

**Final Report: Assessing Wildlife Response to NRCS Conservation Programs Targeting Eastern
Deciduous Forests: 2017-2021
A Conservation Effects Assessment Project (CEAP) Assessment
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Introduction

Eastern forests of North America and the biodiversity they support are jeopardized by myriad threats such as invasive species, diseases, excessive deer browsing, conversion and parcelization, unbalanced age class distributions, lack of natural disturbances (*i.e.*, fire), and unsustainable timber harvest practices (Hain 2006; Rooney & Waller 2003; Dey 2014). Collectively, these factors threaten forest health and resiliency and reduce the population viability of associated species. Indeed, many wildlife species dependent on eastern forests are exhibiting declining populations (*i.e.*, Rosenberg et al. 2019). To reverse these declines, several forest health and habitat management efforts have been initiated in recent years by a diverse group of government agencies, NGO conservation groups, and academics. While efforts on public forestlands are an important component of these efforts (NABCI 2011), those that focus on private lands are critical given that >70 percent of existing forest cover in the eastern United States is privately-owned (Widmann 2015). The sheer amount of forests under private ownership in the eastern U.S. places a huge stewardship responsibility on the shoulders of private landowners (NABCI 2013).

The U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) offers financial and technical assistance to private landowners to plan and implement wildlife habitat improvements on their lands (Cuzio et al. 2013). For example, NRCS initiated the *Working Lands for Wildlife* (WLFW) Partnership in 2012 to improve habitat availability for eight imperiled species including the Appalachian population of the Golden-winged Warbler (*Vermivora chrysoptera*) and a similar effort in the western Great Lakes states through the *Regional Conservation Partnership Program* (RCPP). This migratory songbird breeds in heavily forested landscapes of eastern North America. The implementation of science-based best management practices that create or maintain Golden-winged Warbler breeding habitat is thought to be an important step to reversing the species' decline (Roth et al. 2012). Similarly, NRCS initiated an effort to enhance habitat conditions on private forestlands for another imperiled migratory songbird, the Cerulean Warbler (*Setophaga cerulea*), via a project funded through the *Regional Conservation Partnership Program* (RCPP). To date, over 23,500 acres have been enrolled in WLFW-Golden-winged Warbler (Litviatis et al 2021) and more than 8,000 acres have been enrolled in the RCPP-Cerulean Warbler (Shaffer et al 2022.)

Certainly, the acres enrolled in NRCS's WLFW and RCPP represent progress toward achieving habitat goals for their respective focal species. However, biological monitoring is also a critical part of evaluating the program outcomes. The results of monitoring wildlife response to programs that aim to restore habitat for focal species like Golden-winged and Cerulean warblers are important for several reasons including: 1) gauging the potential contribution that NRCS programs make toward a species recovery; 2) assessing the need to modify existing habitat management guidelines to improve species-specific outcomes; and 3) quantifying the potential benefits that these programs have for other species associated with these habitats.

In 2017, Indiana University of Pennsylvania and its partners continued a collaborative effort to monitor Golden-winged Warbler use of private lands enrolled in NRCS conservation programs and managed habitat on nearby public lands. We also continued a monitoring effort to assess American Woodcock response to NRCS conservation programs. Based on the results of Roberts et al. (2017) and Koh et al. (2016), our partnership initiated a study in 2017 to fine tune a pollinator survey protocol in regenerating timber harvest (McNeil et al. 2018). In 2018 and 2019, we implemented the pollinator survey protocol on over 100 sites managed for Golden-winged Warbler nesting habitat on private and public lands in Pennsylvania. From 2018-2020, we conducted monitoring in Pennsylvania and western Maryland to assess Cerulean Warbler use of 139 sites enrolled in the RCPP-Cerulean Warbler project. We

also completed an analysis that combined avian survey data collected from WLFW-GWWA and RCPP-GWWA sites to examine the potential for Golden-winged and Cerulean Warbler to serve as a pair of focal umbrella species for the conservation of upland deciduous forest bird communities in the Central Appalachians. Finally, we conducted a two-year study that evaluated avian and vegetation communities in paired fenced-unfenced regenerating timber harvests. This project is important because deer exclusion fencing is a conservation practice that is often used for WLFW and RCPP projects.

Herein, we present summary findings from the above-mentioned project components associated with the assessment of forest management efforts that target Golden-winged and Cerulean warbler breeding season habitat in the Central Appalachian and western Great Lakes regions. Many of these project components have been the focus of graduate theses and dissertations, published in peer-reviewed journals, or are currently in review. Along with each project component we have provided citations for all associated written products. The project components summarized below include: 1) Golden-winged Warbler density and occupancy in managed communities in the Great Lakes and Central Appalachians; 2) Golden-winged Warbler post-fledging habitat selection and survival in Pennsylvania; 3) American Woodcock occupancy and density in early successional communities in the central Appalachians and western Great Lakes; 4) Pollinator diversity and density within regenerating timber harvests on public and private lands in Pennsylvania; 5) Cerulean Warbler response to forest management on lands enrolled in RCPP in Pennsylvania and western Maryland; 6) Golden-winged and Cerulean Warbler as a pair of focal umbrella species; 7) assessing the effectiveness of deer exclusion fencing to avian and plant communities in operational-scale regenerating timber harvests. Findings from the assessment efforts summarized here will help ensure an effective, and ever-evolving, long-term conservation strategy for creating and maintaining breeding season habitat for the Golden-winged and Cerulean warblers, and to understanding the degree to which these efforts benefit associated taxa.

