ture conservation efforts. This gathering of data contributes to Bird Atlases, like the Wisconsin Breed Bird Atlas I and II.

As the Wisconsin Society for Ornithology works to improve our conservation efforts and habitat management on the Honey Creek Nature Reserve and work with the Wisconsin Department of Natural Resources for conservation management of habitat for Prairie Chickens at Buena Vista, we rely on a combination of scientific data and citizen science.

There is heartening evidence that birds can respond quickly and positively to conservation action. Many waterfowl species have undergone significant increases in populations largely in part to coordinated conservation efforts in wetlands. Through focused conservation efforts, Peregrine Falcons and Bald Eagles came back from the brink of extinction.

We invite you to join us in protecting natural landscapes in Wisconsin. These habitats and the bellwethers (the birds) of our environment form the foundation upon which our precious resources, our wildlife, and the lives of our children depend. Ultimately, community science fosters a greater appreciation for nature and empowers people to make a difference. Cooperative conservation efforts among the government, conservation organizations, private landowners, hunters, and birdwatchers—and you—can make a difference with your participation and support.

Alicia King
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Soundscapes and Bird Distribution During Post-fledging and Fall Migration in a Southern Wisconsin Forest

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ABSTRACT

Over one-third of North America's bird species, including many Neotropical migrants and forest-dependent species, are facing steep and widespread declines. The post-fledging and fall migration periods of the annual cycle remain poorly understood despite their importance for juvenile survival and fitness. Active forest management practices such as prescribed fire and tree thinning are widely used to restore oak woodland structure and promote biodiversity, yet their influence on bird habitat use during these non-breeding phases is largely unknown. To address this gap, we used bioacoustic monitoring and arthropod sampling to examine spatiotemporal patterns of avian distribution in the Baraboo Hills of southern Wisconsin. The study was conducted across six forested sites representing managed upland woodlands, unmanaged uplands, and stream gorges. We used bioacoustic recordings collected from mid-July to mid-October 2021 to quantify avian activity using the Acoustic Complexity Index (ACI) and measured arthropod biomass with malaise traps along a gradient of management intensity. We used generalized additive models to evaluate temporal and habitat-based variation in ACI, its relationship with arthropod biomass, and habitat use of focal bird species detected through automated acoustic recognition. Diurnal ACI, arthropod biomass, and bird detections all varied seasonally and among habitats. ACI reached its highest value in managed uplands and had three seasonal peaks: one during post-fledging and two during fall migration. Arthropod biomass was positively associated with ACI and was greater in managed than unmanaged uplands, suggesting that food availability influenced avian communities and thus acoustic activity. Focal bird species followed seasonally-dynamic habitat use patterns: managed uplands were used frequently during post-fledging while unmanaged uplands were used frequently during fall migration, and stream gorges were not frequently used. Together, these findings underscore the importance of maintaining diverse and interconnected forest habitats, where a mosaic of managed and

unmanaged areas supports the needs of forest birds throughout the annual cycle.

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INTRODUCTION

Over one-third of North America's bird species are of high or moderate conservation concern, including many Eastern Forest species (North American Bird Conservation Initiative, 2025). To conserve these species, strategies that span the entire annual cycle are increasingly emphasized, yet post-fledging and fall migration periods remain understudied (Faaborg et al., 2010; Marra et al., 2015). Although birds are generally more flexible in habitat use during post-fledging and fall migration than during nesting, habitat quality during these phases continues to play a critical role in survival and fitness (Streby et al., 2014; Vitz & Rodewald, 2011).

For some forest species, post-fledging habitat can differ from nesting habitat, and thus dynamic landscapes with multiple successional stages are required to complete full breeding cycles (Fiss et al., 2020; Streby & Andersen, 2013). For example, Ovenbird (*Seiurus aurocapilla*), Wood Thrush (*Hylocichla mustelina*) and Red-eyed Vireo (*Vireo olivaceus*) fledglings use early-successional forest patches and areas with dense understory vegetation while adult birds select core mature forest habitat while nesting (Burke et al., 2017; Pagen et al., 2000; Vega Rivera et al., 1998). For other species, including Rose-breasted Grosbeak (*Pheucticus ludovicianus*) and Acadian Flycatcher (*Empidonax virescens*), post-fledging and nesting habitats do not differ (Jenkins et al., 2017; Moore et al., 2010).

Habitat associations and within-season movements of forest birds have been linked to food resources as well as vegetation structure. For example, the non-nesting distributions of Ovenbirds and American Redstarts (*Setophaga ruticilla)* were best explained by shrub-level invertebrate prey availability and secondarily by habitat characteristics (Streby et al., 2011a). For seasonal frugivores, fruit availability in regenerating clearcuts may influence habitat movements during the post-fledging period (Vitz & Rodewald, 2007), and molting adult Wood Thrushes were more likely to be found in areas with high fruit density as well as high shrub cover (Gow & Stutchbury, 2013).

