NOCTURNAL INSECT AVAILABILITY IN BOTTOMLAND HARDWOOD FORESTS
MANAGED FOR WILDLIFE IN THE MISSISSIPPI ALLUVIAL VALLEY

Lorraine P. Ketzler^{a*1}, Christopher E. Comer^a, Daniel J. Twedt^b,

^aArthur Temple College of Forestry and Agriculture, Stephen F. Austin State University,
419 East College Street, Nacogdoches, TX 75962

^bU.S. Geological Survey, Patuxent Wildlife Research Center, University of Memphis,
Memphis, TN 38152

*Corresponding Author, Lorraine_p_ketzler@fws.gov

¹Present Address: 107 Highway 85 North, Niceville, FL 32578

ABSTRACT

Silviculture used to alter forest structure and thereby enhance wildlife habitat has been advocated for bottomland hardwood forest management on public conservation lands in the Mississippi Alluvial Valley. Although some songbirds respond positively to these management actions to attain desired forest conditions for wildlife, the response of other species, is largely unknown. Nocturnal insects are a primary prey base for bats, thereby influencing trophic interactions within hardwood forests. To better understand how silviculture influences insect availability for bats, we conducted vegetation surveys and sampled insect biomass within silviculturally treated bottomland hardwood forest stands. We used passive blacklight traps to capture nocturnal flying insects in 64 treated and 64 untreated reference stands, located on 15 public conservation areas in Arkansas, Louisiana, and Mississippi. Dead wood and silvicultural treatments were positively

associated with greater biomass of macro-Lepidoptera, macro-Coleoptera, and all insect taxa combined. Biomass of micro-Lepidoptera was negatively associated with silvicultural treatment but comprised only a small proportion of total biomass. Understanding the response of nocturnal insects to wildlife-forestry silviculture provides insight for prescribed silvicultural management affecting bat species.

KEYWORDS

Bats, bottomland hardwood forest, desired forest conditions, insect availability, Mississippi Alluvial Valley, wildlife forestry

1. Introduction

Insects are important in maintaining the health and diversity of forest ecosystems (Andrewartha and Birch 1984) through pollination and defoliation (Janzen 1987), as well as influencing nutrient cycling processes (Gorham et al. 2002). Although many studies have focused on silvicultural practices to reduce the impact of insect pests (Berryman 1986), less attention has been given to understanding how management actions affect abundance and species composition of forest insect communities (Burford et al. 1999, Ober and Hayes 2008).

Insect abundance is affected by vegetative characteristics such as structural complexity (Gorham et al. 2002), species richness (Haddad et al. 2001), and composition (Schowalter 1986). Greater densities of woody and herbaceous vegetation generally support greater abundance of insects (Gorham et al. 2002). However, specific insect taxa differ in their response to silvicultural methods and intensities used to

promote woody and herbaceous growth (Intachat et al. 1997, Summerville et al. 2004). For example, Burford et al. (1999) found that in Kentucky, abundance of moth families (e.g., Yponomeutidae, Limacodidae, Pyralidae, Geometridae, Notodontidae, and Arctiidae) differed among forest stand age classes. Similarly, Summerville and Crist (2003) found that although there was no difference in moth species richness or abundance between managed and wilderness stands in southern Ohio, the community composition was influenced by management of the surrounding landscape.

Insects provide a major source of food for many wildlife species (Gorham et al. 2002), including bats (Jones and Rydell 2003). Insectivorous bats, particularly lactating females, are capable of consuming up to 73% of their body weight in insects per night (Kuntz et al. 1995). Although the availability of insect prey for bats is often unknown (Dodd et al. 2012a), the diet of bats includes moths, beetles, and flies (Clare et al. 2009, Hamilton and Barclay 1998). However, the insect taxa that are consumed vary with bat species morphology, sympatric species and habitat conditions (Dodd et al. 2012a, Fenton 1990, Freeman 1981, Menzel et al. 2002).

