THE EFFECT OF WHITE-TAILED DEER DENSITY ON BREEDING SONGBIRDS IN DELAWARE

by

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ABSTRACT

Currently, population goals for white-tailed deer (*Odocoileus virginianus*) are based solely on deer data with little consideration given to other parts of the ecosystem. A wider ecological approach is needed to provide managers with a more justifiable target deer density. I investigated the use of breeding birds to determine an ecologically based carrying capacity for deer management by studying the relationship between the forest breeding bird community and deer density in Delaware. Using Breeding Bird Survey (BBS) data from 2005-2009, my own point count data from 2008-2009, and Delaware Division of Fish and Wildlife deer density data from the same time periods, I compared avian species richness and relative abundance to deer density. I divided deer densities into low ($\leq$10 deer/km^2), moderate (11-19 deer/km^2) and high ($\geq$20 deer/km^2) categories. I placed birds into 7 deer-sensitive guilds: interior obligates, ground nesters, shrub nesters, ground gleaners, low canopy foragers, and neo-tropical migrants. The abundance or richness of most guilds and most individual species did not differ by deer density. Of those guilds that did, shrub nesters ($P = 0.074$), interior forest obligates ($P = 0.050$), low canopy foragers ($P < 0.001$), and neo-tropical migrants ($P = 0.023$) had the greatest species richness and/or relative abundance at low or moderate deer densities. Chipping Sparrows ($P = 0.021$), Red-eyed Vireos ($P = 0.023$), Great Crested Flycatchers ($P = 0.044$), Acadian Flycatchers ($P < 0.001$), and Ovenbirds ($P = 0.028$) had the greatest abundances at low or moderate deer densities. Our results suggest that areas in Delaware with deer densities of <20 deer/km^2 have the greatest avian richness and abundance. Thus, management efforts should focus on this level as an ecological threshold that will maintain the quality of the ecosystem as a whole.

Chapter 1

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) abundance in North America, particularly in the Mid-Atlantic and Northeast, is well above historical levels (McCabe and McCabe 1997). Changes in the landscape to support agriculture and silviculture have improved deer habitat and game management has protected deer from overexploitation. Densities of up to 50 deer/ km^2 were recorded in Delaware in 2005 (Bowman 2006), while historically, numbers have been estimated at 3.1 - 4.2 deer/km^2 (McCabe and McCabe 1997). Hansen and Beringer (1997) recommended a density of 15 deer/km^2 to balance the number of deer-human conflicts, damage to forest regeneration, and impacts on other species while still providing viewing and hunting opportunities. Current deer populations are a reflection of human manipulations, not the historical levels at which deer evolved (Waller and Alverson 1997).

White-tailed deer are keystone herbivores in eastern forests (Waller and Alverson 1997), meaning they can have an effect on multiple trophic levels by changing plant species composition and vegetation structure. Deer have been shown to negatively impact populations of herbaceous and woody plants, insects, and birds (Tilghman 1989, Allombert et al. 2005a, McShea and Rappole 2000). Saplings and shrubs increase in size and abundance after deer are excluded from an area (Tilghman 1989, Horsley and Marquis 1983, Harlow and Downing 1970). The groundcover is also affected, with fewer wildflowers and forbs and more ferns, grasses, and exotic species in areas with high deer densities (Gaston et al. 2006, Horsley and Marquis 1983, Eschtruth and Battles 2009). As a result of deer browsing the vegetation, less food and habitat are available for herbivorous insects. Almost all insect orders, with the exception of beetles