Managing forest habitat for wildlife conservation has the potential to benefit a wide range of bird species. In particular, North American woodlands, which covered more than 50 million hectares prior to European settlement, are disappearing due to long-term fire exclusion and mesophication (Hanberry et al., 2018, 2020; Nowacki & Abrams, 2008). Conservation of these habitats involves active management, including prescribed fire and mechanical thinning, and is associated with improving plant, arthropod, and bird diversity (Akresh et al., 2023; Boves et al., 2013; Morris et al., 2013). Altering forest structure can shift patterns of bird movement and habitat use (Leonard et al., 2021), and the influence of woodland management on post-fledging and fall migration habitat is not well understood.

Bioacoustic monitoring is a valuable tool for assessing biodiversity and habitat quality, and evaluating conservation efforts (Bradfer-Lawrence et al., 2019; Burivalova et al., 2021; Campos-Cerqueira et al., 2020; Vega-Hidalgo et al., 2021). Soundscapes—the total collection of sounds within a given environment—can be quantified using acoustic indices, which capture statistical features of recordings such as variation in frequency and amplitude (Alcocer et al., 2022; Bradfer-Lawrence et al., 2019). Among these, the Acoustic Complexity Index (ACI) is particularly sensitive to the temporal and spectral variability of bird vocalizations (Pieretti et al., 2011). In our study area—the Baraboo Hills of southern Wisconsin—ACI has been shown to correlate strongly with forest bird species richness and abundance during the nesting season (Persche et al., 2024).

This study examined how bird communities use three forest habitats—managed upland woodlands, unmanaged uplands, and stream gorges—during the post-fledging and fall migration periods. We aimed to (1) characterize diurnal peaks in ACI across habitats to assess temporal patterns in distribution, (2) evaluate the relationship between ACI and arthropod availability, and (3) examine habitat use among winter residents, Neotropical migrants, and interior forest specialists. Winter residents included four commonly detected species throughout our study area (Table 1). We chose five Neotropical migrant species to examine because they do not have strong habitat associations within upland forests during the breeding season in our study area (Table 1; Persche et al., 2025a). Finally, we chose three interior forest specialists that were less abundant in managed uplands during the breeding season (Table 1; Persche et al., 2025a). We hypothesized that (1) ACI, reflecting avian abundance and richness, would be highest where food resources and structural complexity were greatest, particularly in managed uplands, followed by stream gorges and then unmanaged uplands. We further hypothesized that (2) along a gradient of woodland management in upland sites, aerial arthropod biomass would be positively correlated with avian richness and abundance, and thus ACI. Fi-

Table 1. Focal species in three guilds with common and scientific names. The species-specific threshold above which we considered a BirdNET automated detection to be accurate is also reported.

Common Name	Scientific Name	BirdNET Threshold
Winter Residents		
Black-capped Chickadee	*Poecile atricapillus*	0.304
Northern Cardinal	*Cardinalis cardinalis*	0.211
Tufted Titmouse	*Baeolophus bicolor*	0.253
White-breasted Nuthatch	*Sitta carolinensis*	0.200
Neotropical Migrants		
Red-eyed Vireo	*Vireo olivaceus*	0.200
Rose-Breasted Grosbeak	*Pheucticus ludovicianus*	0.310
Scarlet Tanager	*Piranga olivacea*	0.203
Yellow-billed Cuckoo	*Coccyzus americanus*	0.225
Yellow-throated Vireo	*Vireo flavifrons*	0.800
Interior Forest Specialists		
Ovenbird	*Seiurus aurocapilla*	0.302
Veery	*Catharus fuscescens*	0.200
Wood Thrush	*Hylocichla mustelina*	0.203

nally, we hypothesized that (3) all focal bird groups we examined (Table 1) would favor habitats with greater resource availability and structural habitat complexity during post-fledging and fall migration. By examining acoustic indices, arthropod biomass, and species detections across forest habitats, this study advances understanding of how habitat structure and resource availability shape bird communities during two critical stages of the annual cycle.

METHODS

Study Area: The South Range of the Baraboo Hills (Sauk County, Wisconsin, USA) is a 40 × 4–8 km stretch of quartzite and sandstone bluffs covered by largely contiguous forest (Fig. 1). Forests are dominated by oak, maple, and other central hardwoods, with relict conifers—Eastern Hemlock (*Tsuga canadensis*) and White Pine (*Pinus strobus*)—restricted to protected stream gorges and rocky slopes. Oak forests, primarily Red Oak (*Quercus rubra*) and White Oak (*Q. alba*), form the predominant natural cover (Lange, 1998). Before European settlement, the landscape supported a mix of fire-adapted oak savannas and woodlands on south-facing slopes and blufftops, and mesic forests on north slopes (Mossman & Lange, 1982), with fires occurring roughly every four years (Meunier, 2022).