Silvicultural practices, such as selective harvest, directly impact bat populations within forest stands by changing foraging habitats and roosting sites (Menzel et al. 2002, 2005). Silvicultural treatments prescribed to enhance wildlife habitat by modifying forest structure (e.g., wildlife-forestry; Twedt 2012), have been advocated for management of bottomland hardwood forests on public conservation lands within the Mississippi Alluvial Valley (Twedt and Somershoe 2010, Wilson et al. 2007a). Structural

components such as canopy closure, basal area, and tree species richness can be managed through prescribed silviculture. Silvicultural treatments undertaken to enhance wildlife habitat are beneficial to songbirds (Twedt and Somershoe 2010, Twedt and Wilson 2007). Loeb and O’Keefe (2006) found early successional habitats and canopy gaps were used by bats for commuting and foraging, but the effect of wildlife forestry treatments on nocturnal insects and bats in the Mississippi Alluvial Valley has not been investigated. Continued application of wildlife silviculture in this region behooves wildlife managers to assess its effect on multiple species. To that end, we compared insect biomass in several orders between forest stands that had been subjected to silvicultural treatments and paired untreated reference stands. In addition, we examined the influence of various forest structural and environmental variables on insect biomass to identify those factors that were important for determining insect abundance in these stands.

2. Methods

2.1 Study location

We surveyed 128 bottomland hardwood forest stands (64 treated and 64 reference) within the Mississippi Alluvial Valley on 15 public conservation lands managed by state wildlife agencies (Wildlife Management Areas, WMA) or the U.S. Fish and Wildlife Service (National Wildlife Refuges, NWR) during April to August, 2013, and May to August, 2014. Surveyed WMA and NWR (hereafter referred to as “locations”) were in Arkansas (Cache River NWR, Dagmar WMA, White River NWR), Louisiana (Bayou

Cocodrie NWR, Big Lake WMA, Boeuf WMA, Dewey Wills WMA, Red River WMA, Russell Sage WMA, Three Rivers WMA, Tensas River NWR), and Mississippi (Morgan Brake NWR, O'Keefe WMA, Panther Swamp NWR, Yazoo NWR; Fig. 1).

We surveyed locations sequentially starting from the southernmost to the northernmost location to account for seasonal change within temperate deciduous forests that may influence our focal taxa (Hayes 1997). Surveyed stands (i.e., finite forest areas subjected to a common silvicultural prescription: often referred to as "management units" or "compartments") were mature bottomland hardwood forests. At each study location (WMA or NWR), managers identified stands that were silviculturally treated to enhance wildlife habitat within the past 12 years. We restricted selection of treated stands to ≤ 12 years post-treatment because the predominant effects of silvicultural treatments on birds diminished after circa 12 years (Twedt and Somershoe 2010, Twedt and Wilson 2007).

Silvicultural treatments, including group selection, small patch clearcuts, and individual tree selection (Meadows and Stanturf 1997), were prescribed based on stand conditions and management objectives. Treatments were applied individually or in combination within a single treated stand. Regional application of silvicultural treatments varied among locations and year of application (Twedt and Wilson 2016). Mean area of treated stands was 168 ± 151 ha ($n = 64$) with each treated stand encompassing multiple anthropogenic canopy gaps.

105 Based on availability, we randomly selected up to 3 treated stands at each location.
106 We concurrently selected an equal number (up to 3, for a 1:1 pairing with treatment
107 stands) of adjacent reference stands at each location. Reference stands were chosen to
108 be proximate to treated stands. Reference stands were of similar area, hydrology, and
109 vegetative species composition, but without silvicultural disturbance for >12 years (with
110 preference given to older stands). Due to silvicultural treatments that occurred after our
111 surveys in 2013, some stands were unavailable in 2014. Thus, 22 treatment and 24
112 reference stands were surveyed during 2013 and 2014, but we surveyed 8 new
113 treatment and 6 new reference stands in 2014. Even so, we maintained the 1:1 pairing
114 of treatment and reference stands throughout our surveys.