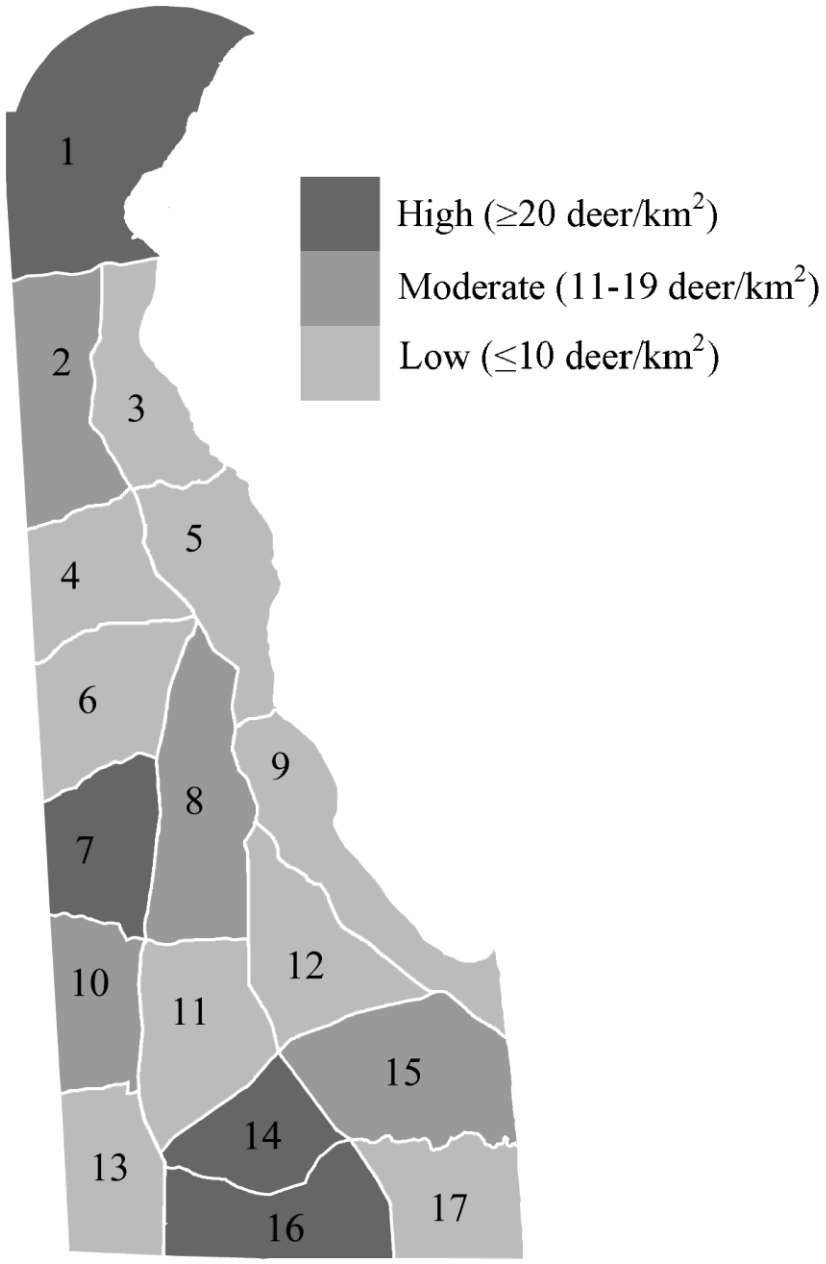
(Coleoptera), are negatively affected, with some groups like the true bugs (Heteroptera), disappearing completely after 50 years in the presence of deer (Allombert et al. 2005a). Fewer insects, in turn, mean less food for insectivorous birds, which can reduce habitat quality. Also, by altering the vegetation structure deer can directly affect bird habitat and transform areas to a point where some bird species may no longer occur. The greater the deer density in an area, the stronger these effects will be.

Many forest songbirds use the understory to forage or nest and most are insectivorous at some point in their life cycle (Martin et al. 1951). McShea and Rappole (2000) found that birds which forage at low or intermediate canopy levels or undergo long migrations increased in number when deer were fenced out of forest plots. In an enclosure study of deer and several exotic ungulates, Casey and Hein (1983) found that bird species associated with the understory increased with lower ungulate density. DeCalesta (1994) found that the mean species richness of intermediate canopy nesters increased by 27% at a density of 4 deer/km^2 compared to 31 deer/km^2. Similarly, DeGraaf et al. (1991) found increased numbers of canopy gleaning species in areas with 1-3 deer/km^2 compared to areas with 13-23 deer/km^2. Allombert et al. (2005b) found that both bird abundance and species richness decreased with a longer history of deer presence on an island in British Columbia. Collectively, these studies show a connection between high deer density and low bird abundance and diversity, especially for certain sensitive guilds; however, many of these studies were conducted under unrealistic conditions. McShea and Rappole (2000) used exclosures to completely remove deer herbivory, while Casey and Hein (1983) used enclosures to maintain deer at unnaturally high densities (83/km^2) for the area. DeCalesta (1994) also fenced deer in at unnaturally high densities (25/km^2) for the study area and kept them in enclosures smaller than their estimated home range. These deer could have

been forced to browse more intensely on the vegetation in the smaller area than they would in a natural setting. These studies are useful in showing differences between areas with no deer and areas with high deer densities but this situation does not often occur in nature, where a large continuum of deer densities exists.

