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The Community Composition of Bark and Wood Boring Beetles in Woodland and Endangered Midwestern Oak Savanna Habitats

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Abstract

The economic and ecological significance of many exotic and native outbreaking species of Scolytine beetles is well understood, however much less is known of most other native Scolytine and woodboring beetles, particularly in the American Midwest. Further, very few studies have focused on oak ecosystems, particularly endangered oak savannas. To investigate the woodboring beetle communities of Midwestern oak savannas we selected a high-quality remnant black oak savanna and adjacent woodland site in Northeastern Illinois. We trapped for 12 weeks from late May to August. Overall, 4.5 times more beetles were found in savanna than woodland sites. There was also greater diversity of all beetles and greater average species richness of exotic species in savanna than paired woodland sites. Interestingly, Bostrichids, particularly the little studied *Scobicia bidentata*, were highly abundant at savanna sites compared to nearby woodland. These results suggest that Midwestern oak savanna may be an important habitat for both native and exotic woodboring beetles and deserves greater attention as habitat for these insects.

Introduction

Bark and ambrosia beetles (Curculionidae: Scolytinae and Platypodinae) are incredibly diverse families with over 470 species in North America alone (Wood 1982, Pfammatter et al. 2011). Most of these species play an important role in woodland ecosystems as primary decomposers, consuming or boring through the phloem and xylem of stressed or fallen trees. This feeding behavior facilitates the entrance of other invertebrates into logs and can promote the abundance of important macro detritivores (Zuo et al. 2016). While many bark beetles feed on stressed and dead trees, nearly 1% of native North American species attack live trees (Bentz et al. 2010). Despite this small percentage, these species have caused widespread mortality of forest trees across the United States, with some becoming more aggressive once introduced through human transport (Pfammatter et al. 2011, Nielson et al. 2010).

Beetles of the family Bostrichidae closely resemble Scolytines and play similar roles in the environment as hardwood borers. Certain species are of economic importance as pests of stored wood and grain (Beiriger et al. 1996). Nearly 70 native and 4 exotic species of Bostrichid occur throughout the United States, although relatively few studies have focused on this family. Due to the economic and ecological significance of Scolytines in North American forests and the lack of information on Bostrichids in wood boring beetle literature, more research on these groups is needed.

Studies of the ecology of bark beetles in the United States have historically focused on the few economically important *Dendroctonus* species that attack conifers. Outbreaks of *D. ponderosae* in western North America and *D. frontalis* in the southeastern United States have garnered much attention (Rosenberger et al. 2017, 2018, Bentz et al. 2010, Asaro et al. 2017). While these species feed on pine, many others are only associated with hardwood trees and are little studied (Dodds 2011, Gough et al. 2014, Raffa et al. 2017). Additionally, virtually no studies have assessed bark and wood boring beetles in relation to oak habitats in the United States.

Midwestern oak savannas are unique biodiversity hotspots, characterized by the presence of a variety of grasses and herbaceous vegetation along with open grown oaks producing between 10-50% canopy cover (Curtis 1959). Black oak savanna is further defined by the dominance of black oaks (*Quercus velutina*) in well-draining, sandy soil. This fire-maintained ecosystem was once dominant in the Midwest, covering over 11 million hectares of land and serving as a buffer between woodland in the east and prairie in the west (Nuzzo 1986). Currently less than 0.2% of Midwestern oak savanna remains and is classified as a critically endangered ecosystem. The causes for this decline include destruction for agriculture, logging, and fire suppression which converts savannas and grasslands into woodlands and forests (Grundel & Pavlovic, 2007).

Little is known about the animal community or the extent to which species may serve as savanna specialists (Grundel & Pavlovic, 2007). Even less is known about the insect communities and the roles they play in these ecosystems beyond some work on Karner blue butterflies (Larsen et al. 2016, Wood et al. 2011). Scolytines have been shown to increase in abundance after fires (Schwilk et al. 2006), suggesting that the historically fire-maintained systems of savanna habitats may be valuable Scolytine habitat.

The objective of our study was to determine if black oak savannas support distinct communities of wood boring beetles from now abundant woodland in the American Midwest. Currently there is a lack of information on bark and wood boring beetle species richness and abundance in the Midwest, particularly for native species. Additionally, there are few studies assessing populations in relation to habitat type. This study is one of the first to our knowledge to focus on beetle communities of any kind in endangered Midwestern black oak savannas.