Figure 1. Public conservation lands surveyed for insect biomass during summer 2013 and 2014 in the Mississippi Alluvial Valley. After our study, Three Rivers WMA and Red River WMA were combined and renamed Richard K. Yancey WMA.

2.2 Insect surveys

Blacklight traps are a standard technique for sampling nocturnal flying insect assemblages (Covell 2005; Dodd et al. 2008, 2012a) that effectively attract moths from up to 25 m (Muirhead-Thomson 1991, White et al. 2016). We surveyed nocturnal flying insects using 10-Watt blacklight bucket traps (Universal Light Trap, BioQuip Products, Gardena, CA, US) powered by 12 V gel-cell batteries (Covell 2005; Dodd et al. 2008, 2012a). We placed HERCON[®] Vaportape II insecticide-treated plastic strips (Hercon Environmental, Emigsville, PA, US) inside the traps, and lifted traps 1.5-2.5 m above the ground. Traps were active from 21:00 to 06:45 h (ca. dusk to dawn). We concurrently surveyed treated and reference stands during one randomly selected night with one active trap per stand. We collected samples each following day and froze them for lab analysis. Insect trap locations were collocated with bat acoustic detection devices as part of a concurrent study of the relationships between insect availability and bat activity. Detectors were situated randomly within stands, within canopy gaps, and >50 m from the edge of the stand (Ketzler 2015), Insect traps were located >200 m from the detectors and >50 m from the edge of the stand.

We analyzed insect biomass collected at each treatment and reference stand. Total arthropod biomass was determined to the nearest 0.01 g. We did not include samples that weighed <0.01 g. In addition to total biomass, we also determined biomass of Lepidoptera (moths), Coleoptera (beetles), and Diptera (flies) because these insect orders are frequent prey for bats (Feldhamer et al. 2009). Because some bat species

forage preferentially on larger or smaller insects, we used the methods proposed by Dodd et al. (2008, 2011, 2012b) to sub-divide Lepidopteran biomass based on wingspan into micro-Lepidoptera (<20 mm) or macro-Lepidoptera (≥20 mm). Similarly, we used body length to separate biomass of micro-Coleoptera (<10 mm) and macro-Coleoptera (≥10 mm). All other Orders were combined as other insect biomass (i.e., total biomass-Diptera-Coleoptera-Lepidoptera = other biomass).

2.3 Vegetation surveys

We surveyed forest vegetation within 10 circular, 0.05 ha (12.62-m radius) plots that were located at ~100 m intervals along two 400 m transects per treatment and reference stand based on surveys used for habitat assessments in the Mississippi Alluvial Valley (Wilson et al. 2007b). We started transects at least 50 m from the edge of the stand at a randomly selected access point and traversed each transect on a randomly selected azimuth, with the restriction that transects not exit the surveyed stand. If barriers were encountered (i.e., oxbow lakes), the observer altered the azimuth of the route but continued the survey transect. If transects crossed, the distance between plots was altered to ensure plots did not overlap. With each plot, we measured diameter at breast height (dbh) of all trees ≥20 cm dbh to calculate basal area of large trees. We identified each tree to species, and classified tree condition as alive, dead, or downed dead wood. We estimated mean percent canopy closure using a spherical densiometer at 4 points in the cardinal directions along the edge of the 10 circular plot boundaries (Twedt and Somershoe 2010). We counted stems of small trees (<20 cm

dbh) within a 4-m radius nested sub-plot (Martin et al. 1997). To characterize stand conditions, all vegetation measures were averaged across all plots within each treated or reference stand.

2.4 Weather parameters

Although our focus was on silvicultural impacts, weather is an important regulator of insect populations (Gandhi et al. 2007). Therefore, we included weather measurements to account for confounding effects. Weather measurements were accessed through the Remote Automated Weather Stations, USA Climate Archive (Western Regional Climate Center) for the stations nearest each surveyed location. We calculated the following weather variables overnight from 21:00 – 07:00 h: mean nightly temperature (°C), relative humidity (mean percent), total precipitation (mm), and mean nightly wind speed (m/s). We also calculated moon illumination as the percent illumination of the moon's face from space for each survey night based on Kiffney et al. (2003) as calculated using the U.S. Naval Observatory's fraction of the moon illuminated calendar (aa.usno.navy.mil/data/docs/moonfraction.php). This variable reflects moon phase without incorporating cloud cover.