In early December 2005 and again in the winter of 2009, the Delaware Department of Natural Resources and Environmental Control (DNREC) Division of Fish and Wildlife estimated the deer density for each of the 17 deer management zones in the state (Bernatas 2006, Bernatas 2009; Figure 1). This level of specificity provides the perfect "natural laboratory" to investigate the effects deer may be having on breeding birds at a range of deer densities. To determine the relationship deer have with forest breeding birds I used 2 data sources: 1) the Breeding Bird Survey (BBS) provided 5 years (2005-2009) of breeding bird data within the deer management zones and 2) point counts directed at forested habitat within the transects where deer density was estimated. My primary objective was to determine if deer were having an impact on breeding bird abundance and species richness. My secondary objective, if an effect was detected, was to find a threshold density for management at which deer had a minimal effect on the abundance and diversity of breeding songbirds in Delaware.

Figure 1. Deer densities obtained from the Delaware Division of Fish and Wildlife deer survey for each of the 17 deer management zones (average of 2005 and 2009 densities).



Chapter 2

STUDY AREA

Most of Delaware is on the Coastal Plain, with approximately 5% of the state in the northwest located on the Piedmont (Hess et al. 2000). About 24% of the state was forested, of which 19% was deciduous forest, 9% was coniferous forest, 28% was mixed forest, and 44% was composed of forested wetlands. The primary forest types were oak/hickory in New Castle and Kent Counties and oak/gum/cypress and oak/pine in Sussex County (Hess et al. 2000). Common canopy species included oaks (*Quercus* spp.), hickories (*Carya* spp.), red maple (*Acer rubrum*), tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), sweet gum (*Liquidambar stryaciflua*), black gum (*Nyssa sylvatica*), American sycamore (*Platanus occidentalis*), wild black cherry (*Prunus serotina*) and loblolly and Virginia pines (*Pinus taeda* and *P. virginiana*; Prasad et al. 2007). Highbush blueberry (*Vaccinium corymbosum*), multi-floral rose (*Rosa multiflora*), sweet pepperbush (*Clethra alnifolia*), *Viburnum* spp., ironwood (*Carpinus caroliniana*), American holly (*Ilex opaca*), greenbrier (*Smilax* spp.), and blackberry (*Rubus* spp.) were common understory species. The average temperatures in Delaware for the past 30 years in May, June, and July were 17º C, 22º C, and 25º C, respectively, and the average precipitation amounts were 11 cm, 9 cm, and 11 cm (NOAA 2010). The weather during my two field seasons did not show any extreme variation from these averages.

METHODS

Deer densities were estimated using aerial surveys and Forward-Looking Infrared (FLIR) technology. In the winters of 2005 and 2009, 1 3.2 km by 12.9 km transect was flown in

each of the 17 deer management zones (Bernatas 2006). Each transect was surveyed from an attitude of 305 m. A video recorder was used to record the thermal signatures of deer. The video was reviewed after all surveys were completed. From the deer counted on these transects, a deer density was extrapolated for each zone by the Delaware Division of Fish and Wildlife. Deer densities for the 2005 season ranged from 4-45 deer/km^2 of deer habitat, post harvest (Bowman 2006). In the winter of 2009, density estimates ranged from 2-17 deer/km^2 of deer habitat, post harvest (J. Rogerson, Delaware Division of Fish and Wildlife, personal communication). The reduction in deer density was a result of increased harvest between the 2 survey periods. I averaged these 2 estimates for each zone to come up with a final deer density that was representative of the entire study period (Table 1). I then separated these densities into 3 categories for my analyses: low (≤10 deer/km^2), moderate (11-19 deer/km^2) and high (≥20 deer/km^2; Figure 1). I modeled my density categories off of DeCalesta's (1994) values. My low category consists of his lowest 2 densities, my moderate category is centered on his density of 15 deer/km^2, and my high category encompasses his highest deer density. I combined his lowest 2 densities because Delaware did not have sufficient low density zones to make separate categories.