Methods

In order to assess species richness and abundance across each habitat type, three different locations were selected in Northeastern Illinois: Pembroke Savanna Nature Preserve (41.075914, -87.639732), Mskoda Land and Water Preserve (41.079417, -87.656744), and Braidwood Dunes and Savanna Nature Preserve (41.259828, -88.195871). Each site represented remnant black oak savanna, degraded savanna (now woodland), and woodland habitats respectively. Within each location three transects were established and separated by at least 150m. Each transect contained five traps baited with ethanol ultra-high release lures (Alpha Scents, Inc.) and separated by 100m each according to methods described by Steininger et al. (2015) and Lenhert et al. (2013). Collections occurred on the same day each week for a total of 12 weeks, beginning May 21 and ending August 13, with an exception of the 2nd week of June in which a collection was unable to occur and thus combined with the following week. After each collection beetles were sorted, pinned, and identified to species utilizing Wood (1982), Beiriger et al. (1996), and other resources.

Throughout the study period, site characteristics were assessed including canopy cover, trees species composition and diameter at breast height (DBH), basal area, and coarse woody debris (CWD) volume. Canopy cover was obtained using a spherical densiometer at each trap in addition to points 15m away in three cardinal directions: north, east, and west. All other characteristics were assessed within a 10m radius fixed plot (0.04 ha) around each trap similar to methods by Reed et al. (2010). All trees with a diameter ≥2.5cm within these plots were measured for DBH using a diameter tape as well as identified to species. Additionally, CWD volume was quantified by measuring all debris with a diameter ≥2.5cm within each plot and recording the radius at each end as well as the total length.

Means for abundance, species richness and diversity (Shannon-Wiener index, H) were calculated for the sum of each trap across the entire trapping period. T-tests were used in R to compare habitat and beetle community differences across savanna and woodland sites. Model assumptions (homoscedasticity and normality of errors) were visually assessed and square root transformation was utilized in most cases to meet model assumptions. Species accumulation curves were constructed using the BiodiversityR package in R.

Results

A total of 558 beetles were caught throughout the 12-week trapping period. Abundance was highest in exotic Scolytines (252), then Bostrichids (242), and lowest in native Scolytines (64) (Table 1). Among Scolytines there were 4 native and 3 exotic species (*Xyleborinus saxesenii*, *Xylosandrus germanus*, *Ambrosiodmus rubricollis*) (Table 1). Exotic specimens accounted for 80% of Scolytines collected. All 9 species of Bostrichidae found were native (Table 1).

Overall 4.5 times more beetles were found in savanna (M = 23.07, SE = 1.03) on average per site (n = 15) across the summer than in woodland sites (n = 12) (M = 5.25, SE = 1.03), t(25) = 5.26, p = 0.000019). More Bostrichids [t(25) = 3.99, p = 0.0005], exotic bark beetles [t(25) = 3.74, p = 0.00095], and native bark beetles [t(25) = 2.49, p = 0.02] were found in savanna than woodland (Fig. 1). Species richness was also greater in savanna for exotic bark beetles [t(25) = 4.92, p = 0.000045] but not native bark beetles [t(25) = 1.44, p = 0.16], or Bostrichids [t(25) = 1.61, p = 0.12] (Fig. 2). Diversity (H) was greater in Pembroke Savanna than in Mskoda Woodland, t(25) = 2.12, p = 0.044 (Fig. 3).