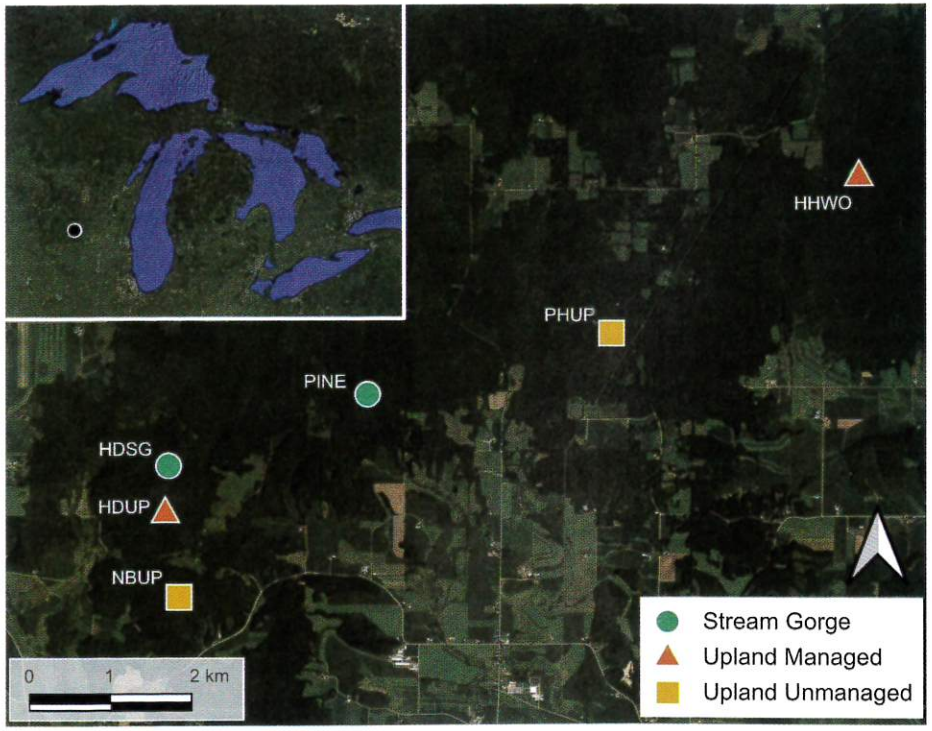

Figure 1. Study area map showing location of stream gorge sites (green circles), managed upland sites (orange triangles) and unmanaged upland sites (yellow squares) in the Baraboo Hills, Sauk Co., WI, USA. Inset map shows location of study area in the context of the Great Lakes region. Site codes shown on map correspond to site history information in Table 2.

Table 2. Study site names and management histories. Study site locations are shown in Fig. 1. An asterisk indicates an upland site that was sampled for arthropod biomass using a malaise trap.

Site Name	Site Code	Management History
Stream Gorges		
Hemlock Draw Stream Gorge	*HDSG*	None
Pine Hollow	*PINE*	None
Unmanaged Uplands		
Natural Bridge Uplands	*NBUP*	None
Pan Hollow Uplands*	*PHUP*	None
Managed Uplands		
Happy Hill Woodland*	*HHWO*	Two years of management, 1 fire
Hemlock Draw Uplands*	*HDUP*	Five years of management, 3 fires

Study Design: We established six study sites (Fig. 1; Table 2) across three forest habitat types: upland sites managed for oak woodland conditions, unmanaged uplands, and unmanaged stream gorges. Study sites were circular with a 100m radius (~ 3ha) and were centered on a bioacoustic recorder. All sites were located >200 m from a road or other hard forest edge and embedded within several thousand hectares of contiguous habitat. The managed sites (Table 2) had predominantly White Oak overstories and open mid- and understories due to periodic mechanical thinning and low-intensity prescribed burns. The unmanaged sites (Table 2) had oak-hickory (*Quercus* and *Carya* spp.) overstories and dense mid- and understories with the remnants of open glade-like ridges. Stream gorge sites (Table 2), within narrow rocky valleys, were located in stands of mature Eastern Hemlock and White Pine, with deciduous trees in the surrounding area including Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula alleghaniensis*), and Red Oak. The understory in stream gorges sites was patchy and included Witch Hazel (*Hamamelis virginiana*), Blue Beech (*Carpinus caroliniana*) and saplings of dominant tree species.

