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Potential benefits of restored Riparian Zones in an agricultural matrix for bat communities

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Potential Benefits of Restored Riparian Zones in an Agricultural Matrix
for Bat Communities

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A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

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Abstract – Riparian buffers planted within agricultural matrices for wildlife conservation are expected to support numerous taxa, but a lack of empirical testing has limited evaluation of these practices. It is imperative that biologists and land managers understand how current conservation practices impact bats so that the ecosystem services provided by bats are maintained as farming practices continue to intensify in regions dominated by agriculture. This study evaluates the effects of planted riparian buffers along streams in an agricultural matrix by comparing acoustic bat activity along streams in active cattle pasture with activity at streams where riparian buffers have been planted. Forest characteristics and insect abundances are also compared to evaluate what specific aspects of the riparian buffers were correlated with increased bat activity. I found that planted riparian buffers support increased bat activity of the medium phonic guild, or forest edge generalists (*Lasiurus borealis* and *Perimyotis subflavus*) with this increase in activity correlated with increases in tree density. Other riparian characteristics, including insect abundance, were not indicators of increased bat activity. These findings support the planting and maintenance of riparian buffers within agricultural areas for wildlife conservation and promoting ecosystem services.

Introduction

Intensification of agriculture and the associated loss of riparian forests negatively affects bat species in a number of ways (Tschardt et al. 2005, Williams-Guillén et al. 2015). Such impacts are detrimental because agriculture relies on the ecosystem services provided by bats, including control of insect pests which saves American farmers billions of dollars annually (Maine and Boyles 2015). The negative impacts of farming include the loss of clean water sources used by bats for drinking and foraging (Kalcounis-Rüppell et al. 2007, Zhang et al. 2007). This happens via mechanisms such as eutrophication, streambank erosion, chemical pollution, and the removal of natural riparian vegetation (Knox 2006, Peterjohn and Correll 1984). Intensification of agriculture also leads to the clearing of forests for pasture or crops, which formerly served as roosting habitat and connecting corridors; which are both especially important in an agricultural setting (Bouvet et al. 2016, Farrow and Broders 2011, Hein et al. 2009, Salvarina 2016, Vonhof and Gwilliam 2007). However, stands of trees that are left behind may be less valuable to bats because they are isolated from other bat habitat within the agricultural matrix (Gehrt and Chelsvig 2003, Wolcott and Vulinec 2012).

Bats are often classified into phonic guilds to limit the effects of misclassification of species. The conclusions drawn using phonic guilds are similar to those drawn from studies identifying calls to species due to similar morphologies and habitat usage but are more conservative and lessen the effects of call overlap between species and misclassification (Denzinger and Schnitzler 2013, Kaiser and O'Keefe 2015).

Bats within the low phonic guild tend to be larger, faster, and forage in uncluttered areas such as agricultural fields or above the canopies of forests (Aldridge

and Rautenbach 1987, Heim et al. 2015, Menzel et al. 2005). Big brown bats, *Eptesicus fuscus*, are habitat generalists in that they are frequently found in a variety of habitats including areas that have been impacted by land conversion such as agricultural fields, often making use of artificial roosts and foraging areas (Ford et al. 2005, Furlonger et al. 1987, Kelly et al. 2016). Hoary bats, *Lasiurus cinereus*, are the largest bats in the region and prefer open flyways where they can best use their high flight speed and large wing-loading capacity (Barclay 1985, Jantzen and Fenton 2013). This species is also known to migrate at extremely high altitudes leading to many collisions with wind-turbines (Jameson and Willis 2014).

Bats within the medium phonic guild tend to be slightly smaller and slower than species in the low guild and are considered forest edge generalists, common in edge habitat but also found in cluttered and open space (Aldridge and Rautenbach 1987, Mendes et al. 2017, Menzel et al. 2005). Eastern red bats, *Lasiurus borealis*, are habitat generalists but show stronger habitat preferences than big brown bats; preferring cluttered forests with closed canopies and less urbanized areas (Elmore et al. 2005, Furlonger et al. 1987, Starbuck et al. 2015). Tricolored bats, *Perimyotis subflavus*, have similar habitat usage characteristics to eastern red bats in that they show some plasticity but are still considered forest-associated bats, especially preferring riparian habitats (Farrow and Broders 2011, Ford et al. 2005, Loeb and O'Keefe 2006).

In the Shenandoah Valley, all bats that echolocate in the high phonic guild belong to the *Myotis* genus and are most often small, slow, obligate forest specialists. These species are rarely found outside of forested habitats, unlike those typically found in agricultural areas, and most often forage in closed canopy, cluttered habitats (Aldridge

and Rautenbach 1987, Ford et al. 2005, Furlonger et al. 1987, Jantzen and Fenton 2013). The little brown bat, *Myotis lucifugus*, is sometimes considered to be a forest edge generalist and has historically been common and important within agricultural settings but has seen precipitous population declines (>70%) due to WNS (Boyles et al. 2011, Coleman and Barclay 2013, Jantzen and Fenton 2013).

Plasticity in habitat selection by bat species allows bats to use multiple habitat types and predate upon a variety of arthropods, despite some degree of specialization enforced by the morphology and call structure of bat species (Saunders and Barclay 1992). Many bat species are considered opportunistic feeders that prey on multiple orders of insects and in a variety of habitats, although there are some limitations based upon size of prey (Carter et al. 2003, Fenton 1990, Storm and Whitaker 2008). Specialization in foraging habits is correlated with jaw and wing morphology and call characteristics (Aldridge and Rautenbach 1987, Bogdanowicz et al. 1999, Norberg and Rayner 1987, Safi and Siemers 2010).

Big brown bats, eastern red bats, and tricolored bats are often considered dietary generalists, however the diet of each species is often dominated by Coleoptera (beetles), Lepidoptera (moths), and Diptera (flies), respectively (Arbuthnott and Brigham 2007, Carter et al. 2003, Vindigni et al. 2009). Increased bat activity has been observed in areas that have greater relative abundances of these orders, despite having lower overall insect abundance (Wolbert 2014). This finding is strengthened by observations that big brown bats flew 1.5-3km to forage at Coleoptera dense sites, and not at sites that were closer and warmer and believed to support overall greater insect abundances (Arbuthnott and Brigham 2007).

Hoary bats have been observed to consume primarily moths in open foraging areas, including those in the Ridge and Valley region of West Virginia (Carter et al. 2003). Little brown bats have one of the most diverse diets of any bat in the eastern United States, consuming multiple orders of insects (Anthony and Kunz 1977, Belwood and Fenton 1976, Carter et al. 2003, Moosman et al. 2012). These findings support the idea that bat species take advantage of a wide range of prey items when available but may retain species and guild specific preferences based upon morphologies and energy needs.

Insect abundances and the relative densities of various orders are seasonal and change greatly over a single summer, impacting the foraging opportunities for bats. These fluctuations are correlated with temperature changes and the emergence of aquatic insects, including Coleoptera. This seasonality has been shown to affect the diets of big brown bats during summer in Ontario, Canada, (Clare et al. 2014) and a similar bat community in Japan. Insectivorous bats in a Japanese riparian forest were shown to swap from foraging on aquatic to terrestrial insects as relative abundances of these insects changed over the summer (Fukui et al. 2006). It is assumed that similar changes occurred in insect populations within our study sites, and that this may influence differences in bat activity over the course of the summer. The foraging activity and habitat usage of insectivorous bats is often dictated by availability of prey (Belwood and Fenton 1976, English et al. 2017, Hagen and Sabo 2011).