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Component Summaries

Component 1: Golden-winged Warbler density and occupancy in managed communities in the Great Lakes and Central Appalachians

McNeil, D.J, A.D. Rodewald, V. Ruiz-Gutierrez, K. Johnson, M. Strimas-Mackey, S. Petzinger, O.J. Robinson, G.E. Soto, A. Dhondt, and J.L. Larkin. 2020. Multi-scale Drivers of Restoration Outcomes for an Imperiled Songbird. *Restoration Ecology* doi: 10.1111/rec.13147

Synopsis: Habitat restoration is a cornerstone of conservation, particularly for habitat-limited species. However, restoration efforts are seldom rigorously monitored at meaningful spatial scales. Poor understanding of how species respond to habitat restoration programs limits conservation efficacy for habitat-restricted species like the Golden-winged Warbler (*Vermivora chrysoptera*, GWWA). We provide one of the first concerted assessments of a national conservation program aimed at restoring songbird habitat across its breeding range. We studied GWWA response to forest habitat restoration across two broad regions with opposing population trajectories and assessed factors driving species use of restored habitats across multiple spatial scales. From 2015 to 2017, we conducted 1,145 ($n = 457$ locations) and 519 point counts ($n = 215$ locations) across the Appalachian Mountains and Great Lakes (respectively) within restored habitats. Warbler abundance within restored habitats across the Great Lakes varied with latitude, longitude, elevation, forest type, and number of growing seasons. In the Appalachian Mountains, occupancy (ψ^{\wedge}) varied with longitude, elevation, forest type, and number of growing seasons. Detections were restricted to areas within close proximity to population centers (usually <24 km) in the Appalachian Mountains, where GWWAs are rare ($\psi^{\wedge} = 0.22$, 95% confidence interval [CI]: 0.20–0.25), but not in the Great Lakes, where GWWAs remain common ($\psi^{\wedge} = 0.87$, 95% CI: 0.84–0.90). Our study suggests that, even when best management practices are carefully implemented, restoration outcomes vary within/across regions and with multiscale habitat attributes. Although assessments of concerted habitat restoration efforts remain uncommon, our study demonstrates the value of monitoring data in the adaptive management process for imperiled species.

McNeil, D.J., A.D. Rodewald, O.J. Robinson, C.J. Fiss, K.V. Rosenberg, V. Ruiz-Gutierrez, K. Aldinger, S. Petzinger, A. Dhondt, and J.L. Larkin. 2020. Regional Abundance and Local Breeding Productivity Explain Occupancy of Restored Habitats in a Migratory Songbird. *Biological Conservation*. 245,

Synopsis: Ecological restoration is a key tool in offsetting habitat loss that threatens biodiversity worldwide, but few projects are rigorously evaluated to determine if conservation objectives are achieved. We tested whether restoration outcomes for an imperiled bird, the Golden-winged Warbler (*Vermivora chrysoptera*; GWWA) met the assumptions of the ‘Field of Dreams’ hypothesis or whether local and regional population dynamics impacted restoration success. From 2015 to 18, we surveyed 514 points located in recently restored successional habitats. We used new- and published data on the survival of 341 nests and 258 fledglings to estimate GWWA breeding productivity. Occupancy and colonization of restored habitats were significantly higher in our Western Study Region (Minnesota and Wisconsin) than our Eastern Study Region (Maryland, Pennsylvania, and New Jersey), a pattern that mirrored broader regional population trends. At local scales, productivity was high in Eastern Pennsylvania (> 3 independent juveniles/pair/year) but low in Central Pennsylvania (1 juvenile/pair/year) while both Western and Central Minnesota hosted intermediate productivity (between 1 and 2 juveniles/pair/year). Productivity and occupancy covaried locally in the Eastern Study Region, while occupancy was high in the Western Study Region, despite intermediate productivity. These differences have profound implications for restoration outcomes, as GWWA possessed robust capacity to respond to habitat restoration in both regions, but this capacity was conditional upon local productivity where the species is rare. Our findings suggest that, even when restoration efforts are focused on a single species and use comparable prescriptions, interactions among processes governing habitat selection, settlement, and productivity can yield variable restoration outcomes.

Buckhart, A. D.J. McNeil, A. Roth, K. Barnstead, and J.L. Larkin. Evaluating Golden-winged Warbler Use of Plant Communities Managed with Shearing in the Western Great Lakes Ecosphere *in review*

Synopsis: Best management practices are often written by researchers to guide land managers and landowners in the creation of habitat for wildlife species of interest. These documents are based on research evaluating the habitat needs of a species, but also describe tools and strategies managers can implement to create or restore desired conditions. Shrubland and sapling shearing is a management practice often used to improve habitat for early successional species, yet little monitoring or research has focused on wildlife response to shearing. The goal of this research was to formally evaluate the effect of shrub and sapling shearing as a best management strategy for Golden-winged Warbler (*Vermivora chrysoptera*) conservation at a regional scale. Specifically, we surveyed for male Golden-winged Warblers during the breeding season in treated shearing sites and untreated reference sites across portions of the western Great Lakes to assess the effects of 1) management practice and interaction with two plant communities, sapling aspen forest and alder-dominated shrublands, and 2) the patch-level vegetation characteristics on male abundance. We found that male Golden-winged Warbler abundance was twice as high in sheared sites than mature reference sites and peaked when sapling cover was ~40%. Male abundance was also negatively associated with percent cover of forbs and non-vegetated ground. These findings highlight the importance of patch-level heterogeneity for Golden-winged Warblers and demonstrate the need for pre-treatment site assessments to help focus conservation and management efforts for target species. We encourage a site-specific nuanced approach to best management practice implementation to maximize cost efficiency and desired species outcomes.