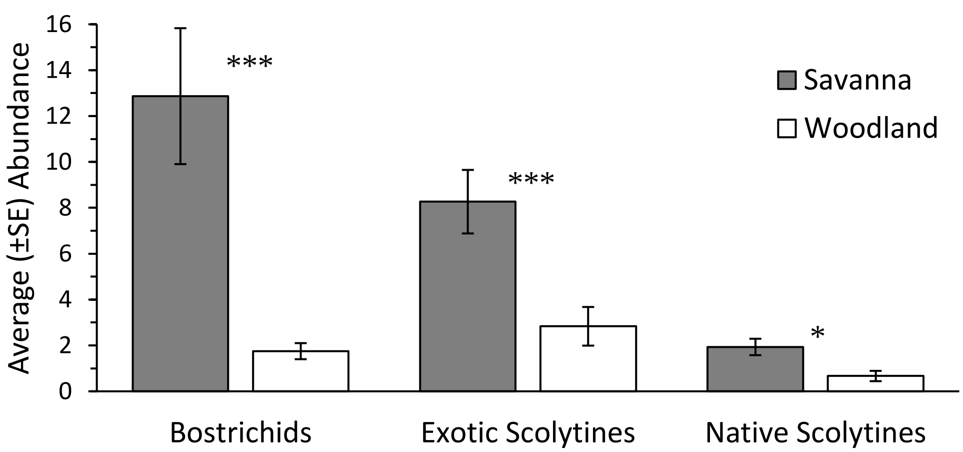

Figure 1. Average abundance of wood boring beetles per trap throughout the sampling period (May 21 – August 13, 2019) in remnant savanna vs. woodland habitats in Northeastern Illinois. *** indicates p-values less than <0.001, **<0.01, *<0.05, NS>0.05.

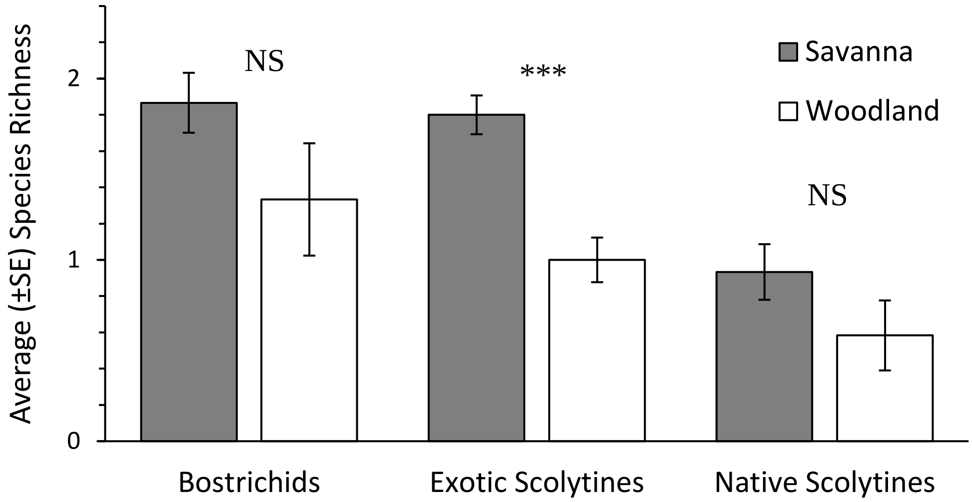

Figure 2. Average species richness of wood boring beetles per trap throughout the sampling period (May 21 – August 13, 2019) in remnant savanna vs. woodland habitats in Northeastern Illinois. *** indicates p-values less than <0.001, **<0.01, *<0.05, NS>0.05.

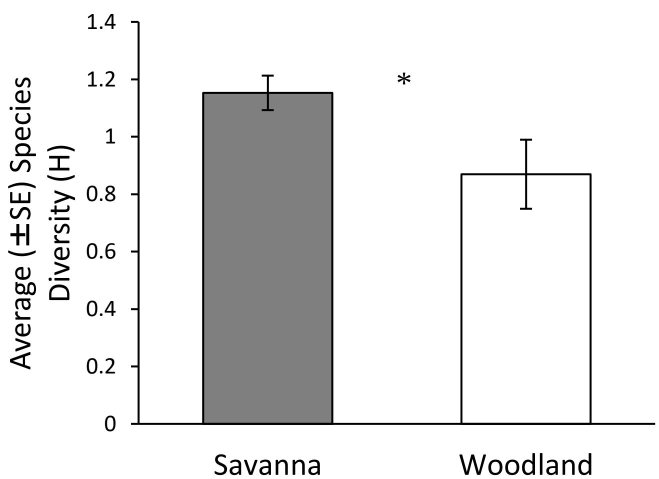

Figure 3. Average species diversity from Shannon-Wiener Index (H) of wood boring beetles per trap throughout the sampling period (May 21 – August 13, 2019) in remnant savanna vs. woodland habitats in Northeastern Illinois. *** indicates p-values less than <0.001, **<0.01, *<0.05, NS>0.05.