Volunteers conducted BBS point counts (Sauer et al. 2008). During these 3-minute counts, they recorded all birds seen or heard within 400 m (0.25 miles). Observers conducted counts in early to mid-June during the first 4-5 hours after sunrise. Because rainy or windy days can affect both bird activity and detectability, observers did not conduct surveys on these days (USGS 2007). I used BBS data from 2005-2009, during which time there were 10 active BBS routes in Delaware (Figure 2). Each route contained 50 roadside points, spaced at 800 m (0.5 mile) intervals. I calculated the percent forest within a 50 m buffer of each point using ArcView GIS

3.2 and the 2007 USGS Land Use Land Cover data file. I considered the following land uses "forest": deciduous forest, evergreen forest, mixed forest, non-tidal forested wetlands, and tidal forested wetlands. I included points on these routes in my analyses if they contained at least 40% forest cover within the 50 m buffer. The BBS was designed to sample a wide variety of habitat types, so I used this cutoff to focus on the points that were actually in a forested setting.

I also conducted targeted point counts, in 2008 and 2009, in forested areas within or contiguous to the corresponding deer survey transects conducted by the Delaware Division of Fish and Wildlife (Figure 3). These points linked the avian survey results with the deer survey results. I was unable to find suitable forested areas within FLIR survey transects in zones 5 or 8, therefore I did not establish point counts within these zones. Points were placed along minor roads with little traffic and were spaced 300 m apart. In 2008, I established and surveyed a total of 206 points and in 2009 I surveyed the same 206 points and added an additional route (n = 12 points) in zone 1 to increase the sample size in high deer density areas. I visited each point 3 times from 15 May—15 July for a total of 1,272 counts. Each count was 5 minutes long, divided into 1 minute intervals. I had a 1 minute acclimation period before I began a count to let the birds adjust to my presence. During the count I recorded every bird seen or heard and placed it into 1 of 4 distance categories: 0-10 m, 10-30 m, 30-50 m and 50+ m (Alldredge et al. 2007). I noted flyovers separately and excluded these observations from my analyses. I started at dawn (approximately 0545) and continued for a maximum of 5 hours on suitable days between mid May and mid July. I did not conduct counts during heavy rain or fog, or wind over 11 km/h (Ralph et al. 1995).

To analyze the effects of deer on songbird populations, I separated species into guilds based on O'Connell et al. (1998) and Bishop and Meyers (2005). Guilds were based on primary habitat, nest placement, foraging height, and migration distance. Guilds that I expected to be sensitive to high deer densities were: interior forest obligates, shrub nesters, ground nesters, ground gleaners, low canopy foragers, and neo-tropical migrants (Table 2; Casey and Hein 1983, DeCalesta 1994, McShea and Rappole 1997, Allombert et al. 2005b, Baiser et al. 2007). These guilds encompass species that nest or forage in the midstory, where deer are browsing, or are particularly sensitive to habitat quality. I chose vulnerable species by selecting those that past studies had found to be vulnerable to deer density, as well as choosing species that were in 2 or more of the vulnerable guilds (Table 2).

Because deer affect the vegetation, which affects songbirds, I performed vegetation surveys at all targeted point count locations. I was prohibited access to 8 sites by landowners but was able to collect data on the remaining 210 sites. To estimate vegetation cover and composition, I walked 25 m into the forest perpendicular to each count site. There, I established nested circular plots, estimating the percent and type of groundcover within 0.0004 ha, and counting the number of midstory stems (identified to species) within 0.004 ha. From this, I calculated the percent non-native stems in the midstory. I also estimated the basal area from the center of each plot at the 5 and 10 factor level, as a measure of forest structure. I used a 2.5 m tall Nudds board to estimate the vertical vegetation profile of the midstory. At each cardinal direction, I placed the board 15 m from the center of the plot and estimated the percent vegetation covering the board, then averaged the values for an estimate of vertical vegetation cover at each point (Nudds 1977).

I conducted all my data analyses using SAS (version 9.1, Cary, NC) with an alpha level of 0.10. For the BBS data, I used a one-way ANOVA, blocking on year with percent forest cover within a 50 m buffer as a covariate, to determine if the relative abundance or species richness of vulnerable guilds was affected by deer density. For species that were detected on ≥25% (n = 73 of 291) of points, I used a one-way ANOVA, blocking on year with percent forest cover within a 50 m buffer as a covariate, to determine if bird abundance was affected by deer density. If I detected significance, I used a protected least significant differences analysis (LSD) to compare among density categories (Sokal and Rohlf 1995).