2.5 Analysis

We performed randomized block analysis of variance (ANOVA) on raw data (Glass et al. 1972) using PROC GLM in SAS (v.9.2, SAS Institute, Inc., Cary, NC). We examined the effects of treatment and forest structural characteristics on insect biomass

while accounting for location (Dellasala et al. 1996, Zar 2010). We blocked locations to reduce the variability inherent in sampling locations across a broad geographic area (Zar 2010). We did not differentiate treated stands by silvicultural intensity, but assumed vegetative measurements sufficiently characterized treatment intensity.

We used principal component analysis (PCA) using PROC FACTOR to derive uncorrelated vegetation and weather variables based on measured values (Jamison et al. 2002, Thompson et al. 2013). We transformed vegetation ($\text{asin}\sqrt{x}$ or $\sqrt{x}$), weather ($\ln[x]$ or $\ln[x+1]$), and insect biomass ($\ln[x+1]$) variables to improve normality (Zar 2010). Because we surveyed locations sequentially, from southern locations to northern locations, we included survey date, along with vegetation and weather variables in PCA. Survey date incorporated a confounded effect for location and date of survey (Summerville and Crist 2003). We rotated the components using their varimax score (Manly 1986) and we used factor loadings to identify relationships between original variables and principal components (Jamison et al. 2002). We used Cook's distance with PROC REG to identify and remove 9 influential outliers that indicated deviance in conditions from all other observations (Gehrt and Chelsvig 2003, Hutcheson and Sofroniou 1999; Zuur et al. 2007, 2010).

We used PROC GLMSELECT to generate 95 candidate regression models for each insect taxon (using biomass by taxon as the response variable). We included silvicultural treatment as a categorical (binary) indicator of stand structure (i.e., treatment = 1, reference = 0), age of the treatment (number of years since treated) as a

within treatment variable, and principal components in all possible subsets, including a null model (intercept-only) and a treatment-only model. We used Akaike's Information Criterion for small sample sizes (AIC_c) and calculated model differences (ΔAIC_c) and model weights (w_i) for each candidate model (Burnham and Anderson 2002). We considered models competitive at $\Delta AIC_c \leq 2.0$ to have support as predictors of insect biomass (Ober and Hayes 2008, Thompson et al. 2013). We calculated the summed weights of these supported models with shared predictors as evidence supporting the relative strength of each predictor (Johnson and Omland 2004, Wagenmakers and Farrell 2004).

3. Results

3.1 Vegetation and weather

We quantified forest structural characteristics on 1,536 plots from 15 April to 12 August, 2013, and 1 May to 15 August, 2014. The time since treatment of stands was 5.1 ± 4.0 years. Treated stands were similar to reference stands for canopy closure, stem density of small trees, density of dead downed wood, density of large trees, and tree species richness (Table 1). Treated stands had lower basal area of large trees ($26.75 \pm 1.58 \text{ m}^2$ per ha compared to $33.85 \pm 1.99 \text{ m}^2$ per ha; $F_{1,111} = 12.5$; $P < 0.01$) and more snags (13 ± 1 per ha compared to 10 ± 1 per ha; $F_{1,111} = 5.6$; $P = 0.02$) than were in reference stands.

Principal components analysis summarizing vegetation, weather, and date variables resulted in five principal components (Table 2). We interpreted principal components as representing increased dead downed wood and snags from large trees (PC1); increased large tree basal area and tree species richness (PC2); increased wind and decreased relative humidity (PC3); combined survey date and increased stem density of small trees as a result of more open canopies (PC4); and increased precipitation and moon illumination (PC5). These five principal components explained 68% of the cumulative variance (Table 2).