Bats are most active at dusk and dawn when their prey are most abundant (Brigham and Fenton 1991, Racey and Swift 1985), emerging from their roosts soon after their prey. However, there are multiple factors influencing the timing of bat emergence and it is not entirely understood how strongly predators of bats influence the emergence

of bats (Lima and O’Keefe 2013, Thomas and Jacobs 2013). It is also unclear how the preferred prey and morphology of bats affect emergence time; it has been observed that bat species that primarily consumed Diptera, which are most abundant earlier in the night, emerged earlier than did bats that preferred later emerging Lepidoptera (Jones and Rydell 1994, Rydell et al. 1996).

Like many taxa, observations indicate that the nightly emergence of bats is balanced between the availability of insects and likelihood of predation (Rydell et al. 1996). Earlier emergence allows for increased access to prey and is associated with bats that have relatively high energy needs, e.g. during lactation, but also increases risk of predation (Russo et al. 2007). Smaller, slower bats typically emerge later than larger bats, perhaps because they are more prone to predation (Thomas and Jacobs 2013). Similarly, bats may be discouraged from emerging in well-lit conditions by an increased risk of predation (Rydell et al. 1996, Speakman 1991). Bats in habitats with high canopy coverage tend to emerge earlier than those in open conditions, presumably because such areas become darker sooner (Russo et al. 2007). Brighter conditions can also reduce prey activity, so it is not entirely clear whether this change in emergence times is solely driven by the risk of predation (Lang et al. 2006).

Bats spend a greater portion of their time roosting than any other activity during the summer months (Barclay and Kurta 2007). Day roosts serve to protect bats from potential predators, provide protection from the elements, and help foster complex social interactions (Barclay et al. 1988, Barclay and Kurta 2007, Vonhof and Barclay 1996). North American bats primarily rely on standing (live or dead) trees and geologic features for day roosts (Barclay and Kurta 2007), although some species including the big brown

bat, little brown bat, silver-haired bat, and eastern red bat have been known to use buildings for day roosting; this includes shingles and awnings (Lausen and Barclay 2006, Mager and Nelson 2001, Randall et al. 2014). The ability to adapt to multiple roost types contributes to the success of these species despite continued habitat loss due to land conversion. The loss of roosting habitat is a leading conservation threat with a strong correlation between roost specialization and extinction risk (Sagot and Chaverri 2015). Therefore, it is important that a diversity of roost types is conserved.

There is variation within the characteristics of roosts predominantly used by North American bat species. Multiple tree species have been used by bats as day roosts (Menzel et al. 1998, Perry et al. 2007, Perry and Thill 2008, Vonhof and Barclay 1996, Vonhof and Gwilliam 2007). The characteristics of these trees are often similar, indicating that other roost characteristics may be greater than the effect of tree species. Big brown bats, silver-haired bats, eastern red bats, tricolored bats, and some *Myotis* species prefer roosts in trees that are taller, are older (≥ 50 years), and are larger in diameter (Perry et al. 2007, Perry and Thill 2008, Vonhof and Barclay 1996, Vonhof and Gwilliam 2007). In addition to the characteristics of specific roost trees, bats have also shown preferences regarding the landscape surrounding their day roosts. Forests with a greater percent of canopy cover, less cluttered understory, and proximity to flight corridors often contain a greater number of roost trees (Mager and Nelson 2001, Perry et al. 2007, Russo et al. 2007, Vonhof and Barclay 1996, Vonhof and Gwilliam 2007). Tricolored bats specifically have been observed roosting in or near riparian buffers, $\geq 90\%$ of the time in some populations (O'Keefe et al. 2009, Perry et al. 2007). This and other findings that tricolored bats preferred edge habitats (Cox et al. 2016, Ethier and

Fahrig 2011) suggests that larger trees along streams in agricultural matrices could provide important roosting habitat for this species.

Agricultural mosaics are often characterized by small patches or linear remnants of forests separated by expanses of non-forested pasture and cropland. This mosaic landscape creates large amounts of edge habitat, which can have significant effects on wildlife (Fahrig 2003, Monck-Whipp et al. 2018). Big brown bats, eastern red bats, tricolored bats, little brown bats and the endangered Indiana bat use edge habitats extensively, despite Indiana bats and similar *Myotis* species being associated with forested conditions and avoiding open areas (Cox et al. 2016, Hein et al. 2009, Murray and Kurta 2004). Increased forest fragmentation which creates more heterogeneous environments can be beneficial for eastern red bats, open space foragers like big brown bat, silver-haired bat, and hoary bat and tricolored bats (Cox et al. 2016, Ethier and Fahrig 2011). The size and width of edge has been found to not have a significant effect on bat activity levels at woodland farmland interfaces, indicating that thin strips of forest may be adequate for promoting bat species adapted for heterogeneous landscapes in these matrices (Lentini et al. 2012, Wolcott and Vulinec 2012).

Bats may use edges for a variety of reasons including protection from wind, which creates turbulence and increases energetic demands of flying (Verboom and Spoelstra 1999). Edges have also been shown to act as identifying features for bats (landmarks), aiding them in navigation (Verboom et al. 1999). Flying insects have also been found to be significantly more active along forest edges, suggesting that edges may also attract bats as sources of prey (Lewis 1970). A final potential cause for bats flying along edges and avoiding open habitat, is protection from predators (Verboom and

Spoelstra 1999). Bats are more susceptible to predators when in the open, especially smaller bats that are adapted to cluttered conditions or forest edges (Lima and O'Keefe 2013).

Thin strips of forest within agricultural matrices may also be important for bats because they connect separated patches of habitat and allow bats access to insect rich agricultural fields that may otherwise be unavailable due to the fields' lack of cover and increased distance from forest edge (Landis et al. 2000, Wolcott and Vulinec 2012). One of the most common types of corridors for bats in these landscapes are riparian strips. These forest remnants provide a multitude of benefits for bats and could play an important role in bat conservation, especially in fragmented agricultural areas (Greenwood et al. 2012, de la Peña-Cuéllar et al. 2015, Stahlschmidt et al. 2012).

Many of the previously mentioned habitat needs of bats are provided by riparian forests, including drinking sources, covered corridors, forest edges, day roosts, and hibernacula (Ellison et al. 2005, Fukui et al. 2006, Geggie and Fenton 1985, Grindal et al. 1999, Rogers et al. 2006, Scott et al. 2010, Swystun et al. 2007). Riparian strips in agricultural areas are known to lessen soil erosion, shade streams by increasing percent canopy cover, and filter out harmful chemicals such as fertilizers and pesticides (Brown and Krygier 1970, Greenwood et al. 2012, Newbold et al. 2010, Zaines et al. 2004). Riparian strips also provide bats with drinking sources and larger concentrations of insects than those available in open spaces (Adams and Hayes 2008, Grindal and Brigham 1998, Kalcounis-Rüppell et al. 2007, Menzel et al. 2005, Stone et al. 2005). Furthermore, the canopy cover provided by riparian forests is beneficial for bats because

it allows bats to emerge and begin foraging earlier (Russo et al. 2007, Thomas and Jacobs 2013).