Component 2: Golden-winged Warbler post-fledging habitat selection and survival in Pennsylvania

Fiss, C.J., D. J. McNeil, A.D. Rodewald, J.E. Duchamp, and J.L. Larkin. 2020. Post-fledging Golden-winged Warblers require forests with multiple stand developmental stages. *Condor* <https://doi.org/10.1093/condor/duaa052>

Synopsis: Our understanding of songbird habitat needs during the breeding season stems largely from studies of nest success. However, growing evidence shows that nesting habitat and post-fledging habitat often differ. Management guidelines for declining species need to be reevaluated and updated to account for habitat shifts that may occur across the full breeding cycle. The Golden-winged Warbler (*Vermivora chrysoptera*) is a declining songbird species for which best management practices (BMPs) are based overwhelmingly on nesting habitat. We studied stand-scale habitat selection by fledgling Golden-winged Warblers during May–July, 2014–2017, in 2 landscapes (2 yr of data for each landscape), 200 km apart in Pennsylvania. Across 4 yr, we radio-tagged and tracked 156 fledglings. We used discrete-choice models to evaluate habitat selection during 2 post-fledging time periods (days 1–5, days 6–28). Fledglings used a variety of cover types, but most telemetry relocations (i.e. 85%) occurred in forest in the stand initiation stage, stem exclusion stage, or mature forest upland. Fledglings primarily selected stand initiation forest during the first 5 days, but preferred habitats differed between regions during days 6–28 post-fledging. Fledglings in one landscape favored stands in the stem exclusion stage while fledglings in the other landscape continued to select stands in the initiation stage. Fledglings moved greater distances as they aged and dispersed ~750 m by day 28 post-fledging. These findings suggest the need to update Golden-winged Warbler BMPs to account for the broader habitat needs of fledglings during the breeding season. In addition, these result of habitat requirements can help guide management of dynamic forest landscapes for birds.

Fiss, C.J., D.J. McNeil, A D. Rodewald, D. Heggansteller, and J.L. Larkin. 2021. Cross-Scale Habitat Selection Reveals Within-Stand Structural Requirements for Fledgling Golden-Winged Warblers. *Avian Conservation and Ecology* 16 (1) article 16.

Synopsis: The post-fledging period remains one of the most understudied portions of the avian lifecycle despite the fact that fledglings require resources distinct from those used during nesting. Post-fledging research can further inform breeding grounds management actions and improve conservation outcomes. While the Golden-winged Warbler (*Vermivora chrysoptera*) is known to make stand-level habitat shifts between nesting and post-fledging, the microhabitat conditions selected by fledglings remains unknown. We used cross-scale habitat selection analyses to evaluate the stand-specific microhabitat conditions required by fledgling Golden-winged Warblers in Pennsylvania. From 2014 through 2017 we radio-tagged and tracked 98 fledglings associated with 80 different sub-broods. We documented habitat use and compared habitat between fledgling and nest sites. Fledglings selected areas with dense overhead and lateral vegetation across stand types. *Rubus* cover and stem density of >2 m saplings were important in stand initiation and stem- exclusion stage stands, respectively. In mature forest upland and forested wetlands, fledgling Golden-winged Warblers selected for patches with lower basal area relative to what was available. Compared to nest sites fledgling locations contained less herbaceous cover and greater overhead vegetation density apparently provided by taller woody vegetation. Our findings suggest that management actions have high potential for creating post-fledging Golden-winged Warbler habitat, especially if factors such as invasive species and over- browsing are controlled during the regeneration stage of stands. Managers may need to take a proactive approach to create the structure required by fledglings in mature forest stand types where largely intact canopies inhibit understory regeneration. Existing management

guidelines for the species should be updated to account for the unique vegetation structure required by fledglings during this stage of the lifecycle.

**McNeil, D.J., V. Ruiz-Gutierrez, A.D. Rodewald, C.J. Fiss, O.J. Robinson, and J. L. Larkin.
Decomposing Heterogeneity in Population Declines: Landscape-specific Variation in
Drivers of Productivity *in revision***

Synopsis: Population dynamics of many species are highly sensitive to variation in survival of immature individuals, yet few studies explicitly estimate survival across life stages. To better understand the demographic components of breeding productivity, we studied variation in nest and fledgling survival over three breeding seasons in a migratory songbird, the Golden-winged Warbler (*Vermivora chrysoptera*), in habitats restored according to species-specific best management practices. We assessed potential effects of breeding phenology and habitat on nest- and fledgling survival and quantified the extent to which survival rates across key life stages (egg, nestling, and fledgling) differed between a high-productivity (Pocono Mountains) and a low-productivity landscape (Pennsylvania Wilds). Variation in nest survival was explained by breeding phenology rather than microhabitat structure, while both phenology and habitat impacted fledgling survival. Our results suggest that landscape-specific differences in productivity stemmed from marked disparities in survival of nestlings and young fledglings (≤ 5 days post-fledging; lowest in Pennsylvania Wilds), but not eggs or older fledglings (> 5 days post-fledging; similar in both landscapes). Additionally, these results demonstrate that variation in breeding phenology can create heterogeneity in local productivity via its asymmetric influence on demography across life stages. Our study also illustrates how the lens through which we study breeding productivity can profoundly shape our conclusions regarding the relative contributions of different life stages to breeding performance. Low nestling- and fledgling survival in the Pennsylvania Wilds, coupled with high begging rates and low body mass, suggests food limitation as a potential driver of differences in productivity between our focal landscapes. Ultimately, our findings underscore the importance of meeting both nesting and post-fledging requirements for species of conservation concern.