Temperature was not a strong variable for any component. Principal component 2 was likely an index of gap recovery post-disturbance as gap dynamics promote species diversity and tree growth (Runkle 1982). Principal component 4 could also represent early gap-phase regeneration when young stems have access to increased resources such as light (Swanson et al. 2011).

3.2 Insect biomass

From 128 stand-night samples surveyed from 15 April to 12 August, 2013, and 1 May to 15 August, 2014, we collected 4,925 g of insect biomass (2,633 g from treated stands and 2,292 g from reference stands; Table 3). Coleoptera were the most prevalent order (94% of the total biomass) with macro-Coleoptera comprising 81% of Coleopteran biomass. Lepidoptera were 2.7% of the total biomass, with macro-Lepidoptera accounting for 68% of this biomass. Diptera comprised only 0.12% of the total biomass. The cumulative biomass for all other Orders was 2.4% of the total

biomass. Mean insect biomass did not differ between treatment and reference stands for total biomass ($F_{1,111} = 0.005$; $P = 0.95$), macro-Lepidoptera ($F_{1,111} = 1.3$; $P = 0.27$), macro-Coleoptera ($F_{1,111} = 0.1$; $P = 0.8$), micro-Coleoptera ($F_{1,111} = 1.2$; $P = 0.29$), Diptera ($F_{1,111} = 0.4$; $P = 0.55$), and other Orders ($F_{1,111} = 0.9$; $P = 0.34$; Table 3). Biomass of micro-Lepidoptera was lower ($F_{1,111} = 4.6$; $P = 0.04$) in treated stands than in reference stands, but accounted for <1% of all biomass.

3.3 Influence of vegetation and weather on insect biomass

Models with support ($\Delta AIC_c \leq 2$) for predicting insect biomass varied among taxa and size classes but generally included only treatment and the first principal component (PC1) as predictors (Table 4). Even though most vegetation measurements (Table 1) and most insect taxa (Table 3) did not differ between treated and reference stands, treatment as an indicator of stand structure had support as a predictor of insect biomass for all taxa comparisons, except Lepidoptera (Table 4). Treatment was positively related to biomass for other insect Orders, and in addition to dead wood (PC1), was positively related to total biomass and biomass of macro-Coleoptera. The null model was the most supported model for Diptera, but treatment had the greatest predictor weight for Diptera (Table 5). Thus, it is likely that there were likely unmeasured effects associated with treatment that influence Diptera.

Models that incorporated PC1 (dead wood) were supported for all taxa except Diptera (Table 4). Dead wood had a positive effect on biomass when considered alone and when associated with treatment for total biomass, macro-Lepidoptera, macro-

Coleoptera, and other orders. However, for smaller size class micro-Lepidoptera and micro-Coleoptera, dead wood was negatively associated with biomass.

4. Discussion

Although most vegetation variables did not differ between treatment and reference stands (Table 1), principal components derived from measured forest variables were useful for predicting insect biomass in bottomland hardwood forests within the Mississippi Alluvial Valley. We found dead wood (snags and downed woody debris of large trees) was the most influential predictor of insect biomass. The presence and abundance of dead wood, particularly in treated stands, were positively related to large size class insect biomass but negatively associated with smaller size class insect biomass. Notably, dead wood provides important shelter, foraging, and reproductive habitat for many beetle and moth species (Stockland et al. 2012).

Forest structural characteristics and microclimate conditions have been found to influence insect taxa in forests (Dodd et al. 2008, 2012b), though we did not find them to be strong predictors in our study. The similarity in variables between treatment and reference stands suggests that silvicultural treatments to enhance habitat for wildlife were implemented with less intensity than most private commercial timber harvests or that sufficient time since treatment elapsed for tree growth to compensate for treatment. We attempted to capture this time effect by using age of treatment as a within treatment effect, but we did not find this variable to be a strong predictor.