Table 1. Average (±SE) number of wood boring beetles caught per trap throughout the sampling period (May 21 – August 13, 2019) in remnant savanna vs woodland habitats in Northeastern Illinois.

Species	**Origin**	**n**	**Pembroke savanna**	**Mskoda woodland**	**Braidwood woodland**
Scolytinae:					
Xyleborinus saxesenii	Exotic	186	7.20 (±1.39)	2.67 (±0.87)	2.80 (±0.78)
Hypothenemus interstitialis	Native	25	1.33 (±0.39)	0.25 (±0.18)	0.13 (±0.09)
Xylosandrus germanus	Exotic	65	1.07 (±0.25)	0.17 (±0.11)	3.13 (±0.96)
Pseudopityophthorus minutissimus	Native	24	0.40 (±0.24)	0.25 (±0.13)	1.00 (±0.47)
Xyleborus xylographus	Native	8	0.20 (±0.11)	0.08 (±0.08)	0.27 (±0.12)
Phloeotribus liminaris	Native	7	0	0.08 (±0.08)	0.40 (±0.27)
Ambrosiodmus rubricollis	Exotic	1	0	0	0.07 (±0.07)
Bostrichidae:					
Scobicia bidentata	Native	208	11.6 (±2.88)	0.92 (±0.31)	1.40 (±0.38)
Amphicerus bicaudatus	Native	15	1.00 (±0.24)	0	0
Lichenophanes bicornis	Native	2	0.13 (±0.09)	0	0
Bostrichidae (M14)	Native	5	0.07 (±0.07)	0.25 (±0.13)	0.07 (±0.07)
Xylobiops basilaris	Native	2	0.07 (±0.07)	0.08 (±0.08)	0
Bostrichidae (M13)	Native	4	0	0.25 (±0.13)	0.07 (±0.07)
Priobium sp.	Native	2	0	0.17 (±0.11)	0
Bostrichidae (M9)	Native	3	0	0.08 (±0.08)	0.07 (±0.07)
Bostrichidae (M20)	Native	1	0	0	0.07 (±0.07)

Flight activity of both Scolytines and Bostrichids varied over the trapping period and from site to site (Fig. 4). Initial flight occurred before trapping began in late May as indicated by some species declining from a peak at the first sampling. Flight continued after trapping stopped as indicated by several species with rising emergence numbers by the end of the trapping period mid-August (Fig. 4). Phenology models are represented for the six most abundant species, however too few of the remaining species were captured to make models. The species accumulation curve for each site indicates that most beetles flying during the study period were likely captured with the trapping effort expended, although some additional beetles may have been found with additional trapping effort in both woodland sites. Most active beetles were likely captured with the effort provided in savanna (Fig 5).