The benefits of riparian forests are observed in every bat guild within Eastern North America. It is somewhat surprising that the open space foragers (big brown bat, silver-haired bat, and hoary bat) preferred riparian areas which are often cluttered in comparison with surrounding areas. This may be due to open space foragers foraging above the canopy, and therefore above the clutter within the buffers (Menzel et al. 2005), reducing the effect of clutter on these bats while still allowing access to insects supported by the buffers. The restoration and conservation of riparian forests may be effective for mitigating two primary challenges facing North American bat species, white-nose syndrome (WNS) and the loss of habitat due to the intensification of agriculture (Calvert and Neiswenter 2012, Greenwood et al. 2012, Stahlschmidt et al. 2012, Wilcox and Willis 2016).

White-nose syndrome (WNS) is the leading conservation concern for many bat species in North America and is estimated to have killed millions of bats, leading to significant increases in conservation of these species (Ford et al. 2011, Froschauer and Coleman 2012, Hoyt et al. 2015, Lorch et al. 2011). WNS has been shown to affect bat species to different extents (Ford et al. 2011, Ingersoll et al. 2016). *Myotis* species (high guild bats) have been devastated by WNS with some populations being completely extirpated (Frank et al. 2014, Frick et al. 2015, Reynolds et al. 2016, Turner et al. 2011, Wilcox et al. 2014). WNS has primarily affected species within the previously common *Myotis* guild, while other species have not been similarly affected. However, tricolored bats have experienced 30% mortality rates in the region of New York, Pennsylvania,

West Virginia, and Tennessee (Ford et al. 2011, Ingersoll et al. 2013, 2016), and are continuing to decline in areas where the fungus that causes WNS is present.

Many researchers suggest that the continued spread of WNS may be inevitable and that it is important that mortality from WNS is mitigated whenever possible (Frick et al. 2015, Lorch et al. 2013, 2016, Maher et al. 2012, O'Regan et al. 2015). Similar to other wildlife diseases (Kapust et al. 2012, Knaepkens et al. 2004), there is evidence that the effects of WNS are exacerbated by the poor health of some bat populations correlated with the loss or degradation of habitat (Wilcox and Willis 2016). The planting of riparian buffers and conservation of other bat habitat are important steps in promoting bat populations affected by WNS, habitat loss, and other challenges.

In previous studies, riparian buffers have been shown to mitigate the negative effects of agriculture on bats by increasing canopy cover, providing an increased abundance of prey, and clean drinking sources (Bourgeois et al. 2016, Greenwood et al. 2012, de la Peña-Cuéllar et al. 2015, Mendes et al. 2017, Stahlschmidt et al. 2012). One of the most important aspects of riparian forests in agricultural landscapes is their use as corridors. Bats are highly mobile, which allows them to access distant patches of habitat within the same night when sufficiently connected through corridors (Heim et al. 2015).

It was expected that much of the Shenandoah Valley was poor habitat for most bat species due to its long history of being predominantly used for agriculture (>200 years). Despite being bordered by the George Washington Jefferson National Forests and Shenandoah National Park, the high agricultural landscape of the Valley has decreased the quality of habitat for bats by reducing availability of connected forests needed for unpolluted water, roosts, vertical structure, and prey. Agricultural fields in the

Shenandoah Valley are likely poor in all four of these habitat characteristics, however, riparian forests planted through the Conservation Reserve Enhancement Program (CREP) may be an effective tool for improving habitat quality for bats in the Shenandoah Valley.

The Conservation Reserve Enhancement Program (CREP), has been planting trees in cleared and damaged riparian zones on formerly agricultural properties within Virginia since 2000. The Commonwealth of Virginia and United States Department of Agriculture (USDA) began the program in order to remove riparian habitat and other wetlands from agricultural production. All sites involved with this study belong to the Chesapeake Bay watershed and are part of the 27,000 acres the CREP program hopes to install within the Chesapeake Bay watershed to reduce nutrient load into the Bay (Virginia Agricultural Cost-Share (VACS) BMP Manual 2017).

There are 3 practices within CREP involving different types of riparian and wetland restoration. This study monitored sites that had undergone practice No. CRFR-3; the planting of riparian forest buffers between 35ft and 300ft wide in former cattle pasture. These properties were no longer being used commercially, with very limited mowing, and no grazing having been allowed on the designated property since enrollment in the program 10-17 years prior to the present study in 2017 (Virginia Agricultural Cost-Share (VACS) BMP Manual 2017). CREP and similar programs in other states have been shown to be effective at promoting habitat for waterfowl, raptors, and some farmland birds, but no study has assessed the effects of these programs on bats (O'Neal et al. 2008, Pabian et al. 2013, Wilson et al. 2010). I expected that these riparian buffers produced by CREP would support bats similarly to other young, restored riparian zones and that these benefits will change over time and increase in value as these riparian

forests regenerate. However, the effectiveness of CREP for restoring riparian zones has not been evaluated sufficiently, and its effects on bat population have never been studied prior to this study.

The two primary objectives of the current project were (1) to evaluate the efficacy of CREP for bat conservation and (2) to identify specific characteristics of CREP buffers that were most related to increased bat activity. This was accomplished by recording bat activity with acoustic detectors, taking basic forest measurements within each buffer, measuring percent canopy cover over the streams, and collecting insects at each site over the course of the summer field season.

The central hypothesis of this thesis is that riparian buffers created through CREP support bat communities by providing benefits similar to those of natural riparian buffers (Stahlschmidt et al. 2012). I tested this hypothesis by measuring levels of acoustic activity of bats and comparing this activity to site characteristics such as enrollment in CREP, canopy cover, average tree density, basal area of trees within buffers, and insect abundances. I predicted that a high richness of bats and a significantly greater number of bat passes would be recorded at CREP sites. It was also predicted that this increase in bat richness and recorded activity would be correlated with an increase in diversity of insect populations, relative abundance of Coleoptera and Lepidoptera, and in physical structure provided by trees. I expected any observed differences in bat or insect populations to be due to differences in physical structure and the maintenance of stream banks through the exclusion of livestock.

Field-site Descriptions

I conducted this study across six private landholdings containing riparian zones in Rockingham, Shenandoah, and Augusta Counties, in the Shenandoah Valley of Virginia, United States (Fig. 1). All sites contained a stream suitable for use by livestock as a drinking source and existed within a greater agricultural matrix dominated by land used for cattle pasture or hay production, with few, remnants of forest. I paired riparian zones based on similarity in surrounding land use and amount of forested area, stream size, and proximity to one another. Paired riparian zones were located in the same county, within 10km of one another, and were comprised of one treatment and one control site. Treatment sites were those containing planted riparian buffers installed through a continued enrolment in the CREP program. These sites had been enrolled in the CREP program 11-16 years and were some of the first properties enrolled in the program in Virginia. Control sites were pastures where livestock were not fenced out of the waterway and were characterized by degraded stream banks and unrestored riparian zones typical for the region.

Sites were located in Augusta County, Virginia (38.158° N, 79.206° W), Shenandoah County, Virginia (38.750° N, 78.638° W) and Rockingham County, Virginia (38.525°N, 78.7833°W). Streams were first or second order and ranged in width from approximately 1m to 5m (Table 1). Control sites had a few remnant trees, such as American sycamore (*Platanus occidentalis*), black walnut (*Juglans nigra*), and osage orange (*Maclura pomifera*). CREP sites ranged in tree density from 60 to 280 trees per ha (Table 1). Commonly planted trees were: white ash (*Fraxinus americana*), *Acer* sp., and

American sycamore. This type of variation amongst CREP sites is typical for enrolled riparian buffers (Bradburn et al. 2010).