To determine whether deer density was affecting the detection probabilities of the birds counted in targeted surveys, I used Program DISTANCE 5.0 (Thomas et al. 2010). I found that detection probabilities were not affected by deer densities, so I left the raw counts unadjusted (Williams et al 2002). For all abundance analyses of targeted point counts, I used the maximum value from the 3 visits to each point. For these data, I again used a one-way ANOVA, blocking on year with percent forest cover within a 50 m buffer as a covariate, to determine if the abundance or richness of vulnerable guilds was affected by deer density. For species that were counted on ≥25% (n = 106 of 424) of points, I used a one-way ANOVA, blocking on year with percent forest cover within a 50 m buffer as a covariate, to determine if bird abundance was affected by deer density. I again used a protected LSD analysis to compare the mean number of species or birds between deer densities when I detected significance.

To further examine the effect of deer density on songbird species from targeted point count data, I used Program PRESENCE 2.3 (Hines 2006; http://www.mbr-pwrc.gov/software/presence.html). I first defined a set of *a priori* models that could explain

detection probability and site occupancy (Table 3). I started with a constant occupancy model and examined all the variables that could explain detection probability individually (survey, time, date, or constant detection). I chose the best model for detection for each species based on ΔAIC values (Burnham and Anderson 2002). I then modeled the best detection variable with the occupancy variables (deer density, percent forest cover in a 50 m buffer, an additive function of the two, year, a global model, and constant occupancy; MacKenzie 2006). I chose the best models for each species based on ΔAIC or ΔQAIC (to adjust for lack of fit) values. I then examined the ß values for the deer density variable for all species where it was a factor in one of the top models.

I used a one-way ANOVA to determine if deer density affected the vegetation variables I estimated, because vegetation is the main means by which deer would have an effect on songbirds. I analyzed the following vegetation variables: the percent grass, forbs, woody vegetation, organic matter, and bare soil in the groundcover, the basal area of a point (Factor 5 and 10), the percent of exotic midstory stems, and the vertical vegetation structure of a point. For each vegetation characteristic where significance was detected, I conducted a protected LSD analysis to compare means between deer densities.

Table 1. Deer densities (deer/km^2) of the 17 deer management zones in Delaware as measured by the Delaware Division of Fish and Wildlife in 2005, 2009, an average of the 2 years. Density categories used for comparisons of avian relative abundance and species richness among deer densities.

Zone	2005	2009	Average	Category
1	45	11	28	High
2	17	10	13	Moderate
3	13	4	8	Low
4	14	4	9	Low
5	15	2	9	Low
6	5	5	5	Low
7	32	8	20	High
8	21	7	14	Moderate
9	16	4	10	Low
10	13	11	12	Moderate
11	17	4	10	Low
12	14	3	8	Low
13	6	7	7	Low
14	29	16	23	High
15	21	5	13	Moderate
16	32	8	20	High
17	4	8	6	Low

Table 2. Avian guilds (based on O'Connell et al. [1998] and Bishop and Meyers [2005]) and species vulnerable to high deer densities used for comparisons of avian relative abundance and species richness among deer densities categories. Species found to be sensitive to deer density in the reviewed literature are in bold.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Acadian Flycatcher *Empidonax virescens*	X					X	X
American Goldfinch *Spinus tristis*			X				
American Redstart *Setophaga ruticilla*	X				X	X	X
Baltimore Oriole *Icterus galbula*						X	
Barn Swallow *Hirundo rustica*						X	
Black-and-white Warbler *Mniotilta varia*	X	X				X	X
Black-billed Cuckoo *Coccyzus erythropthalmus*			**X**		**X**	**X**	**X**
Blue Grosbeak *Passerina caerulea*			X			X	X
Brown Thrasher *Toxostoma rufum*			X				