For each forest stand on a WMA or NWR, unique silvicultural treatments were prescribed based on forest conditions and management objectives of agencies and forest managers (Twedt and Wilson 2016, USFWS 2006). Large variation in treatment intensity among treated stands likely reduced the predictive effects of vegetative variables and age of treatment on insect abundance in our models. That we did not detect a difference in tree species richness between treated and reference stands may be attributable to recommendations to retain species diversity when prescribing treatments (Wilson et al. 2007a).

In bottomland hardwood forests, precipitation is not typically a limiting factor (Taylor et al. 1990), and our field seasons were within the average rainfall estimates for the region (National Oceanic and Atmospheric Administration 2015). Likely the abundance of standing water within study stands maintained humidity in the microclimate and decreased the immediate impact of precipitation and other weather variables. Also, because we collected climatic data from weather stations at a distance from research locations, weather parameters reflect regional weather patterns rather than weather conditions within study stands. Moon phase seemed to have had little influence on insect abundance.

Silvicultural prescriptions have historically been implemented to reduce the effects of specific insect pest species (Amman and Logan 1998), but we observed positive responses in insect abundance associated with silvicultural treatments. Although our model associations were not strong, they indicate that even weakly associated

parameters may impact different insect taxa and size classes within forested ecosystems. Other vegetation variables, such as herbaceous plant structure and composition may be important in structuring arthropod communities. These factors likely contributed to the influence of treatment for prediction of insect abundance despite lack of clear differences between treated and reference stands for many of the vegetation characteristics we measured.

Silvicultural manipulations can positively influence bat prey by promoting higher abundance of specific insect taxa. If increased foraging opportunities for insectivorous bats are a management priority, silvicultural treatments promoting wildlife habitat, particularly dead wood, are likely beneficial for providing higher insect abundances. Silvicultural practices that promote increased snag availability may be useful within stands that are lacking snags as an available resource. However, longer-term studies may be needed to fully describe the influence of silvicultural treatments and dead wood retention on insect abundance.

Particular attention should be applied to important taxa, such as moths, especially when considering conservation focused on Rafinesque's big-eared bats (*Corynorhinus rafinesquii*), which demonstrate high selection for Lepidopteran prey (Lacki et al. 2007). In treated stands, the reduction in biomass of small size class insects may affect bat community composition. Generally, smaller bats are expected to forage on smaller and softer prey (Norberg and Rayner 1987). As such, these species could be impacted by a reduction in small prey biomass. Tri-colored bat (*Perimyotis subflavus*) and the

southeastern myotis (*Myotis austroriparius*) generally fit this expectation, preferring prey such as caddisflies (Trichoptera; Feldhamer et al. 2009). Even so, we found Trichoptera constituted only 0.2% of total biomass within sampled bottomland hardwood stands.

We caution against large-scale habitat conversion focused on one taxonomic group such as bats. As well, we remind readers that our study occurred over two years, a relative snapshot in the development of forest structural characteristics. Wildlife that depend on these stands are in a constant state of flux, and as conditions change over time, the wildlife within these stands change accordingly. We recommend that dietary preferences of bats in the southeastern United States be studied in greater detail, to determine if bats in this region are indeed preferentially selecting specific taxa as prey items. Recommendations for desired forest conditions for wildlife in the Mississippi Alluvial Valley promote retention of dead wood (Wilson et al. 2007a). Thus, this management strategy indirectly promotes food resources (i.e., insects) used by other animals, specifically bats. Therefore, silvicultural treatments to promote desired forest conditions for wildlife may increase bat use of bottomland hardwood forest stands in the Mississippi Alluvial Valley as a result of increased prey availability.

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Table 1. Mean ($\bar{x}$), standard error, minimum, and maximum values for forest structural characteristics measured in 128 silviculturally treated and reference stands at 15 study areas in the Mississippi Alluvial Valley 2013-2014.