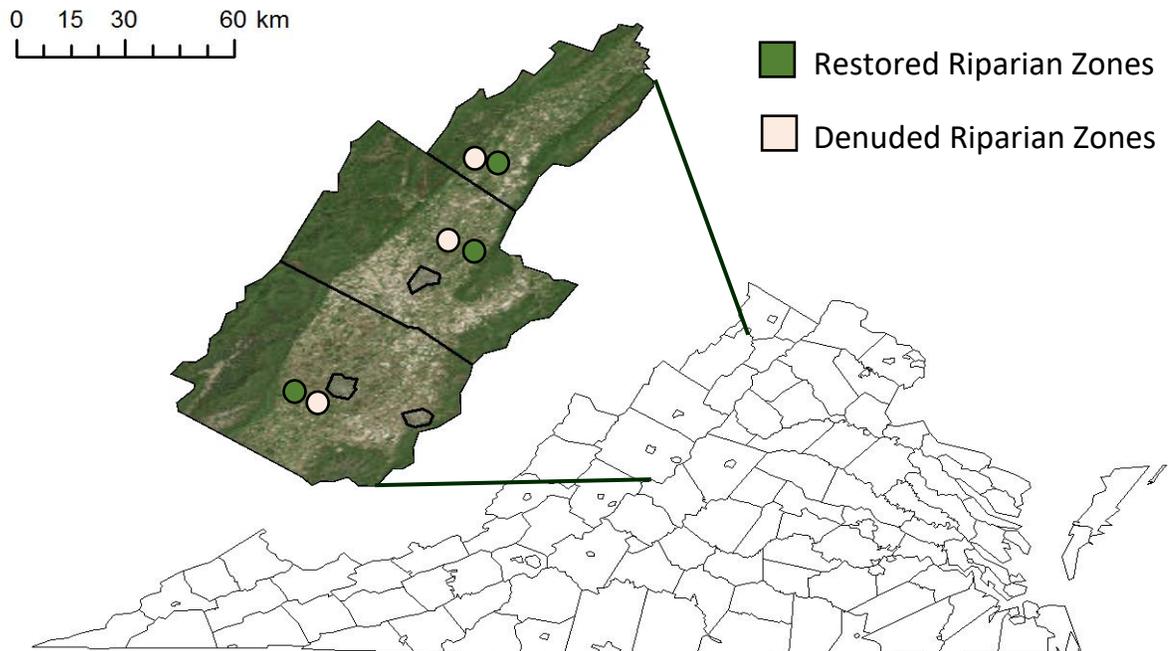


Figure 1. Location of field sites are indicated with green or tan markers, indicating riparian treatment. The southernmost sites were in Augusta County, the middle sites were located in Rockingham County, and the northernmost sites were in Shenandoah County. All sites were located within the Shenandoah Valley.

Methods

Data collection

Experimental design

I collected field data from May 21st to August 19th 2017 at the 3 pairs of sites. Data were collected at each site over 10 separate 3-night periods (pseudo-replicates). Each pair of sites was monitored simultaneously during data collection, resulting in a maximum of 30 nights of data collection at each site. Data collection consisted of deploying a full-spectrum bat detector to record the echolocations of bats, a malaise style insect trap to collect flying insects, and a temperature logger to monitor for extremes in temperature (hereafter “deployment”) (described in detail below). Specific deployment locations at each site were randomly selected from a pool of open areas where chance of detection of flying bats was greatest by randomly placing a point using ArcMap and then deploying at the nearest suitable open area along the stream. Detectors, insect traps, and temperature loggers were rotated between pairs of sites in a round-robin pattern throughout the field season in order to help account for seasonal variation over the course of the field season. Farm fencing (5.08cm x 10.16in paneling) supported by steel t-posts (1.524m tall, with .3m driven into ground) around the bat detectors and insect traps protected the equipment from cattle. Although not required for protection, fencing was erected at the CREP riparian buffers to replicate the potential effects on the collection of flying insects. The effect of the fence on recording bat activity is believed to be minimal because the fences likely did not occupy a significant amount of the space available to the bats and would not be a novel occurrence within the agricultural matrices within which data was collected. To evaluate the structure of the riparian buffers at each site, I

quantified all trees greater than 10cm diameter at breast height (dbh) within a 100x10m transect randomly placed at each riparian zone.

Bat monitoring

I monitored bats activity at each stream site using 2 Pettersson D500x (Pettersson Elektronik AB, Uppsala, Sweden) full spectrum bat detectors and microphones. I protected detectors from inclement weather by housing the detector within an elevated plastic ammunitions box. Microphones were elevated to approximately 2.44m and shielded from direct rainfall with PVC piping split across its diameter (modified from Barnett 2014). I set detectors to begin automatically recording 15 minutes prior to civil sunset and to stop recording 15 minutes after civil twilight. Detectors were set to the medium trigger sensitivity for the entirety of the field season. I stored recorded bat call sequences on compact flash (CF) cards inside detectors prior to downloading them onto a computer at the conclusion of each deployment.

Insect collection

I passively collected insects concurrently with the monitoring of bat activity using 2 malaise style Land and Air Intercept Traps (BioQuip Products, Rancho Dominguez, CA) with flat catchment trays, approximately .61m in diameter, placed beneath the malaise traps which acted as pan traps for the collection of *Coleoptera* that are often missed by malaise style traps. Malaise style traps were chosen instead of black-lights which are typically used when collecting bat prey (Dodd and Rieske 2013, English et al. 2017, Fulton et al. 2014), because malaise traps are passive, and therefore unlikely to cause bias by attracting insects or foraging bats. Insect traps were deployed at ground level because most sites lack structure to hang traps and the necessity of fencing to

protect the equipment. I collected trapped insects at the end of each deployment and stored the insects in ethanol, except for Lepidoptera which were stored in a lab-freezer. Orthoptera (grasshoppers and crickets) were excluded from insect trapping because they were able to freely enter and leave the pan trap, resulting in inconsistent catch effort for the order. A single HOBO Water Temperature Pro v2 Data Logger (Onset Computer Corporation, Bourne, MA) was hung approximately 2.1m off the ground from a nearby tree during each deployment to monitor temperatures while insect and bat data were collected to monitor for extremes or outliers in temperature that could bias results. Similarly, weather conditions were monitored throughout the field season. No data was excluded from analysis due to both types of sites being monitored during each night.

Forest inventory

I established a single 100x10m transect parallel to the stream in each riparian zone. A random point 5m from the stream edge was chosen as the starting point of each transect. A new random point or direction was chosen if the original placement was not suitable due to safety or land ownership concerns. All trees (>10 cm dbh) were measured, identified to species, and recorded as either a snag or living tree. Percent canopy cover over the stream at each field site was estimated by averaging the values obtained using a densiometer while standing in the middle of the stream directly parallel to the beginning, middle, and end points of the transect. Percent canopy cover readings were done across the span of two days to avoid the effects of seasonal variability.