Component 3: American Woodcock occupancy and density in managed communities in the Central Appalachians and western Great Lakes

McNeil, D.J., K.J. J Johnson, and J.L. Larkin. A Multi-Regional Assessment of American Woodcock (*Scolopax minor*) Response to Habitat Management Programs Targeting a Declining Songbird in the Eastern United States. Journal of Applied Ecology *in review*

Synopsis: Balancing the variable habitat needs of multiple species within the same landscape presents a major challenge for land managers and conservationists. Often, habitat management efforts that target a particular species (*e.g.*, surrogate species) are believed to benefit others that require similar habitat conditions. Studies that assess the extent to which single-species habitat management benefits associated species are warranted. One species for which the implementation of habitat management guidelines is believed to benefit associated species is the Golden-winged Warbler (*Vermivora chrysoptera*). To address widespread population declines of the Golden-winged Warbler, species-specific best management practices were developed and are guiding habitat-based conservation programs across the species' breeding range. To date, thousands of hectares of Golden-winged Warbler nesting habitat have been created across portions of the Appalachian Mountains and Great Lakes regions. One species expected to benefit from this habitat management is the American Woodcock (*Scolopax minor*). This popular game bird has been declining for decades largely due to the loss of early successional communities like those required by the Golden-winged Warbler. Herein, we examine the extent to which habitat management that

targets Golden-winged Warblers contributes to American Woodcock conservation goals across a broad geographic extent. Additionally, we assess various site and landscape level factors to elucidate the context dependencies associated with successful conservation outcomes for this non-target species. From 2015-17, we conducted 1,554 American Woodcock surveys at 774 unique locations managed using Golden-winged Warbler best management practices across the Great Lakes and Appalachian Mountains. American Woodcock density was highest at sites in the Great Lakes region (0.84 – 1.24 males/ha) as compared to the Appalachian Mountains (0.30 males/ha). Density was also dependent upon within-stand conditions (*e.g.*, basal area, woody regeneration) and landscape features (*e.g.*, wetland cover, mixed forest cover), the latter of which yielded strong geographic heterogeneity in woodcock responses. Our results demonstrate that American Woodcock can benefit from habitat management that targets the Golden-winged warbler, but the extent of these benefits is heavily driven by regional, landscape, and within-stand contexts. Collectively, low Golden-winged Warbler and American Woodcock responses to habitat management in the central Appalachians is alarming and suggests their regional populations have dropped below a threshold needed to produce adequate numbers of individuals to effectively colonize newly created early successional communities.

Gray, L., D.J. McNeil, J.T. Larkin, H.A. Parker, D. Shaffer, and J.L. Larkin. Quantifying Detection Probability of American Woodcock (*Scolopax minor*) on Transects Sampled with Thermal Cameras. *Wildlife Society Bulletin in revision*

Synopsis: Developing effective monitoring techniques for sensitive wildlife populations is essential for improving conservation outcomes. The American woodcock (*Scolopax minor*) is a declining game bird traditionally surveyed by documenting displaying males in spring but such surveys are limiting in a variety of important ways. Thermal technology may overcome many limitations of traditional monitoring techniques, however, the efficacy of this method for detecting woodcock remains unknown. To quantify woodcock thermal detection probability, we deployed- and searched for heat-emitting woodcock mounts along transects within early-successional habitats in central Pennsylvania, 2020. Most woodcock mounts were successfully discovered by technicians but detection was imperfect (n=63/110 detected; 57.2%) and declined as a function of increasing vegetation density and distance-from-transect. Although detection probability of woodcock was imperfect, thermal cameras may provide a solution to researchers aiming to assess presence/density of woodcock, and possibly similar bird species, especially when coupled with analytical methods that account for imperfect detection.

Gray, L. 2021. A Comparison of American Woodcock (*Scolopax Minor*) Occupancy in Two Early Successional Communities of the Central Appalachian Mountains. MSc. Thesis, Indiana University of Pennsylvania, Indiana, PA

Synopsis: American woodcock (*Scolopax minor*) populations have experienced steady, range-wide declines for at least the past fifty years, which is largely attributed to breeding habitat loss. Standardized population monitoring efforts are conducted annually across the species' breeding range; however, these efforts are not designed to assess local responses to habitat restoration. Although American woodcock populations are known to respond positively to some habitat management practices (*e.g.*, timber harvest and shrubland mowing), few studies have directly compared how the species responds to different practices. With that in mind, conservation efforts are most immediately needed in the Appalachian Mountains portion of the woodcock breeding range where population declines are most pronounced. This study had one primary objective: 1) Compare the influence of management practice and landscape context on American woodcock using autonomous recording units (ARU). From 15 April – 5 May 2020, we quantified male American woodcock occupancy probability at 133 locations in timber harvests (n=86) and old fields (n=47)

using ARUs. We detected singing male American woodcock at 69 of 133 (51%) survey locations. Among these, we confirmed occupancy at 41 of 86 (47%) timber harvest sites and 28 of 47 (59%) old field sites. Probability of occurrence by woodcock was best explained by the amount of >20yrs old forest within 125 m of each survey location; whereby occupancy probability (ψ) declined by a factor of nine as percent >20yrs old forest increased from 0% ($\psi = 0.80$) to 80% ($\psi = 0.09$). In contrast, we found no evidence that management practice (timber harvest vs old field) explained variation in American woodcock occupancy. Our study suggests that, in the central Appalachians, old fields and timber harvests serve as woodcock singing grounds habitat at similar rates when they occur within comparable local landscapes. Additionally, our findings demonstrate the immense value of using ARUs to conduct repeat visits within the management footprints across scores of managed sites to access American woodcock occupancy during a single season.

