. HUNTINGTON, AND P. BAZAKAS. 2000. Restoring savanna using fire: Impact on the breeding bird community. *Rest. Ecol.*, **8**:30–40.

DE GRAFF, R. M, N. G. TILGHMAN, AND S. H. ANDERSON. 1985. Foraging guilds of North American birds. *Env. Manage.*, **9**:493–536.

FABER-LANGENDOEN, D. AND M. DAVIS 1995. Effects of fire frequency on tree canopy cover at Allison Savanna, eastcentral Minnesota, U.S.A. *Nat. Areas. J*, **15**:319–328.

FARRIS, K. L., E. O. GARTON, P. J. HEGLUND, S. ZACK, AND P. J. SHEA. 2002. Woodpecker foraging and the successional decay of ponderosa pine, p 237–246. *In*: W.F. Laudenslayer Jr., P. J. Shea, B. E. Valentine, C. P. Weatherspoon, T. E. Lisle (technical coordinators). Proceedings of the symposium on the ecology and management of dead wood in western forests, Reno, Nevada, November 2–4, 1999. U.S. Forest Service General Technical Report PSW-181, Albany, California, USA.

GRIGAL, D. F., L. M. CHAMBERLAIN, H. R. FINNEY, D. V. WROBLEWKI, AND E. R. GROSS. 1974. Soils of the Cedar Creek Natural History Area. Misc. Report 123. University of Minnesota Agr. Exp. Stn, St. Paul.

GRUNDEL, R. AND N. B. PAVLOVIC. 2007. Distinctiveness, use, and value of Midwestern oak savannas and woodlands as avian habitats. *The Auk.*, **124**:969–985.

HERKERT, H. R. 1994. Breeding birds of the midwestern grassland-forest transition zone: Who were they and where are they now? p. 151–154. *In:* J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni (eds). Proceedings of the North American Conference on Barrens and Savannas 1994, Illinois State University, Normal, Illinois.

HOLDEN, Z., P. MORGAN, M. ROLLINS, AND R. WRIGHT. 2006. Ponderosa pine snag densities following multiple fires in the Gila Wilderness, New Mexico. *Forest Ecol. Manage.*, **221**:140–146.

HORTON, S. AND R. MANNAN. 1988. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forest. *Wildl. Soc. Bull.*, **16**:37–44.

IRVING, F. D. 1970. Field instruction in prescribed burning techniques at the University of Minnesota. *Proceedings of the Tall Timbers Fire Ecology Conference*, **10**:323–331.

JOHNSTON, C. N. 2007. Ecological and behavioral impacts of snag density on cavity nesting birds in the oak savanna. M.Sc. Thesis, Bowling Green State University.

MORRISON, M. L. 1995. Wildlife conservation and restoration ecology. *Restor.* and *Manage. Notes*, **13**:203–208.

MORRISON, M. AND M. RAPHAEL. 1993. Modeling the dynamics of snags. *Ecol. Appl.*, **3**:322–330.

NUZZO. V. 1986. Extent and status of Midwest oak savanna: pre-settlement and 1985. *Nat. Areas J.*, **6**:6–35.
PETERJOHN, B. AND J. R. SAUER. 1994. The North American breeding bird survey. *Birding*, **26**:386–398.
PETERSON, D. W. AND P. B. REICH. 2001. Prescribed fire in oak savanna: Fire frequency effects on stand structure and dynamics. *Ecol. Appl.*, **11**:914–927.
RAPHAEL, M. G. AND M. WHITE. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. *Wildl. Monogr.*, **86**:1–66.
ROBINSON, S. K. 1994. Bird communities of restored barrens and savannas of southern Illinois, p. 147–150. *In:* J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni (eds). Proceedings of the North American Conference on Barrens and Savannas 1994, Illinois State University, Normal, Illinois.
SAMPLE, D. W. AND M. J. MOSSMAN. 1994. Birds of Wisconsin oak savannas: past, present, and future, p. 155–159. *In:* J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni (ed). Proceedings of the North American Conference on Barrens and Savannas 1994, Illinois State University, Normal, Illinois.
SAUER, J. R., J. E. HINES, J. E. FALLON, K. L. PARDIECK, D. J. ZIOLKOWSKI, JR., AND W. A. LINK. 2014. The North American Breeding Bird Survey, Results and Analysis 1966–2012. Version 02.19.2014 USGS Patuxent Wildlife Research Center, Laurel, MD.
SCOTT, V. E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. *J. For.*, **76**:26–28.
SCOTT, V. E. AND J. A. WHELAN. 1978. Dead trees used by cavity-nesting birds on the Fraser Experimental Forest: A case history. USDA For. Serv. Gen. Tech. Rep. RM-360, 4 p. Rocky Mt. For. And Range Exp. Stn., Fort Collins, CO.
TESTER, J. R. 1989. Effects fire frequency on oak savanna in east-central Minnesota. Bull. *Torrey. Bot. Club*, **116**:134–144.
THOMPSON, F. R., III, REIDY, J. L., KENDRICK, S. W., FITZGERALD, J. A. 2012. Songbirds in managed and non-managed savannas and woodlands in the central hardwoods region, p. 159–169. *In*: Dey, D. C.; Stambaugh, M. C.; Clark, S. L.; Schweitzer, C. J., (eds). Proceedings of the 4th fire in eastern oak forests conference; 2011 May 17–19; Springfield, MO. Gen. Tech. Rep. NRS-P-102. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

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