Data analysis

Identification of bat passes

I used the SonoBat D500x file attributer 2.7 (SonoBat Inc., Arcata, California) to name and embed deployment notes as metadata to each downloaded bat pass as it was

uploaded to the main computer for the project. The passes were also scrubbed with the file attributor to remove noise and poor-quality passes according to retailer's and manufacturer's suggestions. I manually analyzed recorded echolocation calls using SonoBat 4.0.7 to estimate bat activity at the riparian zones. To limit the effects of inaccuracies in call identification, passes were assigned to one of 3 phonic groups based on their minimum call frequencies (f_0) and call shape: low-frequency (<30kHz), medium-frequency (30-50kHz), and high-frequency (30-60kHz) (Table 1, Kaiser and O'Keefe 2015). Inferences drawn from these phonic groups are similar to those drawn from identifying calls to species due to similar habitat usage within phonic groups (Denzinger and Schnitzler 2013). For the purpose of estimating species richness within deployments, passes were also identified to species, or lowest possible classification if I was unable to assign a species identification confidently. This was done using reference calls from the SonoBat call library and known call characteristics (Szewczak et al. 2011). Passes that contained more than two bats were included in analyses only if I could discern that the calls were produced by individuals of different species or if at least two calls were overlapped in time and differed in minimum frequencies or time-frequency patterns (as per Jameson and Willis 2014). A single data entry was made for each bat within the shared pass, including phonic guild and species identification information when possible. When assigning species, big brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) were grouped together, as were *Myotis* sp., to account for significant call overlap between these species (Betts 1998, Cox et al. 2016, Loeb and O'Keefe 2006). It is believed that silver-haired bats do not occur in the region in significant numbers outside of early spring and late fall, limiting the likelihood that they

would make up a significant proportion of calls recorded. It was also predicted that the majority of *Myotis* calls would be those of *Myotis lucifugus* (little brown bats) because the species has historically been widespread within the region, including agricultural environments (Timpone et al. 2011). Evening bats (*Nycticeius humeralis humeralis*) and Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) were not believed to be within the study area (Timpone et al. 2011, R. Reynolds, Virginia Game and Inland Fisheries, Verona, VA, pers. comm., W.M. Ford, Virginia Polytechnic Institute and State University, Blacksburg, VA, pers. comm.), and were excluded from possible species identification (Table 1).

Table 1. The bat species groupings used when identifying passes to species and the individual species expected to be contained within each species group. The frequency group column indicates which phonic group I expected the passes of each species to be assigned to.

Phonic guild	Species groups
Low	Big brown (<i>Eptesicus fuscus</i>) and Silver-haired (<i>Lasionycteris noctivagans</i>) Hoary (<i>Lasiurus cinereus</i>)
Medium	Eastern red (<i>Lasiurus borealis</i>) Tricolored (<i>Perimyotis subflavus</i>)
High	Little brown (<i>Myotis lucifugus</i>), Eastern small-footed (<i>M. lebeii</i>), Northern Long-eared (<i>M. septentrionalis</i>), and Indiana (<i>M. sodalis</i>)

Flying insect identification.

A subsample of the collected flying insects was identified to Order. Due to time constraints, I randomly selected at least two separate deployments from each riparian

zone for insect analysis. I excluded deployments where a portion of the bottom of the tray used as a pan trap was exposed due to evaporation or was believed to have overflowed prior to pick-up (typically due to storms or other events that would alter the collection of flying insects). Insect data were used to estimate diversity of flying insects at each site, to the level of order.

Statistical analysis.

I conducted statistical analyses using R 3.3.3 (R Core Team 2017) and with the packages ‘lme4’ (Bates et al. 2017), ‘stats’ (R Core Team 2017), and ‘vegan’ (Oksanen et al. 2018). Generalized linear mixed effect models (GLMM) were used to analyze the activity of each phonic guild across treatments, comparing the number of passes per night during each deployment.

$$\text{Calls/Night} \sim \text{Season} * \text{Riparian Treatment} + \text{Site}$$

The number of passes per night during each deployment was rounded to the nearest lower integer to best represent the count aspect of our data, which followed a Poisson distribution. Similar models were run for total bat activity across all phonic guilds and within each guild assuming a log-link function and a Poisson distribution in the ‘lme4’ package of R. Within our model, I included two fixed effects, season and treatment and a single random effect, site. The factor of season was included to account for seasonal variation observed over the course of the field season and was a categorical variable that divided the deployments by the date in which they took place: May 21st - June 17th, June 18th - July 23rd, and July 24th - August 19th. The riparian treatment factor referred to whether the deployment took place at a site with a restored or denuded riparian zone. The effect of site was included to account for variation across the six sites

where detectors were deployed and avoid the analysis of pseudo-replicates. The ‘statistics’ package of R was used to apply Holm-Bonferroni corrections to all recorded p-values (Holm 1979).

An adjusted species richness was found for each site by first determining which species or species group were identified during each three-night deployment. The number of deployments that the species or species groups were recorded at each site were then adjusted by the number of recordings that took place at that site. These were used as measures of adjusted species richness at each site.

Sample size was too low to create GLMMs for insect data in the same way that models were run for bat data. Using the ‘vegan’ package of R, I estimated order diversity of flying insects at each site using a Simpson Diversity Index and a Shannon-Weaver Diversity index. Simpson Diversity Index was calculated as D_1 ,

where:

$$D_1 = 1 - \sum_{i=1}^S p_i^2$$

p_i was the proportion of orders i , and S is the number of orders captured so that the sum of p_i is equal to 1 (Simpson 1949, as discussed in Hurlbert 1971, and errors based on Heck et al. 1975). Similarly, the Shannon-Weaver Diversity index was calculated as H

where:

$$H = -\sum_{i=1}^S p_i \log_b p_i$$

p_i was the proportion of orders i , and S is the number of orders captured so that the sum of p_i is equal to 1 and b is equal to the base of the natural log (Shannon and Weaver 1949).

The effects of riparian forest structure on total bat activity and on the activity of each bat guild were evaluated by comparing basal area per hectare, stem count per

hectare, and average percent canopy cover at each site. Generalized linear models (GLM) were used to analyze the effect of these forest characteristics on total bat activity and the activity of each phonic guild.

Median Calls/Night ~ Forest Characteristic

The number of passes per night during each deployment was rounded to the nearest lower integer to best represent the count aspect of our data, which followed a Poisson distribution. The median of these values was used as the dependent variable at each site. Similar models were run for total bat activity across all phonic guilds and within each guild assuming a log-link function and a Poisson distribution in the 'lme4' package of R. Within each model, I included a single effect; the forest characteristic being evaluated as a determinant of bat activity. The 'statistics' package of R was used to apply Holm-Bonferroni corrections to all recorded p-values (Holm 1979).

Results

Effect of Riparian Treatment

I surveyed the six sites from May 21st through August 19th of 2017 and recorded 6,663 calls over 128 detector nights. The number of detector nights at all six sites within the two riparian treatments are given, where a partial night indicates that recording began 15 minutes prior to sunset and ended prior to midnight due to equipment failure or the deployed compact flash (CF) card becoming full due to insect noise (Table 2).

I excluded the planted Shenandoah riparian zone from models run because our methods did not accurately record bat calls at this site. The very narrow stream and thick overstory present at this site created a cluttered fly-way that prevented bats from flying directly over the waterway where our detectors were directed. This problem was exacerbated by insect noise at the site, which often resulted in memory cards being filled within the first survey night with recordings that were later scrubbed as noise. If detectors were placed at more open areas along the outer edge of the riparian buffer, a more accurate depiction of bat activity would most likely have been collected for this site. The adjusted species richness is presented for this site, with the understanding that this is not representative of a full or complete monitoring of the site during the field season.