Component 4: Pollinator diversity and density within regenerating timber harvests on public and private lands in Pennsylvania

Lee, M., D.J. McNeil, C.L. Mathis, C.M. Grozinger, and J.L. Larkin. 2021. Microhabitats Created by Log Landings Support Abundant Flowers and Insect Pollinators within Regenerating Mixed-Oak Stands in the Central Appalachian Mountains. <https://doi.org/10.1016/j.foreco.2021.119472>

Synopsis: Despite their role as keystone organisms, insect pollinator populations have declined across many regions. Although pollinator populations face a multitude of threats, among the most important is habitat loss and degradation. In eastern North America, forested landscapes are thought to serve as strongholds for robust pollinator populations, however, even these high-quality landscapes are increasingly unsuitable for pollinators due to suppression of natural disturbances, which results in mature forests with few floral resources. To enhance landscapes for forest-dependent wildlife, land managers increasingly recognize the value of silviculture for promoting forest regeneration to support early-successional species. Although timber harvest has proven to be an invaluable tool for enhancing forest pollinator habitat, the role of microhabitat components like log landings remains unassessed. Log landings (open areas where harvested logs are loaded for transport) may serve as an important microhabitat component of early seral stands because they are expected to support open conditions and high floral abundance. We sampled 20 log landing/timber harvest interior pairs for bees, butterflies, floral resources, and structural vegetation in the Pocono Mountains of Pennsylvania from June-September 2019. Hierarchical distance models revealed that log landings supported twice as many bees (897 vs 351 bees/ha) and five times as many butterflies (433 vs 88 butterflies/ha) as timber harvest interiors. Likewise, log landings supported about 14 times as many floral resources than timber harvest interiors (109,572 vs 8,431/transect). Among log landings, those with the most floral resources also supported the most bees and butterflies. Collectively, our results support the hypothesis that log landings serve as concentrated resource hubs for bees and butterflies. Future work exploring the role of different plant species (e.g., native vs exotic) in habitat quality for early-successional pollinators would prove useful.

Mathis C.L. D.J. McNeil, Jr., M.R. Lee, D.I. King, C.M. Grozinger, C.R.V. Otto, and J.L. Larkin. 2021. Pollinator communities vary with vegetation structure and time since management within regenerating timber harvests of the Central Appalachian Mountains. *Forest Ecology and Management* 496: (2021) 119373

Synopsis: Native pollinator populations across the United States are increasingly threatened by a multitude of ecological stressors. Although the drivers behind pollinator population declines are

varied, habitat loss/degradation remains one of the most important threats. Forested landscapes, where the impacts of habitat loss/degradation are minimized, are known to support robust pollinator populations in eastern North America. Within heavily forested landscapes, timber management is already implemented as a means for improving forest health and enhancing wildlife habitat, however, little is known regarding the characteristics within regenerating timber harvests that affect forest pollinator populations. In 2018 and 2019, we monitored insect pollinators in 143 regenerating (≤ 9 growing seasons post-harvest) timber harvest sites across Pennsylvania. During 1129 survey events, we observed over 9100 bees and butterflies, 220 blooming plant taxa, and collected over 2200 pollinator specimens. Bee and butterfly abundance were positively associated with season-wide floral abundance and negatively associated with dense vegetation that inhibits the growth of understory floral resources. Particularly in late summer, few pollinators were observed in stands >6 years post-harvest, with models predicting five times more bees in 1-year-old harvests than in 9-year-old harvests. Pollinator species diversity was positively associated with floral diversity and percent forb cover, and negatively associated with percent tall (>1 m) sapling cover. These results suggest that regenerating timber harvests promote abundant and diverse pollinator communities in the Appalachian Mountains, though pollinator abundance declined quickly as woody stems regenerated. Ultimately, our findings contribute to a growing body of literature suggesting that dynamic forest management producing a mix of age classes would benefit forest pollinators populations in the Central Appalachian Mountains.

Mathis C.L., D.J. McNeil, Jr., M.R. Lee, C.M. Grozinger, C.R.V. Otto, and J.L. Larkin. Can't See the Flowers for the Trees: Factors Driving Floral Abundance within Early-successional Forests in the Central Appalachian Mountains. Canadian Journal of Forest Research *in revision*

Synopsis: Silviculture can be a powerful tool for restoring and enhancing habitat for forest-dependent wildlife. In eastern North America, regenerating timber harvests support abundant wildflowers that provide essential forage for native pollinators. Factors driving floral resource availability within regenerating forests remains almost entirely unstudied. Recent efforts to increase the amount of regenerating forests (< 10 yr old) through overstory removal harvest in the central Appalachian Mountains provide an opportunity to investigate the development of forest wildflower communities following canopy removal. We conducted 1,208 surveys of blooming plants across 143 harvests, recording 1,525,245 flowers representing 220 taxa spanning 47 families. The number of blooming flowers within recently harvested stands was negatively associated with fern and sapling cover but positively associated with grass and bramble (*Rubus* spp.) cover. Early in the growing season, more flowers bloomed in older regenerating stands (*e.g.*, > 5 yr old) but this pattern reversed by the end of the growing season. Ultimately, our study demonstrates that the abundance of flowers available to pollinators within regenerating hardwood stands varies with factors associated with advancing succession. Forest managers who intend to provide floral resources to flower-dependent wildlife like pollinators via silviculture should recognize the potential tradeoff between woody regeneration (*i.e.*, saplings) and pollinator forage availability.