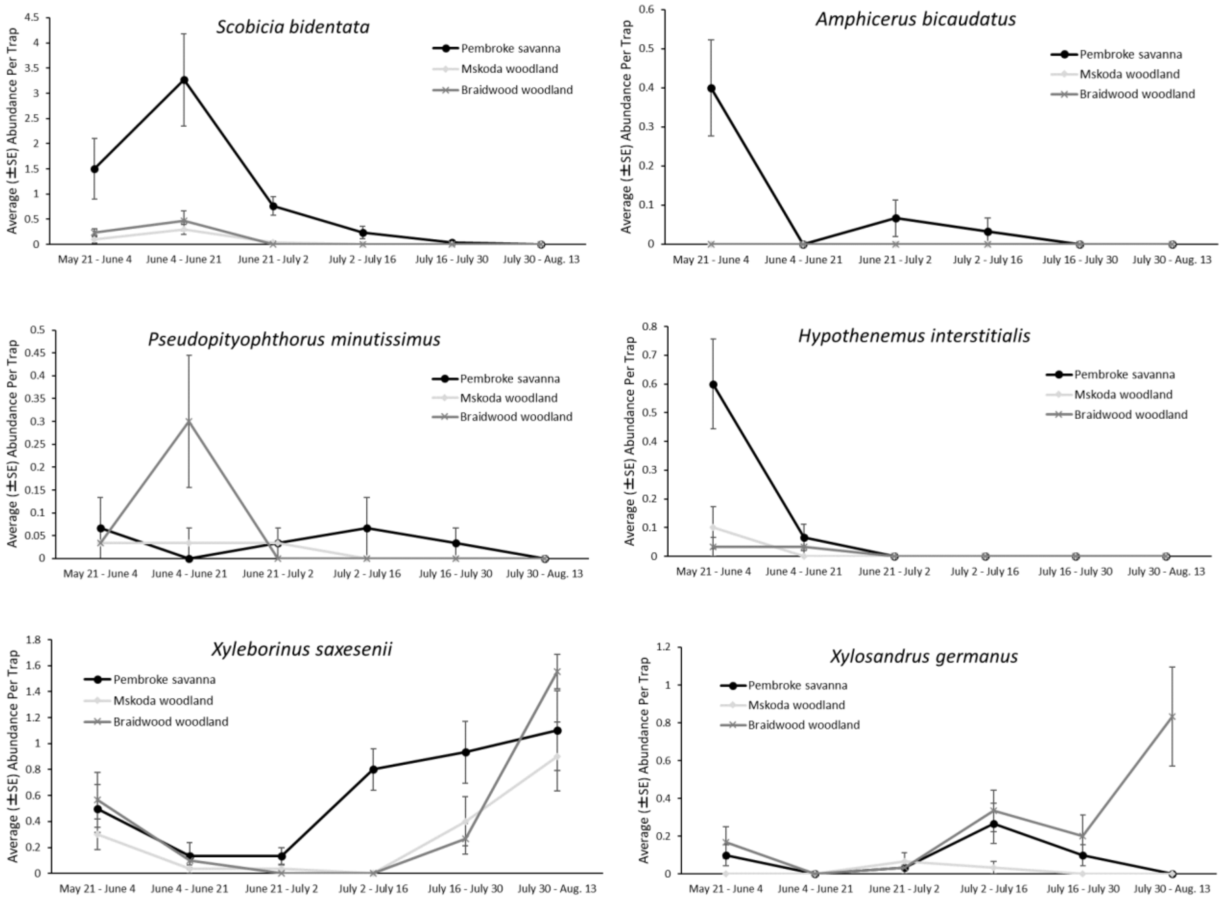

Figure 4. Phenology of the 6 most abundant species within each habitat type over the 12-week trapping period (May 21 – August 13, 2019) consisting of 2 Bostrichids (*S. bidentata* and *A. bicaudatus*), 2 exotic Scolytines (*P. munutissimus* and *H. interstitialis*), and 2 exotic Scolytines (*X. saxesenii* and *X. germanus*).

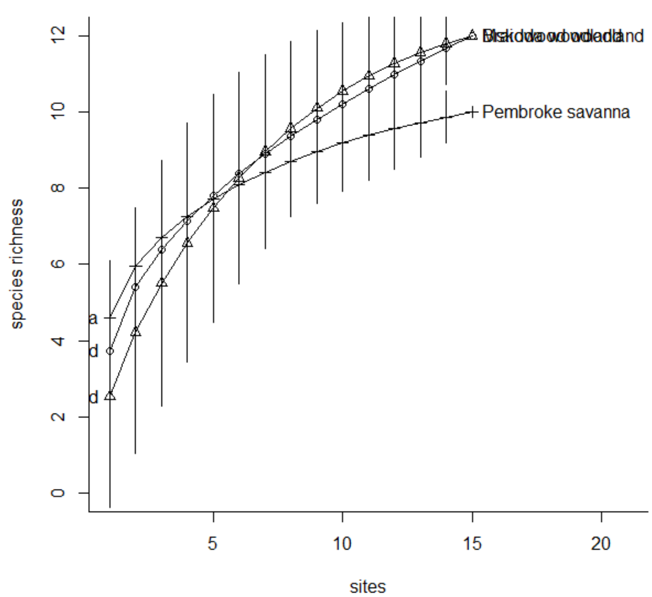

Figure 5. Species accumulation curves of all wood boring beetles within each habitat type over the 12-week trapping period (May 21 – August 13, 2019).