Field Data Collection: We used one Bioacoustic Audio Recorder (BAR Recorders, Frontier Labs) per site, set to record continuously for 24-hour periods every other day from 15 July–15 October 2021. We used a 44.1 kHz sample rate, 40 dB gain, and one omnidirectional microphone per recorder. Recorders were attached to a tree trunk 2m above the ground. In stream gorge sites, recorders were located >30 m from the stream, and as water levels were low in the late summer and fall sounds from the stream did not mask biological sounds detected by the recorders.

To measure an index of arthropod biomass, we set one malaise trap within 50m of the recorder in three upland sites which encompassed a gradient of woodland management (Table 2). The traps were open continuously between 15 August and 15 October, checked every 7-10 days, and arthropod specimens were weighed in an alcohol-wet state using a lab balance accurate to within 0.01-g following methods in (Hallmann et al., 2017). Mean arthropod biomass per trap day (mg) was calculated for each interval between trap checks.

Data Analysis: All statistical analyses were carried out in R version 4.2.2. Due to challenges with equipment, the exact number of recording days per week varied within each site. For example, data from four days were removed due to storms that caused water droplets to fall directly on the top of the recorder or nearby leaves. Additionally, we limited our recording data to complete 24-h cycles to avoid biasing diel patterns in the soundscape.

To process the bioacoustic data, we calculated Acoustic Complexity Index (ACI), following methods described by (Truskinger et al., 2014), and using the Analysis Program (Towsey et al., 2018). We limited our soundscape phenology analysis to diurnal ACI (30 min prior to sunrise - 30 min after sunset each day).

We modeled diurnal ACI in each forest habitat type across post-fledging and fall migration using generalized additive models (Wood, 2006) in the R package 'mgcv' (Wood, 2011). ACI was transformed as $1/x^2$ using a box cox transformation in the R package 'MASS' (Venables & Ripley, 2002). We controlled for spatial autocorrelation and site effects by including 'site' as a random effect in all models. We considered covariates including habitat type, as well as Julian date and hour of the day with smoothing terms and tested all possible combinations including interaction terms. For all candidate models, we tested model fit using 'gam.check' and 'concurvity' with a cutoff value of 0.8 in the R package 'mgcv' (Wood, 2011). We only considered models that met all assumptions and had no collinearity or concurvity between predictors, and used AIC to rank candidate models. Model output was visualized using the R package 'ggplot' (Wickham, 2016).

We compared arthropod biomass and ACI values across upland sites along a gradient of management intensity using boxplots of raw data. We considered two time periods corresponding to the avian life cycle: post-fledging (15 July–31 August) and fall migration (1 September–15 October). We tested statistical significance of mean values using Wilcoxon signed rank tests, a nonparametric equivalent of t-tests, and plotted mean arthropod biomass per trap day and mean diurnal ACI in each study site using the R package 'ggplot' (Wickham, 2016).

To detect focal bird species at each study site across the season, we used the deep learning model BirdNET (Model Version V2.4; Kahl et al., 2021) to detect bird calls of all regional bird species in our recordings. We randomly selected 100 calls per focal species to validate the detections using the sound analysis program RavenPro (Version 1.6; K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology), and classified them as true or false. We then fit a logistic regression in R, setting the probability of a true positive to 0.9, in order to establish a species-specific threshold (Table 1), using the confidence scores assigned by BirdNET, above which we considered all the detections to be accurate. Using a sliding window of five days, we calculate the detection probability for each species in each habitat for each day of the season. We modeled this detection probability for each focal species across the study period using generalized additive models in the R package 'mgcv' (Wood, 2006; 2011). Detection data were not transformed, and all models included habitat type and week of the season. We again tested model fit using 'gam.check' and 'concurvity' in the R package 'mgcv' (Wood, 2011) and visualized output using the R package 'ggplot' (Wickham, 2016).