Component 5: Cerulean Warbler response to forest management on lands participating in NRCS's Regional Conservation Partnership in Pennsylvania and western Maryland

Shaffer, D. 2022. Cerulean warbler (*Setophaga cerulea*) use of managed forests enrolled in private lands conservation programs in Pennsylvania and western Maryland. MSc. Thesis, Indiana University of Pennsylvania, Indiana, PA

Synopsis: The Cerulean Warbler (*Setophaga cerulea*) is a migratory songbird exhibiting one of the most dramatic and sustained population declines of all eastern forest birds by 1.9%, annually. Population declines for this species are understood to be driven, in large part, by breeding grounds habitat loss. Indeed, the structurally-complex forest required by nesting Cerulean Warbler has become increasingly rare in eastern forests. In 2013, science-informed best management practices were created that described a series of silvicultural techniques to create or enhance Cerulean Warbler nesting habitat in the Appalachian Mountains. From 2016-2020, USDA-NRCS and several partners implemented these BMPs across more than 3,800 ha of private forest lands. Understanding how Cerulean Warbler respond to conservation efforts on private lands is important given >70% of Appalachian forests are privately-owned. We used single-season occupancy models to evaluate Cerulean Warbler response to management and habitat features on private forests enrolled in NRCS programs in Pennsylvania and western Maryland. From 2017-2020, we conducted 684 avian point counts and 342 vegetation surveys across 139 unique locations. Study sites were either pre-treatment (n=56) or post-treatment (n=104). Across all sites, mean Cerulean Warbler occupancy probability was low (0.16; 95%CI: 0.10- 0.23). Site occupancy was negatively related to distance to nearest known Cerulean Warbler population. Although sites were managed using species-specific best management practices, Cerulean Warbler occupancy was low and likely driven by pre-existing forest conditions at managed sites. Indeed, both DBH (median: 34.7 cm; 95%CI: 32.3- 35.9) and basal area (median = 23.5 m²/ha; 95%CI: 20.7- 23.7) were relatively low for pre-treatment, mature forests. Such conditions are characteristic of past unsustainable harvest practices (e.g., high grading) that commonly occur on private lands in eastern deciduous forests. Future efforts to implement Cerulean Warbler-BMP guidelines should prioritize sites that are proximate to existing Cerulean Warbler breeding populations. Even then, managers should recognize that a legacy of exploitative timber harvests on private land may prevent the near-term attainment of some habitat features important to Cerulean Warblers (i.e., DBH ≥ 40.6 cm), and thus likely limit colonization of managed stands by the species.

Component 6: An empirical assessment of Golden-winged and Cerulean Warblers as a potential pair of umbrella species for avian communities in upland deciduous forests of the Central Appalachians

Rhinehart, T.A., J.L. Larkin, D.J. McNeil, C.J. Fiss, D. Shaffer, J. Cohen, and J. Kitzes. Benefits of Golden-Winged Warbler and Cerulean Warbler habitat restoration for non-target forest birds: An empirical test of the focal species concept. in review

Synopsis: Although the broad goal of conservation biology is to protect biodiversity, many conservation activities focus on the protection or recovery of a single species. However, in a diverse ecological community, the strategy of conservation planning or management for a single focal species may not be able to effectively provide benefits for other species in the community. It is increasingly argued that a suite of multiple focal species may better be able to guide management to achieve broader community-wide conservation and restoration goals. We provide one of the first empirical evaluations of the ability of large-scale, multiple focal species habitat management programs to provide community-wide conservation benefits. Specifically, we evaluated the extent to which habitat management conducted through NRCS conservation programs intended to benefit a pair of imperiled forest songbird species, the Golden-Winged Warbler and Cerulean Warbler, provides benefits to non-target forest bird species in the eastern United States. Using data from 1,820 point count surveys across portions of three central Appalachian states, we found that management to benefit these two species increases occupancy

probabilities for 22 (39%) of 65 non-focal species, including seven Appalachian Mountain Joint Venture conservation priority species. All but one of these species had increased predicted occupancy in the particular “residual basal area x time-since-treatment” conditions that most benefit Golden-Winged or Cerulean Warbler. In contrast, only four (6%) species were found to have significantly lower occupancy in treated forests than in untreated forests. Occupancy probability for the remaining 39 (60%) species was found to be indifferent to treated and untreated forests. Species richness in forests treated using GWWA and CERW guidelines is estimated to increase by 4.2-7.1 species. Overall, our analysis concludes that forest management for this pair of focal species has significant and widespread co-benefits for many other members of the upland deciduous forest bird community in the Central Appalachian region.

Component 7: Effectiveness of deer exclusion fencing for successful regeneration forests and diversity avian communities in operational-scale regenerating timber harvests

Parker, H. A., J. T. Larkin, D. Heggenstaller, J. Duchamp, M.C. Tyree, C.S. Rushing, E. Just-Domoto and J.L. Larkin. 2020. Evaluating the impacts of white-tailed deer (*Odocoileus virginianus*) browsing on vegetation in fenced and unfenced timber harvests. *Forest Ecology and Management*, 473, 118326.