Adjusted species richness

The big brown and silver-haired species group (low phonic guild) was observed in every deployment, with the exception of deployments at the planted buffer in Shenandoah County (Table 2). Eastern red bats (medium phonic guild) were also detected in most deployments (Table 2). Tricolored bats (medium phonic guild) were observed at >80% of deployments at the planted buffer in Rockingham County and 60%

of deployments at the unrestored buffer in Rockingham County. Tricolored bats were observed <50% of deployments at the other buffers (Table 2). Hoary bats (low phonic guild) were detected at $\geq 80\%$ of deployments at the planted and unrestored Augusta sites, unrestored Shenandoah site, and unrestored Rockingham site (Table 2). *Myotis* spp. (high phonic guild) were detected during $\geq 80\%$ of deployments at half of the sites (Table 2). However, the actual number of recordings that were identified as hoary bats and *Myotis* spp. within those deployments is relatively small with often a single call being identified to the species or species group during a deployment.

Table 2. The adjusted species richness for each site. The percent of deployments a species was observed is adjusted by the number of nights surveyed.

	Adjusted Species Richness					
	<u>Augusta</u>		<u>Shenandoah</u>		<u>Rockingham</u>	
	Planted	Unrestored	Planted	Unrestored	Planted	Unrestored
Nights Surveyed	13.5	27.5	18.0	23.5	22.0	23.5
Big brown and Silver-haired	100%	100%	67%	100%	100%	100%
Eastern red	100%	100%	67%	88%	100%	80%
Hoary	100%	90%	11%	88%	44%	80%
Tricolored	33%	40%	11%	25%	89%	60%
<i>Myotis</i> spp.	83%	30%	0%	25%	89%	80%

Effects of riparian treatment and season on bat activity

With the exclusion of the restored Shenandoah riparian zone, total bat activity across all guilds was not significantly greater at planted riparian buffers ($z = 1.6$; $p = 0.3$)

but was significantly different over the course of the field season ($z = 4.8$; $p \leq 0.0001$) (Table 3). Activity of the medium phonic guild was significantly greater at planted riparian buffers than at unrestored riparian buffers ($z = 2.5$; $p = 0.04$) and was significantly different over the course of the field season ($z = 14.1$; $p \leq 0.0001$) (Table 3). Riparian treatment did not significantly affect the activity of bats in the high and low phonic guilds (Table 3). Activity of the low phonic guild was significantly different over the course of the field season ($z = -7.4$; $p \leq 0.0001$) (Table 3).

Table 3. Significance of riparian treatment and seasonality on recorded bat activity.

Effect	Estimate	Std. Error	Unadjusted p-value	Holm-Bonferroni corrected p-value (α/k)
Total Bat Activity				
Intercept	2.805	0.627		
Riparian Treatment	0.664	0.421	0.114	0.342
Seasonality	0.125	0.026	< .001	< .001
High Guild Activity				
Intercept	-5.130	3.702		
Riparian Treatment	2.108	2.202	0.339	0.678
Seasonality	0.353	0.213	0.098	0.098
Medium Guild Activity				
Intercept	-0.125	0.765		
Riparian Treatment	1.292	0.509	0.011	0.045
Seasonality	0.603	0.043	< .001	< .001
Low Guild Activity				
Intercept	3.837	0.777		
Riparian Treatment	0.045	0.522	0.931	0.931
Seasonality	-0.265	0.036	< .001	< .001

Original p-values were found by correcting the original α of .05 by the index of comparison (k). Original p-values were grouped by individual effect for the index of comparison; four p-values within each grouping.

Insect and Riparian Forest Characteristics

Insect abundance and diversity

Of the insects collected over the course of the field season, 6,090 insects were identified to order. All presented data and findings indicate trends; as larger sample sizes over a greater portion of the summer field season would be required for more meaningful

statistical tests. Diptera comprised the majority of insects identified at all six sites, which is common for agricultural areas (Table 4). The riparian buffers in Augusta County appear to have had the greatest abundances with 1,693 and 425 median flying insects compared to the other buffers which had median abundances between 401 and 27 (Table 4). For two pairs of buffers (Augusta and Shenandoah), the unrestored riparian buffer tended to have a much greater abundance of insects, primarily Diptera: 1,404 and 302 compared to 236 and 11 (Table 4). The buffers in Rockingham County had much more similar flying insect median abundances to one another than did the other pairs of sites (Table 4).

The five most abundant flying insect orders collected (Diptera, Homoptera, Lepidoptera, Hymenoptera, and Coleoptera) are common prey for bats in the region, indicating that restored and denuded riparian zones may be suitable for foraging (Carter et al. 2003). Planted riparian zones had Simpson Diversity Indices ($1 - D$) of: 0.60, 0.70, and 0.70 (Augusta, Shenandoah, and Rockingham) compared to unrestored riparian zones: 0.30, 0.41, and 0.60 (Augusta, Shenandoah, and Rockingham). This diversity indicates a trend of sites with planted riparian zones containing flying insect populations that are more diverse at the ordinal level, though these flying insect populations may be less rich and less abundant than those at unrestored riparian zones. The differences in flying insect diversities observed is likely due in large part to their respective evenness being influenced by differences in Diptera abundance (Table 4). I would expect increased bat activity at the planted riparian buffers because they supported more diverse insect populations, although a decrease in abundance of insects at these buffers may have a greater effect on bat activity.

Table 4. Flying insect data are organized by order across pairs of sites and riparian treatments. Data are the median abundances from the deployments at each site that were randomly selected for identification. ‘Unknown Flying’ are specimens that were determined to be capable of flying but unable to be identified to the ordinal level and are included in the ‘Total Flying’ group. Only specific orders are included in diversity indices.

	Median Abundances					
	<u>Augusta</u>		<u>Shenandoah</u>		<u>Rockingham</u>	
	Planted	Unrestored	Planted	Unrestored	Planted	Unrestored
Deployments Identified	4	1	1	3	3	3
Diptera	236	1404	11	302	36	54
Homoptera	117	63	8	31	26	22
Lepidoptera	6	128		5	4	4
Hymenoptera	20	44	5	20	5	3
Coleoptera	19	19	3	22	4	6
Trichoptera	9	34		4	1	2
Heteroptera	3	1		1	3	2
Ephemeroptera				5	2	
Psocoptera	3			1	2	1
Odonata	1			5		
Plecoptera	3			1		
Neuroptera						1
Unknown Flying	4			2	14	
Ground Insects	217	54	122	55	29	40
Total Flying	425	1693	27	401	111	95
Simpson's (1 - D)	0.5954	0.3040	0.6996	0.4105	0.7098	0.6154
Shannon-Weaver (H)	1.2292	0.7010	1.2827	0.9809	1.5865	1.3352

Effects of riparian buffer forest characteristics on bat activity

There were no clear trends concerning tree basal area (> 10 cm dbh) or canopy cover related to recorded bat activity. Within each pair of sites, the site with a planted riparian zone had higher stem counts (40-120 more trees per hectare); contrary to this pattern, the Rockingham unrestored riparian zone had a greater stem count than did the planted riparian zones in Augusta and Shenandoah counties. A generalized linear model with stem count as the independent effect, showed the effect of stem count to be marginally significant on total bat activity (all guilds combined) ($z = 2.0, p \leq .1$) (Fig. 2). When calls were assigned to the three phonic guilds, stem count had a significant, positive effect on recorded activity of the medium phonic guild ($z = 4.0, p \leq .001$) but not the recorded activity of the low phonic guild ($z = .3, p = .9$) (Fig. 2).