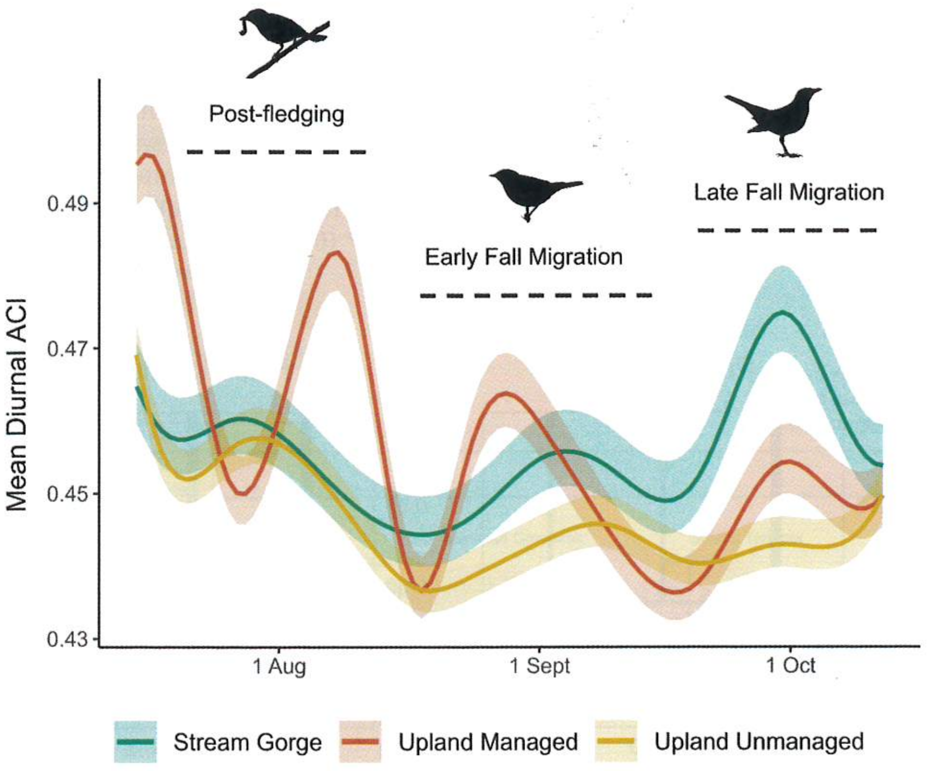

Figure 2. Modeled mean diurnal Acoustic Complexity Index (ACI) during post-fledging and fall migration in three forested habitats in the Baraboo Hills (Sauk Co., WI, USA). Stream gorge sites are shown in green, while managed upland woodlands are shown in orange and unmanaged uplands are shown in yellow. 95% confidence intervals are shown in lighter color. Migration season is divided into early fall (i.e., peak warbler and vireo migration), and late fall (i.e., peak sparrow and thrush migration).

RESULTS

Diurnal ACI varied significantly among forest habitat types over the study period. Each habitat followed a unique seasonal and daily soundscape pattern. Mean diurnal ACI showed three major peaks corresponding to the post-fledging period (late July–early August), early fall migration (late August–early September), and late fall migration (late September–mid-October; Fig. 2). During post-fledging and early fall migration, ACI was significantly higher in managed uplands than in other habitats, whereas during late fall migration, ACI was highest in stream gorges (Fig. 2). Peak ACI values were greatest during the post-fledging period, followed by late fall migration and then early fall migration. As hypothesized, unmanaged uplands exhibited the lowest ACI throughout the study, with significant differences from other habitats occurring primarily during fall migration (Fig. 2).

Arthropod biomass was consistently higher in at least one managed site (HHWO and HDUP) relative to the unmanaged site (PHUP) across both seasons, as hypothesized (Fig. 3). During the post-fledging season, mean arthropod biomass per trap day was highest at the low-management-intensity site, HHWO (1.28 mg; $P < 0.05$), compared to PHUP (0.77 mg), but did not differ