Parameter	Treatment N=64				Reference N=64				ANOVA Statistics	
	$\bar{x}$	SE	Min	Max	$\bar{x}$	SE	Min	Max	F*	P-value**
Canopy Closure (%)	79	0	76	89	79	0	76	86	2.9	0.1
Basal Area (m ² /ha)	27	2	5	71	34	2	14	81	12.6	0.0
Stem Density (#/ha)	3702	355	200	14100	3803	341	133	11483	0.1	0.8
Snag Density (#/ha)	13	1	2	60	10	1	0	45	5.6	0.0
Dead Downed Wood Density (#/ha)	9	1	0	37	10	1	0	33	1.1	0.3
Tree Species Richness	11	0	3	18	10	0	5	18	3.5	0.1

* F-statistics calculated with numerator degrees of freedom = 1, denominator degrees of freedom = 111.

** P-value presents the difference between treatment and reference stand means performed using a randomized block analysis of variance.

Table 2. Factor loadings used to identify relationships between measured forest structural characteristics and their principal components (PC) from 128 silviculturally treated (N=64) and (N=64) reference stands at 15 study areas in the Mississippi Alluvial Valley 2013-2014. Eigenvalues and cumulative variance included. We considered variables with bold faced loadings as characterizing factors of the PC.

	PC1	PC2	PC3	PC4	PC5
Day	0.10	0.07	0.12	-0.68	0.23
Basal Area	0.24	0.74	-0.23	-0.22	-0.19
Canopy Closure	-0.43	-0.47	-0.07	-0.51	-0.05
Stem Density	0.01	-0.12	-0.05	0.72	0.11
Snag Density	0.82	-0.04	-0.14	-0.13	0.05
Down Wood Density	0.79	0.15	0.13	0.12	-0.05
Tree Species Richness	-0.18	0.85	-0.03	-0.00	0.19
Moon Illumination	0.07	0.12	0.24	-0.02	0.65
Wind Speed	-0.19	-0.03	0.87	-0.00	0.31
Air Temperature	-0.52	0.32	0.32	0.42	0.06
Relative Humidity	-0.14	0.04	-0.79	0.22	0.42

Precipitation	-0.06	-0.08	-0.18	-0.04	0.78
Eigenvalue	2.085	1.784	1.674	1.427	1.235
Cumulative Variance	0.174	0.322	0.462	0.581	0.684

Table 3. Mean ($\bar{x}$), standard error, minimum, and maximum insect biomass (g) at 128 silviculturally treated (N=64) and reference (N=64) stands at 15 study areas the Mississippi Alluvial Valley, 2013-2014. Biomass weighed to the nearest 0.01g, biomass <0.01g not considered.

Insect Taxa	Treatment				Reference				ANOVA Statistics	
	$\bar{x}$	SE	Min	Max	$\bar{x}$	SE	Min	Max	F*	P-value**
Macro-Lepidoptera	0.6	0.1	0.0	5.5	0.8	0.2	0.0	6.5	1.3	0.3
Micro-Lepidoptera	0.2	0.0	0.0	1.6	0.4	0.1	0.0	2.6	4.6	0.0
Macro-Coleoptera	30.6	5.7	0.0	209.7	28.7	4.2	0.0	135.7	0.1	0.8
Micro-Coleoptera	8.9	3.8	0.0	239.5	4.7	1.1	0.0	54.5	1.2	0.3
Diptera	0.1	0.0	0.0	1.2	0.0	0.0	0.0	0.4	0.4	0.6
Other Orders***	0.8	0.1	0.02	3.9	1.1	0.3	0.2	20.0	0.9	0.3
Total Biomass	41.1	8.0	0.02	346.1	35.8	4.9	0.2	160.4	0.005	1.0

* F-statistics calculated with numerator degrees of freedom = 1, denominator degrees of freedom = 111.

** P-value presents the difference between treatment and reference stand means performed using a randomized block analysis of variance.