When comparing locations and site characteristics, average canopy cover [t(25) = -7.9, p<0.0001] and tree density [t(25)=-7.17, p<0.0001] were greater in woodland sites (Fig. 6). Course woody debris volume was also higher in woodland sites [t(25)=-2.37, p=0.026], however savanna and woodland did not differ significantly in the number of snags [t(25)=1.32, p=0.20] (Fig. 6).

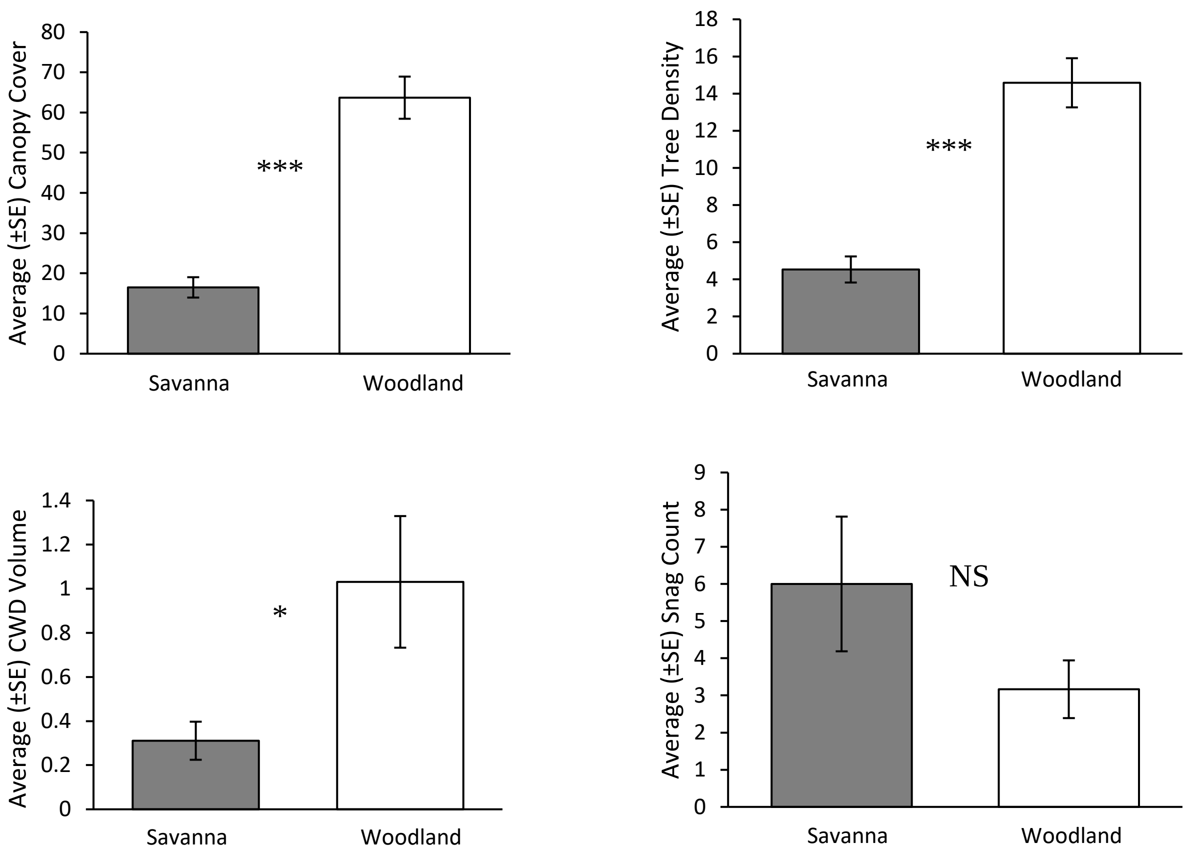

Figure 6. Average canopy cover, tree density, coarse woody debris (CWD) volume, and snag count within savanna and woodland habitats. *** indicates p-values less than <0.001, **<0.01, *<0.05, NS>0.05.

Discussion

Our study suggests a clear distinction in species dominance and composition of wood boring beetles in remnant Midwestern oak savanna and woodland habitat types during the summer months. We show that both Bostrichids and exotic Scolytines are more successful at colonizing savannas than woodlands. Savannas harbor a greater abundance of both native and exotic wood boring beetles (Fig. 1) and this habitat supports a greater species richness of exotic Scolytines (Fig. 2). These are intriguing findings as woodlands contain greater tree density, providing more host material and more course woody debris for colonization. Reed et al. (2010) suggest that bark beetle abundance is correlated with increased stand age and deadwood volume, however our woodland sites on average contained greater CWD volume and no significant difference in snags, yet savanna sites had much greater abundance of beetles.