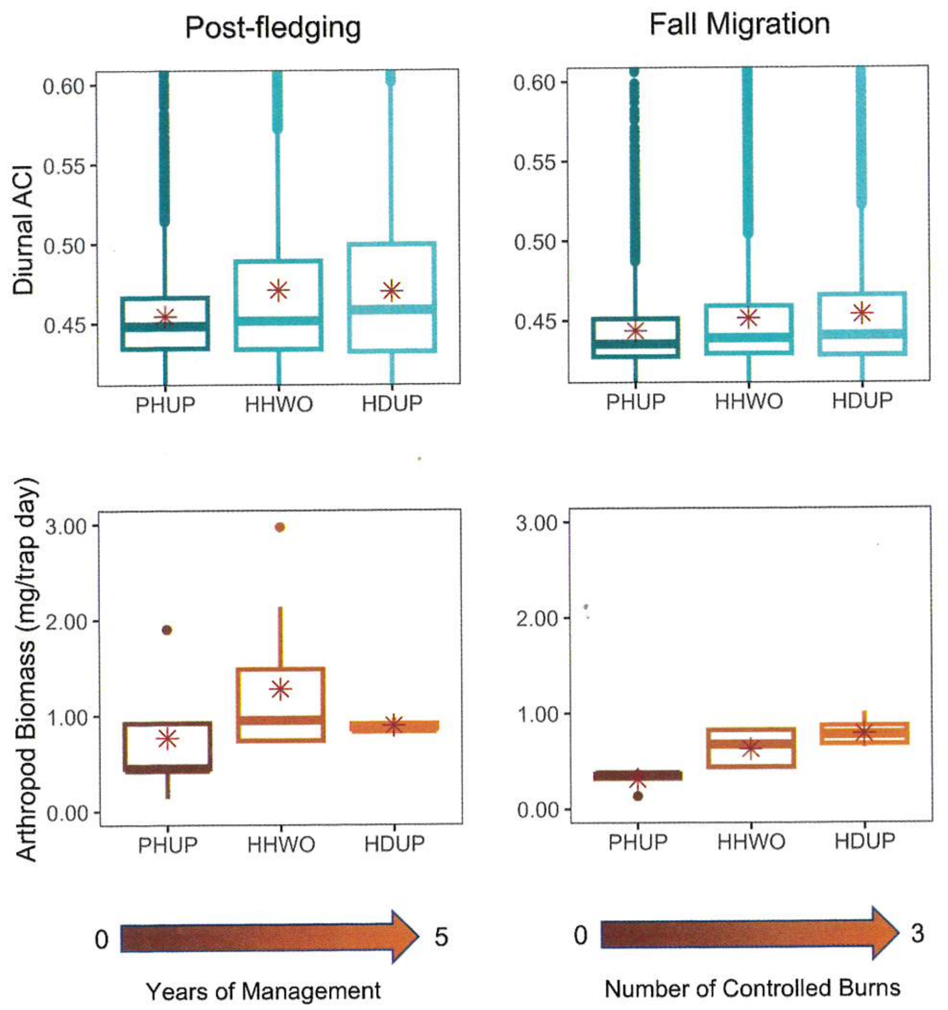

Figure 3. Diurnal Acoustic Complexity Index (ACI) and arthropod biomass collected in malaise traps at three upland sites across a gradient of woodland management in 2021. ACI was significantly different ($p<0.05$) between PHUP and HHWO during post-fledging but not for any other pairs of sites. Arthropod biomass was significantly different between all three sites during the fall and between PHUP and HHWO during post-fledging.