*** Other Orders = Total Biomass – Lepidoptera, Coleoptera, and Diptera.

Table 4. Difference in Akaike's Information Criterion (ΔAIC_c) for most predictive models of insect biomass collected in blacklight bucket traps from 128 silviculturally treated and reference stands at 15 study areas the Mississippi Alluvial Valley, 2013-2014. Model with $\Delta AIC_c = 0.00$ is selected best model. Models with $\Delta AIC_c \leq 2.00$ were considered competitive. AIC_c weights (w_i) represent the relative likelihood of each model. Parameter estimates (β) presented for top models. Best models with $AIC > 2.0$ are presented with the Null and Global models for comparison with competitive models.

Taxon Models	<u>AICc</u>	<u>$\Delta AICc$</u>	<u>w_i</u>	<u>β</u>
Total Biomass				
pc1 ^a + treatment ^b	109.2	0.0	0.9	42.5
pc1	113.7	4.5	0.1	-2.4
Null	200.0	90.7	1.8 ⁻²⁰	-5.6
Global	1036.9	927.6	3.4 ⁻²⁰²	0.0
Macro-Lepidoptera				
pc1	-153.4	0.0	0.8	2.2
pc1 + treatment	-151.1	2.3	0.2	-57.6
Null	-85.3	68.1	1.2 ⁻¹⁵	-1.9
Global	888.6	1042.0	4.2 ⁻²²⁷	0.0
Micro-Lepidoptera				
pc1	-373.0	0.0	0.8	-7.2

pc1 + treatment	-370.8	2.2	0.3	72.3
Null	-260.6	112.4	3.0^{-25}	-7.1
Global	666.7	1039.8	1.2^{-226}	0.0
Macro-Coleoptera				
pc1 + treatment	144.3	0.0	0.9	41.7
pc1	147.9	3.6	0.1	-3.2
Null	210.6	66.3	3.5^{-15}	-4.5
Global	1081.7	937.3	2.5^{-204}	0.0
Micro-Coleoptera				
pc1 + treatment	28.5	0.0	0.6	-152.5
pc1	28.9	0.5	0.4	13.8
pc1 + age(treatment) ^c	55.5	27.0	<0.1	-165.5
Null	106.8	78.3	5.5^{-18}	5.6
Global	922.2	893.7	7.8^{-195}	0.0
Diptera				
Null	-554.8	0.0	0.6	-7.1
treatment	-553.6	0.6	0.4	-10.2
pc2	-547.4	7.4	0.0	4.4
Global	339.8	894.6	3.5^{-195}	0.0
Other Orders				
pc1	-154.2	0.0	0.7	23.2
treatment	-152.5	1.7	0.3	86.5
pc1 + age(treatment)	-118.4	35.8	<0.1	108.8
Null	-89.1	65.0	5.2^{-15}	68.9

Global	775.9	930.1	7.6^{-203}	0.0
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^a pc1 (principal component 1) is interpreted as representative of snags and downed dead wood.

^b treatment = silvicultural treatment as a categorical (binary) indicator of stand structure (i.e., treatment = 1, reference = 0).

^c age(treatment) = years since stand was treated.

Table 5. Akaike weights (w_i) summed for models with each parameter, and evidence ratios (w_1 / w_2) presented as the relative evidence to favor one parameter over another for predicting insect biomass in the Mississippi Alluvial Valley 2013-2014.

Taxon Parameters	Σw_i	$\Sigma w_1 / \Sigma w_2$
Macro-Lepidoptera		
pc1	1.000	4.115
treat	0.243	
Micro-Lepidoptera		
pc1	1.000	4.032
treat	0.248	
Macro-Coleoptera		
pc1	1.000	1.164
treat	0.859	
Micro-Coleoptera		
pc1	1.000	1.799
treat	0.556	
age(treatment)	<0.01	

Diptera

treat	0.354	19.667
pc2	0.018	

Other Orders

pc1	1.000	3.290
treat	0.304	
age(treatment)	<0.01	

Total Biomass

pc1 ^a	1.000	1.106
treat	0.904	

^a Highest parameter $w_i = w_1$

^b Second-highest parameter $w_i = w_2$