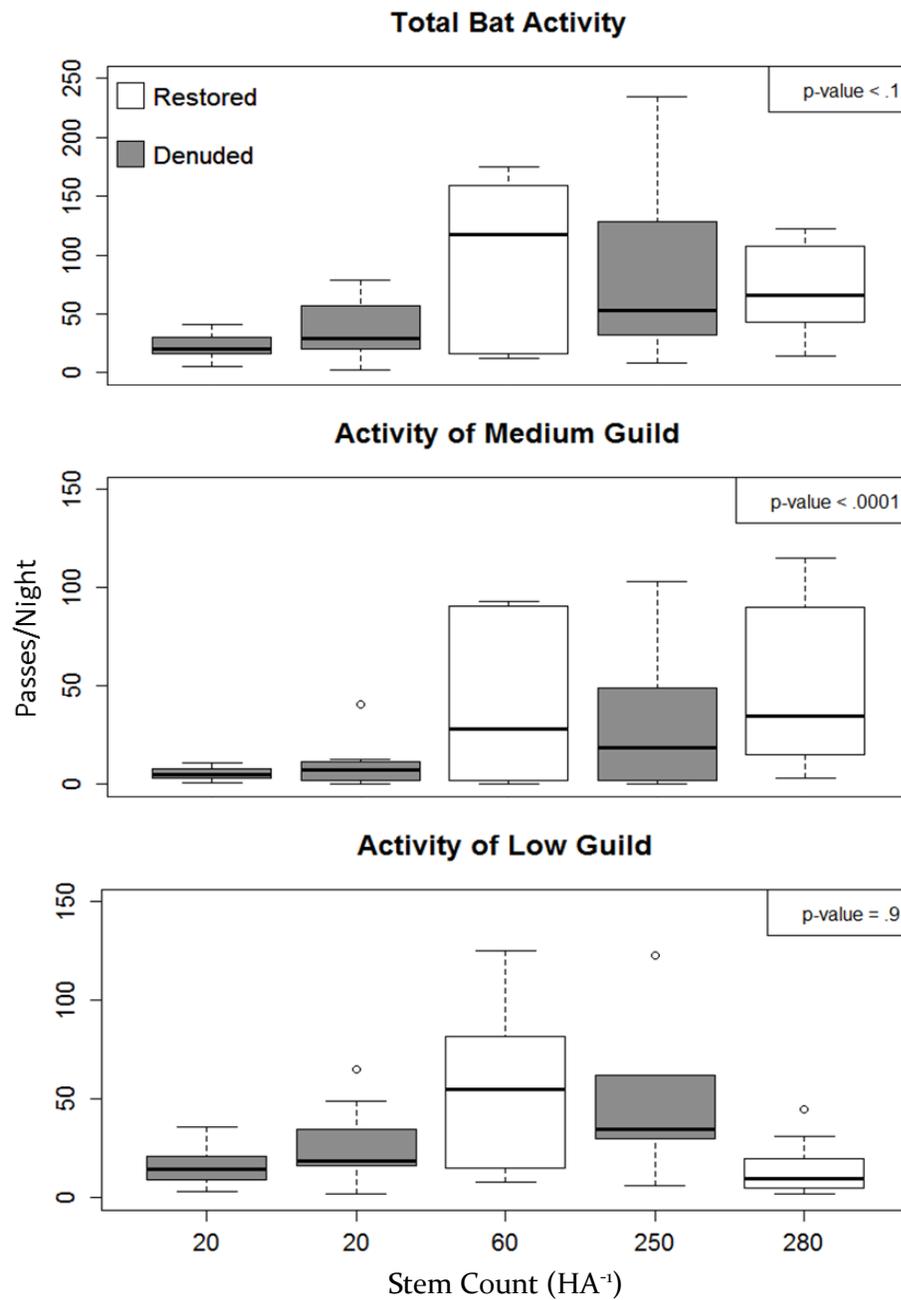


Figure 2. Bat activity is measured across the stem count (HA^{-1}) (not to scale) at each site. The Shenandoah planted riparian zone is not included due to errors in methodologies and the high guild is not shown due to a lack of recorded calls. Displayed p-values are corrected using the Holm-Bonferroni method.

Discussion

This study is the first to evaluate the effect of riparian buffers planted through the Conservation Reserve Enhancement Program (CREP) on bat activity. The collected acoustic data, suggests that the bat community within the agricultural matrix of the Shenandoah Valley primarily consists of big brown bats and eastern red bats. These species are the two most common species in the region, especially in more developed areas, and were predicted to comprise the majority of bats within agricultural fields of the Shenandoah Valley (Timpone et al. 2011).

I predicted that bat activity, especially within the medium phonic guild, would be greater at CREP than control sites because of increased basal area and stem density of trees, and more abundant insect populations. The effect of canopy cover was expected to be minimal due to the lack of canopy provided by the planted riparian buffers. There was no difference in total bat activity between riparian treatments (Table 3), but planted riparian buffers were found to significantly increase activity of medium phonic guild bat species (eastern red bat and tricolored bat) (Fig. 2). These species are known to be forest edge generalists and have been observed using heterogeneous habitats, especially along the edges of habitat interfaces (Ford et al. 2005, Hein et al. 2009). The thin buffers created through CREP are similar to the regenerative forests with sparse vegetation known to be of importance to medium phonic guild bats (Loeb and O'Keefe 2006). The eastern red bat was commonly recorded at all sites, and likely produced the majority of calls within the medium phonic guild, based upon call identifications and previous surveys (Ford et al. 2005, Timpone et al. 2011). Tricolored bats are most most active in and near riparian buffers, which would suggest that buffers planted through CREP may

be suitable habitat for the species even in areas that are less cluttered, or are more affected by anthropogenic input, despite the species primarily being found in coastal plain and piedmont regions (Ford et al. 2005, Johnson et al. 2008, Kalcounis-Rüppell et al. 2007). The benefits of riparian buffers for tricolored bats within agricultural areas may be limited by a lack of trees within the buffer, as the only sites where tricolored bats were identified in >50% of deployments were those in Rockingham County, which had stem counts of 250 and 280 trees per hectare.

Greater basal area, canopy cover, and tree count have previously been associated with increased bat activity (Mager and Nelson 2001, Perry et al. 2007, Perry and Thill 2008, Vonhof and Gwilliam 2007). In the studied riparian buffers, the number of trees present was the only evaluated buffer characteristic that was found to have a marginal effect on total bat activity ($p \leq .10$) and was significantly correlated with activity of the medium phonic guild ($p \leq .001$). The trees within planted riparian buffers were relatively small (average dbh = 20.4cm) and young (≤ 18 years), typical of young regenerating forests. These buffers were relatively dense, had a cluttered understory, and did not provide much canopy cover over the streams they paralleled. The unrestored riparian buffers were mostly clear of trees, except for the unrestored buffer in Rockingham County which was comprised of slightly larger trees (average dbh = 29.6cm) and was similar to planted riparian buffers in tree density.

The effect of increased tree count on bat activity was consistent across riparian type, with increased bat activity being observed at buffers with >60 trees per hectare; regardless of tree size or recorded canopy cover. This indicates a threshold for tree count to have an effect on bat activity at riparian buffers in agricultural matrices and that the

number of trees may be the most important factor when determining the effectiveness of riparian buffers within these habitats. The physical structure that dense riparian buffers provide is an important consideration for future conservation strategies.