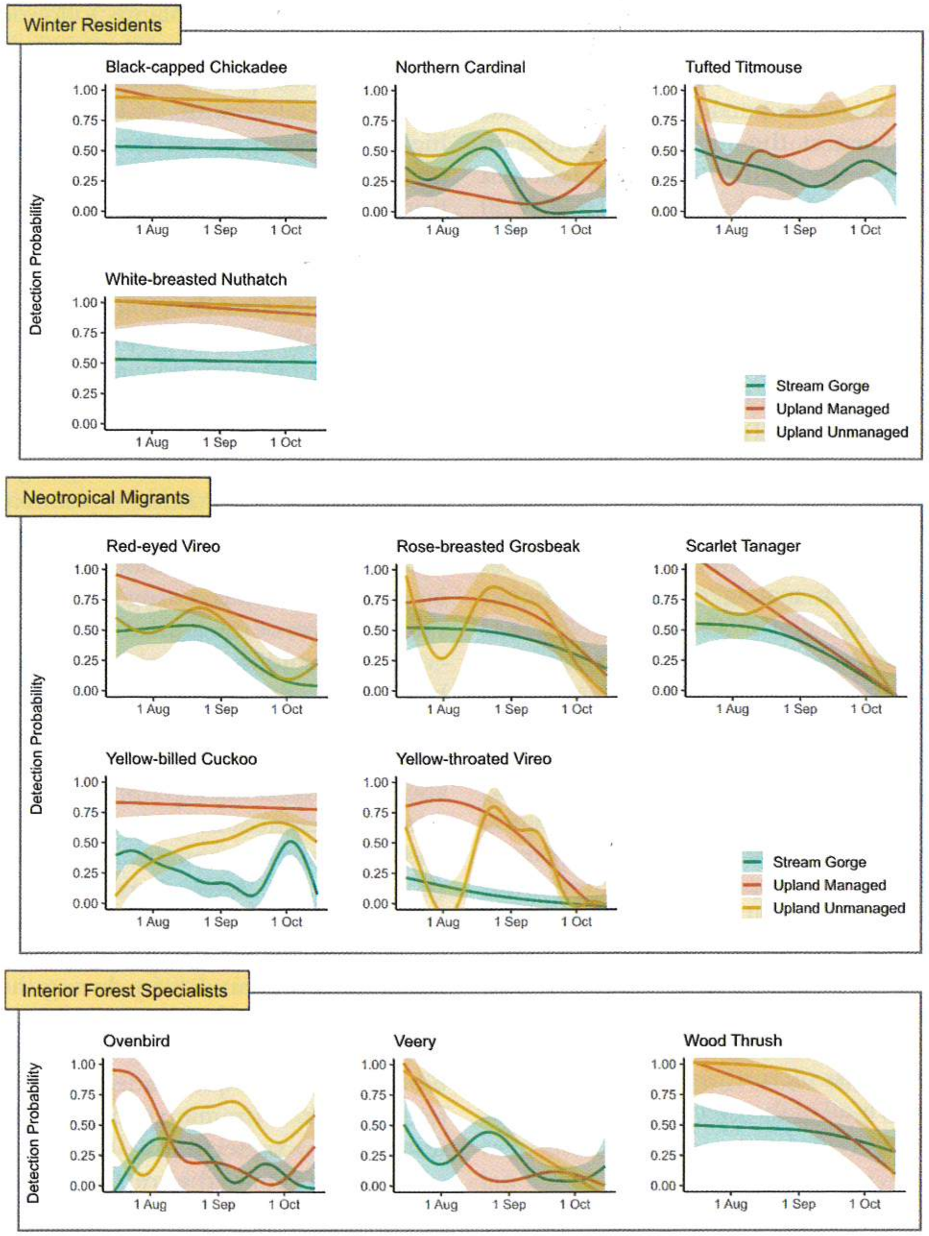

Figure 4. Modeled daily detection probability for each species of three focal guilds in each forest habitat type in the Baraboo Hills (Sauk Co., WI, USA). Stream gorge sites are shown in green, while managed upland woodlands are shown in orange and unmanaged uplands are shown in yellow. 95% confidence intervals are shown in a lighter color.

significantly from HDUP (0.89 mg). Mean biomass at PHUP and HDUP were not significantly different. During fall migration, arthropod biomass was greatest at the high-management-intensity site, HDUP (0.80 mg), followed by HHWO (0.64 mg) and PHUP (0.30 mg; $P < 0.05$).

Mean diurnal ACI mirrored the distribution of arthropod biomass (Fig. 3). During the post-fledging season, ACI was significantly higher at HHWO (0.471) than at PHUP (0.454; $P = 0.01$), while ACI at HDUP (0.470) did not differ significantly from either of the other sites. During fall migration, HDUP exhibited slightly higher ACI (0.454) than HHWO (0.452; $P = 0.06$), and both managed sites had higher ACI than PHUP (0.444; $P < 0.05$).

All twelve focal bird species exhibited distinct seasonal detection patterns among habitats (Fig. 4). As hypothesized, managed uplands were frequently selected during the post-fledging season, particularly by Neotropical migrants. Contrary to our hypotheses, unmanaged uplands were frequently used during fall migration by nearly all species examined, and were important for winter residents and interior forest specialists throughout the study (Fig. 4). Unexpectedly, stream gorges were used less often than other habitats by nearly all of the species throughout the study (Fig. 4).

Discussion

Our findings show that bird distribution during the post-fledging and fall migration periods is shaped by interacting effects of forest habitat type, arthropod food resources, and seasonality. Diurnal ACI had distinct seasonality among habitats, and tended to be highest in managed uplands followed by stream gorges and then unmanaged uplands. Arthropod biomass was positively correlated with ACI and was higher in managed sites, suggesting that food availability influences bird activity, and thus soundscapes. Bird guilds also showed seasonally-dynamic habitat use with managed uplands being important during post-fledging, while unmanaged uplands were frequently used than during fall migration, and stream gorges were used less often. Collectively, these findings indicate that landscape position and habitat management influence both resource availability and acoustic activity, and that a given bird species may use a variety of forest habitats during these transitional stages of the annual cycle.

Previous studies in Baraboo Hills uplands during the avian breeding season showed that unmanaged forests support lower bird species richness and abundance than managed sites, largely due to differences in habitat structure and arthropod resource availability (Persche et al., 2025a; Persche et al., 2025b). Based on these patterns, we expected unmanaged sites to show similarly reduced avian activity during the post-fledging and fall migration periods. While we found that arthropod biomass and ACI were indeed consistently lower in unmanaged uplands, distribution patterns of the focal species we examined were more complex. During the post-fledging period, many Neotropical migrant focal species were detected less frequently in unmanaged uplands and appeared to shift toward managed upland sites. This aligned with previous research showing that fledgling birds often move into structurally complex, early-successional habitats after leaving the nest (Burke et al., 2017; Pagen et al., 2000; Streby et al., 2011b). However, two other species, Veery and Wood Thrush, were detected most frequently in unmanaged uplands throughout the study period.

During fall migration, habitat use patterns shifted among focal bird species. Compared to managed uplands, unmanaged uplands were used equally or more often by all species that appeared to avoid them during the post-fledging period. Unmanaged sites were also frequently used by resident species and interior forest specialists throughout the study. As arthropod biomass in unmanaged sites was lower than it was in managed sites during fall migration, other factors such as canopy cover or landscape position may be driving habitat selection. After decades of fire exclusion in these sites, the resulting low arthropod biomass could be an ecological trap, leaving migrating birds vulnerable to limited food resources and reduced chances of survival during migration. Conversely, the amount of arthropod biomass we measured in unmanaged uplands in this study could still be greater than that of forest fragments, and thus arthropod biomass may not be limiting in this extensive forest landscape during migration. Finally, other food resources (i.e., fruit, seeds, arthropod biomass in the forest canopy), or a particular group of arthropods, could be more important than total understory arthropod biomass in shaping bird distribution across uplands during the fall.