Further, our species phenology data suggests differences in emergence between habitat types. *X. germanus* for example had a population surge later in the year at the Braidwood woodland site while declining at the other paired sites nearly 50 km away (Fig. 4). This difference in separate woodland sites suggests that site characteristics may influence the development and lifecycles of wood boring beetles in this study. Other species, such as *S. bidentata* and *X. saxesenii*, were present in each site and displayed similar emergence trends at each location, although abundance was far greater in the savanna before evening out later in the year.

One important defining factor that separates savanna from woodland is the presence of fire regimes to maintain open savanna ecosystems. Pembroke savanna experiences these burns to prevent it from degrading into a woodland. These fires alter site characteristics, particularly by reducing available deadwood material for breeding, and increasing stressed trees used as hosts. Each of these factors contributes to the complexity of both habitats and may influence the bark and wood boring beetle communities.

Overall, our Scolytine species abundance findings are similar to those of previous studies in nearby areas. Helm et al. (2015) recorded *X. saxesenii* and *X. germanus* in far greater abundance than other exotic species in Northeastern Illinois. Reed et al. (2010) found *X.*

saxesenii as most abundant overall, and numerous other exotic Scolytines in far greater abundance than most native species, similar to our results. Our study did not find as many species as these previous investigations however, and overall abundance was much lower. These differences may be attributed to a more focused study with a shorter trapping period, fewer traps within smaller locations, less variability in lure use, and less habitat variation.

One surprising finding was the high abundance of Bostrichids, especially within savanna sites. Beetles of the family Bostrichidae are little studied species with little work focusing on their regional distribution and community compositions in the Midwest. *S. bidentata* was the most abundant beetle found in this study and occurred in far greater numbers in savanna sites. Apple twig borer (*A. bicaudatus*) was also found in abundance in the savanna, but never occurred at either woodland site. Little is known about *A. bicaudatus* beyond its tendency to infest apple and grape twigs along with madrone and oak comprising its native host (Cranshaw et al. 2017).

Finding a high abundance of both Bostrichids in the savanna raises questions as to the generalizability of these findings to all savanna types, and the potential for savanna specialists of which there are few known animal species. One potential explanation for Bostrichid abundance in savannas is the condition of the trees and deadwood at these sites. Bostrichids are known to infest furniture and stored or seasoned wood (Baker 1972). The savanna sites chosen for this study are characteristically dry and sandy, thus the downed logs and CWD are drier and less broken-down compared to the rotting and moist woody debris of the woodland, showing similarities to furniture and stored wood products. Future work should investigate this hypothesis further.

More work on woodboring beetle communities in savannas is needed. Many species emerged and may have peaked activity before we began trapping in late May. Based on our phenology data (Fig. 4), future studies should begin earlier in the year and ideally trap for longer as Pfammatter et al. (2011) and Helm et al. (2015) have. Further assessment should also be conducted of the difference between savanna and woodland habitat types, including dead limb counts, plant community assessments, and moisture levels of downed woody debris. Pairing more savanna and woodland sites will also better determine how generalizable our findings are to other locations. Investigations focusing on Bostrichid beetles, particularly *S. bidentata* and *A. bicaudatus*, which have been little studied to date, will be incredibly valuable to expanding the knowledge of this family and the roles they play in various ecosystems.

Overall our results demonstrated a difference in the bark and wood boring beetle communities of woodland and savannas in the American Midwest. Many savanna systems are in decline around the world, both in temperate and tropical regions (Noss et al. 1995). Unfortunately, the insect communities of these ecosystems are rarely investigated despite oak savannas once dominating the American Midwest. Our work shows similar or more beetles in savannas than woodlands, and specifically more Bostrichids (Fig. 1) despite fewer trees (Fig. 6). Native insect communities that utilize stressed or dead trees may be abundant in these ecosystems due to the historical reliance on regular burn cycles that cause stress and kill trees. Despite this little to no work has investigated such communities in savannas to date, and more work is needed to characterize these communities before they are lost.

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