The lack of physical structure (trees) in agricultural fields may leave bats exposed to external pressures such as wind and predators. Riparian corridors may also shelter bats from wind turbulence, reducing the energetic cost of flying in these corridors. By flying along dense riparian corridors, agile bats may avoid raptors which often hunt in open areas. It is unlikely that the planted buffers are providing significant roosting habitat as the trees within these buffers are young and thin, however these trees may be used by bats to rest for short periods, especially in areas that are otherwise cleared of vertical structure. This shelter from external pressures may reduce energetic costs associated with commuting between roosts and foraging habitats or could allow bats to fly along corridors that would otherwise be inefficient (Verboom and Spoelstra 1999). Lastly, planted riparian buffers could be supporting more preferable insect populations, despite this not being evident in the insects collected.

Higher bat activity has been attributed to habitats supporting more abundant or diverse insect populations. I expected to see similar effects at planted riparian buffers which were predicted to support favorable prey communities for bats by lessening soil erosion, creating a forested habitat, and supporting highly mobile insects (Fahrig et al. 2015, Greenwood et al. 2012, Treitler et al. 2016). However, restored and denuded riparian buffers supported similar insect orders and relative abundances, with the exception of increased abundances of Diptera at denuded riparian buffers. It is possible that this relative increase in Diptera could support improved foraging opportunities for

bats, though I would expect to see a related increase in bat activity, especially activity amongst medium phonic guild bats which are known to forage upon a greater number of soft-bodied insects such as Diptera. An opposite trend was observed, which would suggest that planted riparian buffers are being used at higher levels due to factors other than prey availability. It is possible that our insect sampling methods were inefficient for explaining bat activity due to limited sample size and our trap's ineffectiveness at collecting higher flying insects often predated upon by bats (Monck-Whipp et al. 2018). Diet analyses of bats captured at similar sites are required before more conclusive inferences can be made regarding the foraging activities of bats at these sites. All of these factors may be contributing to the increase in activity of the medium phonic guild. These effects may be less substantial for bats within the low phonic guild that likely are better adapted for open space foraging, moderating the benefits of riparian buffers.

A similar increase in activity was not observed for open-space foragers within the low phonic guild or bats within the high phonic guild adapted for foraging in cluttered environments. The big brown and silver-haired bat species group was detected during every deployment to each site with the exception of the Shenandoah restored riparian buffer, where zero bat recordings were collected during some deployments with no evidence of detector failure. Big brown bats are one of the most observed species throughout the region and are known to use a variety of habitat types (Timpone et al. 2011). Hoary bats were observed in the majority of deployments, $\geq 80\%$ of deployments at four sites. All of the low phonic guild bat species within the region are known to forage in open areas such as fields, which may explain their prevalence in my study and the minimal effect of planted riparian buffers on their likelihood of being detected.

The high phonic guild, represented by the *Myotis* species, was recorded in $\geq 80\%$ of deployments at three of the sites, however it was common for a single call to be recorded to the species group within a deployment. It was also difficult to differentiate between true *Myotis* calls and short, narrow band calls produced by other species of bats. These factors likely inflated the perceived prevalence of the genus within surveyed riparian buffers. These results differ from those recorded during mist net events from 2000-2011 in Rockingham and Shenandoah counties which indicated the little brown bat was once the second most common species in the counties (Timpone et al. 2011). However, the bat communities in this region are believed to have been strongly impacted by white nose syndrome (WNS) which has led to this and other *Myotis* species becoming rare (R. Reynolds, Virginia Game and Inland Fisheries, Verona, VA, pers. comm.). A precipitous decline in the species within the region would be consistent with studies in other areas where the WNS causing fungus has spread (Francl et al. 2012, Frick et al. 2015, Turner et al. 2011).

Despite the activity of bats within the phonic guilds being affected by the planting of riparian buffers, restored and denuded riparian buffers supported similar species of bats with little difference in the likelihood of a species being detected between treatment types. The increased clutter of these buffers did not support a greater number of species, nor did it prevent species of bats from being present. The species richness of bats between pairs of sites was more similar than richness within riparian treatments, suggesting that larger landscape level characteristics played a role in the likelihood of a bat species being observed. A larger sampling scheme that surveyed more buffers within

the region may be effective in differentiating between larger and smaller scale landscape level characteristics.

The heterogeneity in the agricultural landscape created by the planting and maintenance of riparian buffers may allow bats from the medium guild greater access to insect rich agricultural fields. These relatively isolated buffers may be acting as ecological sinks from surrounding forest, helping to drive agro-ecological interactions in these fields thus benefitting bats in the medium phonic guild and agricultural production (Heim et al. 2018).

Conservation implications

As bat species continue to decline due to habitat loss and white-nose syndrome, it is imperative that bats are conserved in a variety of habitats, including agricultural areas where they control insect pests. Current bat conservation efforts are focusing on protected lands and species imperiled by white-nose syndrome with emphasis on maintaining roosting habitat, but it is also imperative that common bat species are also protected so that they are not lost as bioindicators, sources of insect pest control, and model systems for research (Agosta 2002). Initiatives like the Conservation Reserve Enhancement Program can be effective tools for promoting bats in these ignored habitats, without siphoning funds from other bat conservation initiatives. Although riparian projects often focus on soil and water conservation, it is important to recognize that these types of programs can be important components of wildlife management plans and may be affecting taxa other than focal species (white-tailed deer, waterfowl, and songbirds).

Conservation projects in agricultural areas, including the restoration of riparian buffers, are becoming increasingly important as the effects of agricultural intensification,

climate change, and habitat loss continue to be felt by wildlife populations. However, not all conservation projects may produce similar results and a lack of long-term monitoring of conservation projects is a recognized issue that limits improvement upon current practices and the overall effectiveness of conservation programs. Conservation projects are often ignored after their initial installation and assumed to be effective. Without long-term monitoring, consultants, government agencies, and other land managers are less able to make informed management decisions and improve upon current conservation practices. This study fills a significant gap in knowledge concerning hundreds of restoration projects. Our findings suggest that buffers planted through CREP are an effective tool in promoting forest generalist bat species and the effects of these buffers may be similar to those provided by naturally occurring riparian buffers, supporting the planting and continued conservation of riparian buffers on private land.

During the identification of potential field sites, I repeatedly came across two concerns regarding CREP. Many land managers have expressed concern with the Conservation Reserve Enhancement Program due to multiple installations failing to generate second stage growth within the buffer, often caused by invasive plants or browsing by white-tailed deer (Bradburn et al. 2010, Tomlin and Kastindiek, James Madison University, Harrisonburg, VA, unpublished. data). The second major concern with the program is that because the projects are done on private property, the land owner suffers no repercussions for clearing the planted buffers or reintroducing cattle into the streams once their initial contract is completed (5-15 years). In order for conservation efforts on private land, including riparian buffers planted by CREP, to be successful these

issues must continue to be dealt with through land owner education and other conservation initiatives.

If riparian buffers in agricultural areas are preserved until they are able to develop into mature forest stands, then it can be expected that the benefits these buffers provide will change over time. I expect that older riparian buffers planted through CREP will continue to support medium phonic guild bats and we may also begin to see a significant increase in calls from the low phonic guild due to more abundant and diverse insect populations supported by later successional habitat. Older, larger trees within maintained riparian buffers may also provide roosting habitat for multiple bat species, including those affected by WNS.

I have provided evidence that riparian buffers planted through the Conservation Reserve Enhancement Program positively impact the bat community of the Shenandoah Valley, specifically bats of the medium phonic guild (eastern red bats and tricolored bats). The acoustic data gathered paired with forest transects indicate that the planting and maintaining of trees along waterways has significant conservation implications for bats in an agricultural matrix. Acknowledging the young age of planted buffers and local scope of our project, I recommend continued monitoring of riparian buffers planted through CREP across Virginia.

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