Synopsis: Ensuring the recruitment of desired tree species is a primary goal when considering successful regeneration of timber harvests. Deer populations that are overabundant relative to forage availability within their local landscapes pose a considerable challenge to successful forest regeneration. We evaluated the short-term (< 10 years) impact of white-tailed deer browsing on woody structure and composition in northcentral Pennsylvania. Specifically, we compared woody plant species density, height, and cover within 10 pairs of fenced and unfenced regenerating timber harvests. Percent of browsed stems was higher in unfenced harvests for red maple (*Acer rubrum*), oaks (*Quercus* spp.), *Rubus* spp., sassafras (*Sassafras albidum*), and witch hazel (*Hamamelis virginiana*). Stem density did not differ between fenced and unfenced harvests for any species except *Rubus* spp., which was greater in the former. However, height of serviceberry (*Amalanchier* spp.), sassafras, northern red oak (*Quercus rubra*), *Rubus* spp., and red maple was taller in fenced harvests. Both vertical and horizontal vegetation density were greater in fenced harvests, suggesting a more structurally complex understory in fenced harvests. *Rubus* spp. and tall (> 1.5 m) sapling cover were greater in fenced harvests, while unfenced harvests had greater forb, fern, and blueberry/huckleberry (*Vaccinium* spp./*Gaylussacia* spp.) cover. Our results suggest that browsing by deer in the years initially (< 10 years) following timber harvest may not immediately impact woody species density, but can considerably reduce seedling height, overall horizontal and vertical structure, and composition of vegetation strata. Reduced sapling height and greater prevalence of blueberry/huckleberry, forbs, and ferns in unfenced harvests threaten the successful recruitment of desired species into the future overstory. Our results from large, operational-scale timber harvests combined with those from previous small-scale studies stress the potential value of deer exclusion fencing to achieve successful forest regeneration. Future research should examine the timing of fence removal to achieve forest regeneration success, while also providing deer access to available foraging opportunities during the later portion of stand initiation.

Parker, H.A., C.S. Rushing, J.T. Larkin, J.E. Duchamp, R.W. Rohrbaugh, D.J. McNeil, and J.L. Larkin. 2022. Avian response to plant community composition and structure in regenerating timber harvests protected by ungulate exclusion fencing. *Avian Conservation and Ecology* 17(1):2. <https://doi.org/10.5751/ACE-02005-170102>

Synopsis: Forests of eastern North America have been negatively impacted by excessive white-tailed deer browsing for decades. Previous studies have shown how deer-driven changes to forest structure, plant species composition, and microhabitat negatively impact forest birds. However, most experimental studies used relatively small plot sizes with few replications, limiting the transferability of findings to operational-scale timber harvests and landscape-scale management. We studied the influence of white-tailed deer browsing on breeding bird communities in ten pairs of operational-sized fenced and unfenced regeneration timber harvests in northcentral Pennsylvania. Based on a previous study that examined correlations between bird and deer abundance in Pennsylvania, we developed species-specific predictions about how density would vary between fenced and unfenced harvests. We predicted six species would show a negative response to deer and three would show a neutral response. Overall, diversity and composition of breeding bird communities did not differ between fenced and unfenced harvests. However, four species showed a negative response to deer, four showed a neutral response to deer, and one showed a positive response to deer. Thus, six of nine focal species aligned with our predictions: negative (n=4) and neutral (n = 2). Densities of two remaining focal species were associated with vegetative features that also were consistent with our predictions. Our final focal species showed a strong positive association with unfenced harvests, contrary to our prediction. Our findings demonstrate that deer-induced impacts on vegetation in operational-scale timber harvests can have considerable influence on densities of some avian species. We conclude that the use of deer-exclusion fencing after timber harvests is an effective and sometimes necessary management tool to achieve maximum forestry and wildlife benefits.

Other Assessment Outcomes

Spoken Presentations

- Parker, H.A., Larkin, J.T., Heggenstaller, D., Tyree, M., Duchamp, J., Rushing, C., Just Domoto, E., Larkin, J.L. 2020. The influence of white-tailed deer (*Odocoileus virginianus*) browsing on vegetation and avian communities in fenced and unfenced timber harvests. 2020 PA TWS Annual Conference. October 9
- Parker, H. A., Heggenstaller, D., Larkin, J. T., Duchamp, J., Tyree, M., Larkin, J. L. 2020. The influence of White-tailed deer browsing on vegetation and avian communities in fenced and unfenced timber harvests. The Wildlife Society 2020 Annual Conference. Sept. 28 – Oct. 2.
- Parker, H.A., Larkin, J.T., Heggenstaller, D., Tyree, M., Duchamp, J., Rushing, C., Just-Domoto,, E., Larkin, J. L. The influence of white-tailed deer (*Odocoileus virginianus*) browsing on vegetation and avian communities in fenced and unfenced timber harvests. North American Ornithological Conference. August 10-15, 2020.
- Parker, H. A. and J.L. Larkin, 2019. The influence of deer browsing on avian communities in fenced and unfenced timber harvests. Joint meeting of the Association of Field Ornithologists and the Wilson Ornithological Society. Cape May, NJ October 27-30.
- Larkin, J.L., C. Lott, D. J. McNeil, C.J. Fiss, and B. Costanzo. 2019. Using Biological Monitoring Data to Drive Precision Conservation on Private Lands. American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, NV Sept 29-Oct. 3
- Larkin, J.L., D. J. McNeil, A. D. Rodewald, C. J. Fiss, and V. Ruiz-Gutierrez. 2019. Microhabitat and Landscape Influences on Occupancy of Golden-Winged Warblers in Managed Habitats. GWWA occupancy American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, NV Sept 29-Oct. 3
- McNeil, D.J., A. D. Rodewald, C. J. Fiss, A. A. Dhondt, V. Ruiz-Gutierrez, J. L. Larkin Comparing Golden-winged Warbler Full Season Productivity and Occupancy Across Four Regions of the Breeding Distribution. 2019. American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, NV Sept 29-Oct. 3
- Fiss, C.J., D.J. McNeil, Amanda D. Rodewald, J.B. Cohen, and J.L. Larkin. 2019. Avian Communities