Although ACI was strongly correlated with avian richness and abundance during the breeding season in the Baraboo Hills (Persche et al., 2024), its relationship with distribution of focal species was weaker during post-fledging and migration periods. This may reflect the reduced prominence of bird vocalizations in the soundscape during late summer and fall, when singing declines following the breakup of nesting territories, and insect sounds dominate the soundscape. Consequently, ACI may be more sensitive to overall acoustic activity driven by bird abundance, rather than by the presence of the twelve focal bird species we examined in this study.

The twelve focal bird species we examined all followed different seasonal detection patterns, likely driven by habitat associations, foraging behavior, and migration strategies. Three of the four winter residents—Black-capped Chickadee, Tufted Titmouse, and White-breasted Nuthatch—were most frequently detected in unmanaged uplands, closely followed by managed uplands, and were detected less often in stream gorges. The fourth winter resident, Northern Cardinal, displayed a more complex seasonal pattern with a pronounced detection peak in stream gorges during August and in unmanaged uplands during early September. Northern Cardinals were detected most often often in unmanaged uplands and least often in managed uplands throughout the study period.

Of the Neotropical migrants, Red-eyed Vireo, Rose-breasted Grosbeak, Scarlet Tanager, and Yellow-throated Vireo followed similar trajectories: they were most abundant in managed uplands (except for Rose-breasted Grosbeak) at the start of the study, and their detection probabilies gradually reduced during the season as more individuals migrated. These four species were detected least often in stream gorges throughout the study. In unmanaged uplands, they were frequently detected at the end of nesting season, rarely detected during post-fledging, and then frequently detected during fall migration. Yellow-billed Cuckoo detections were highest in managed uplands and lowest in stream gorges throughout the season, with intermediate and seasonally increasing presence in unmanaged uplands. Because Yellow-billed Cuckoos are know to move widely following the abundance of caterpillars (Hughes et al., 2020), their distribution during this study may have been related to colonial caterpillar species rather than the forest habitat types we examined per se.

Among the three interior forest specialists, Ovenbirds had the most dynamic seasonal habitat use pattern. They were detected more frequently in managed uplands than unmanaged uplands during post-fledging, but the opposite was true during fall migration. This shift from interior forest breeding habitat to early-successional habitat that provides more cover during post-fledging has been observed across the breeding range (Porneluzi et al., 2020), and Ovenbirds also were found to be less abundant in shrub-sapling habitat during fall migration in Pennsylvania (Rodewald & Brittingham, 2004). Finally, we detected Ovenbirds an intermediate amount in stream gorges where detection probability remained fairly low throughout the season. This parallels findings from Ohio, where migrating Ovenbirds were more abundant in upland than riparian forests (Rodewald & Matthews, 2005), and from breeding habitat where Ovenbirds tend to avoid steep rocky areas (Mossman & Lange, 1982; Porneluzi et al., 2020). Veeries had the highest detection probability in unmanaged uplands throughout the season, although they were also detected frequently in managed uplands during post-fledging and stream gorges during fall migration. Given their preference for mesic and often early-successional forest habitats during nesting as well as migration (Heckscher et al. 2020), this distribution pattern was unexpected. Wood Thrush detections were highest in both upland habitats at the end of nesting season and declined steadily through post-fledging and fall migration in managed uplands and stream gorges, but continued to occur in unmanaged uplands more often than in other habitats through fall migration. Thus, unlike in other studies (see Evans et al., 2020), we did not observe a shift away from mature forest habitat towards shrubby early-successional habitat during the post-breeding period.

Overall, this study contributes to our understanding of the ecological value of maintaining diverse, interconnected forest habitats. Each of the twelve focal bird species, and the total acoustic complexity of each site, followed distinct temporal and spatial patterns across the three habitat types. Every habitat was selected by forest birds during at least one period of the post-fledging and fall migration seasons. This study demonstrates that managed and unmanaged uplands play complementary roles for over half of the bird species we examined. Managed uplands, with their early-successional structure and high arthropod biomass, provided important habitat for many species during the post-fledging period, while unmanaged uplands became increasingly important during migration. These findings support the view that resilient landscapes, containing a mosaic of habitat structures and management histories, enhance overall habitat quality by allowing birds to exploit heterogeneous resources (Anderson et al., 2023; Beller et al., 2019). In light of widespread bird declines, forest management strategies that sustain both structural heterogeneity and habitat connectivity will be essential for conserving migratory bird populations through all stages of the annual cycle.

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Data Availability: Data available upon request.

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