- Associated with Central Appalachian Forests Enrolled in NRCS's Working Lands for Wildlife Partnership. American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, NV Sept 29-Oct. 3.
- Mathis, C. L., D. J. McNeil Jr., M. R. Lee, C. Grozinger, D. King, C. R. V. Otto, K. R. Urban-Mead, and J. L. Larkin. (2019). Factors Affecting Native Pollinator Diversity and Density in Regenerating Managed Forests. Oral Presentation at The Wildlife Society / American Fisheries Society Joint Annual Conference. Reno, NV Sept 29-Oct 3.
- Lee, M., C.L. Mathis, D.J. McNeil, C. Grozinger, and J.L. Larkin. Butterfly communities occupying early successional deciduous forests of the Central Appalachian Mountains. 2019. The Wildlife Society: Pennsylvania Chapter Conference. State College, PA. February 23.
- Mathis, C.L., M. R. Lee, D.J. McNeil, C. Grozinger, and J.L. Larkin. 2019. Habitat Ecology of Native Bee Communities within Early Successional Deciduous Forests of the Central Appalachian Region within Pennsylvania. The Wildlife Society: Pennsylvania Chapter Conference. State College, PA. Feb. 23.
- Mathis, C.L., Lee, M. R, McNeil, D. J., Grozinger, C., J.L. Larkin. 2018. Habitat Ecology of Native Pollinator Communities within Early Successional Deciduous Forests of the Central Appalachian Region within Pennsylvania. Entomological Society of Pennsylvania Conference. Lancaster, PA. November 2018.
- Larkin, J.L., D.J. McNeil, A.D. Rodewald, and K.E. Johnson. 2018. Breeding bird community response to NRCS Working Lands for Wildlife practices applied for golden-winged warblers. Northeast Association of Fish and Wildlife Agencies (NEAFWA) 74th Annual Conference. Burlington, VT. April -15-17.
- Fiss, C.J., J.L. Larkin, D.J. McNeil, and A.D. Rodewald. 2018. What do golden-winged warbler fledglings tell us about how to structure young forest habitat within the mature forest matrix? Northeast Association of Fish and Wildlife Agencies (NEAFWA) 74th Annual Conference. Burlington, VT. April -15-17.
- Johnson, K.E., J.L. Larkin, D.J. McNeil, and A.D. Rodewald. 2018. Local and landscape scale effects on American woodcock use of early successional communities managed for golden-winged warblers. Northeast Association of Fish and Wildlife Agencies (NEAFWA) 74th Annual Conference. Burlington, VT. April -15-17.
- McNeil, D.J., E.L. Moser, A.D. Rodewald, and J.L. Larkin. 2018. Evaluating native pollinator density in regenerating timber harvests practices associated with NRCS Working Lands for Wildlife. Northeast Association of Fish and Wildlife Agencies (NEAFWA) 74th Annual Conference. Burlington, VT. April -15-17.

Natural Resource Professional Trainings

- Larkin, J.L. 2021. Golden-winged Warbler use of managed habitats in the western Great Lakes. Invited presenter for the Webinar: Improving Restoration Success: Building collaborations, improving restorations and learning as we go. University of Minnesota Extension. Oct 21.
- Larkin, J.L. 2021. The habitat matrix - stepping down bird management from landscape to stand. Invited speaker for the U.S Fish and Wildlife Service's 12-part monthly lecture series, *Forests for the Birds: Conserving America's Forest Birds*. July 20; Archived at <https://fws.rev.vbrick.com/#/videos/0f2e975d-6d71-4116-bd6e-f6019b8b7837>
- Larkin, J.L. 2021. The importance of landscape-scale forest management to meet the full breeding season needs of eastern forest birds. Invited webinar presented to Working Lands for Wildlife Webinar: in pursuit of the shifting mosaic. Feb. 25.
- Larkin, J.L. 2020. The importance of private forests to the conservation of forest birds in the Appalachian Mountains. Invited webinar presented to Maryland Woodland Owners via University of Maryland Cooperative Extension. Oct. 21.

- Larkin, J.L. 2020. Outcomes from NRCS Golden-winged Warbler Conservation Efforts. Web presentation to NRCS state and local personnel, July 24.
<https://www.youtube.com/watch?v=MOVz0Q061lg>
- Larkin, J.L. 2020. Conservation Outcomes of NRCS's Working Lands for Wildlife in Eastern Forests. NRCS Stakeholders Meeting. Webinar; August 25.
- Larkin, J.L. 2020. Conservation Outcomes of NRCS's Working Lands for Wildlife and Regional Conservation Partnership Program in Eastern Forests. Briefing to NRCS Field Staff. Webinar; July 24.
- Larkin, J.L. 2020. Conservation Outcomes of NRCS's Working Lands for Wildlife. Briefing to the Chief of NRCS. Webinar; March 25.
- Larkin, J.L. 2019. Field tour demonstrating the link between forest birds and forest management in Pennsylvania. Brodhead Watershed Association. Cresco, PA. May 17
- Larkin, J.L. 2018. Assessing Avian and Pollinator use of Private Forests Enrolled in NRCS Working Lands for Wildlife-Golden-winged Warbler. PA NRCS State Technical Committee meeting, Harrisburg, PA. Oct. 16