Table 2. cont.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Brown-headed Nuthatch *Sitta pusilla*	X						
Carolina Chickadee *Poecile carolinensis*					X		
Carolina Wren *Thryothorus ludovicianus*					X		
Chimney Swift *Chaetura pelagica*						X	
Chipping Sparrow *Spizella passerina*			X				
Chuck-will's-widow *Caprimulgus carolinensis*						X	
Common Yellowthroat *Geothlypis trichas*			**X**		**X**		**X**
Eastern Kingbird *Tyrannus tyrannus*						X	
Eastern Towhee *Pipilo erythrophthalmus*		**X**					**X**
Eastern Wood-Pewee *Contopus virens*						**X**	**X**

Table 2. cont.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Field Sparrow ***Spizella pusilla***							**X**
Gray Catbird *Dumetella carolinensis*			X				
Great Crested Flycatcher *Myiarchis crinitus*						X	
Hairy Woodpecker *Picoides villosus*	X						
Hooded Warbler ***Wilsonia citrina***	**X**		**X**		**X**	**X**	**X**
House Wren *Troglodytes aedon*					X		
Indigo Bunting ***Passerina cyanea***			**X**			**X**	**X**
Kentucky Warbler ***Oporornis formosus***	**X**	**X**		**X**		**X**	**X**
Louisiana Waterthrush ***Seiurus motacilla***	**X**	**X**		**X**		**X**	**X**
Northern Cardinal *Cardinalis cardinalis*			X				

Table 2. cont.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Northern Flicker *Colaptes auratus*				X			
Northern Mockingbird *Mimus polyglottos*			X				
Northern Parula *Parula americana*						X	
Orchard Oriole *Icterus spurious*						X	
Ovenbird *Seiurus aurocapilla*	**X**	**X**		**X**		**X**	**X**
Pileated Woodpecker *Dryocopus pileatus*	X						
Pine Warbler *Dendroica pinus*	X						
Prairie Warbler *Dendroica discolor*			X		X	X	X
Prothonotary Warbler *Protonotaria citrea*						X	
Purple Martin *Progne subis*						X	

Table 2. cont.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Red-eyed Vireo *Vireo olivaceus*			X			X	X
Red-winged Blackbird *Agelaius phoeniceus*			X				
Ruby-throated Hummingbird *Archilochus colubris*						X	
Scarlet Tanager *Piranga olivacea*	X					X	X
Summer Tanager *Piranga rubra*						X	
Swamp Sparrow *Melospiza georgiana*			X				
Tufted Titmouse *Baeolophus bicolor*					X		
White-breasted Nuthatch *Sitta carolinensis*	X						
White-eyed Vireo *Vireo griseus*			X		X		X
Willow Flycatcher ***Empidonax trailii***			**X**			**X**	**X**

Table 2. cont.

Species	Interior forest obligate	Ground nester	Shrub nester	Ground gleaner	Low canopy forager	Neo-tropical migrant	Vulnerable species
Wood Thrush ***Hylocichla mustelina***			**X**	**X**		**X**	**X**
Worm-eating Warbler *Helmitheros vermivorum*		X		X		X	X
Yellow Warbler *Dendroica petechia*			X		X	X	X
Yellow-billed Cuckoo ***Coccyzus americanus***			**X**		**X**	**X**	**X**
Yellow-breasted Chat *Icteria virens*			X			X	X
Yellow-throated Vireo *Vireo flavifrons*						X	

Table 3. Models used to evaluate factors affecting occupancy for species counted in Delaware, 2008-2009. ψ represents occupancy covariates, *p* represents detection covariates.

Model	Description
ψ (deer density), *p* (covariate)	occupancy as a function of deer density and detection as a function of the best modeled covariate
ψ (deer density+forest), *p* (covariate)	occupancy as an additive function of deer density and percent forest cover within a 50 m buffer and detection as a function of the best modeled covariate
ψ (forest), *p* (covariate)	occupancy as a function of percent forest cover within a 50 m buffer and detection as a function of the best modeled covariate
ψ (year), *p* (covariate)	occupancy as a function of the year of the survey and detection as a function of the best modeled covariate
ψ (.), *p* (covariate)	constant occupancy and detection as a function of the best modeled covariate
global	occupancy as an additive function of all occupancy covariates and detection as a function of all detection covariates

Figure 2. Breeding Bird Survey (BBS) routes in Delaware, 2005-2008. Highlighted points have > 40 % forest cover and were points used for comparisons of avian relative abundance and species richness at different deer densities. Background shading indicates deer density (light = low, medium = moderate, dark = high).

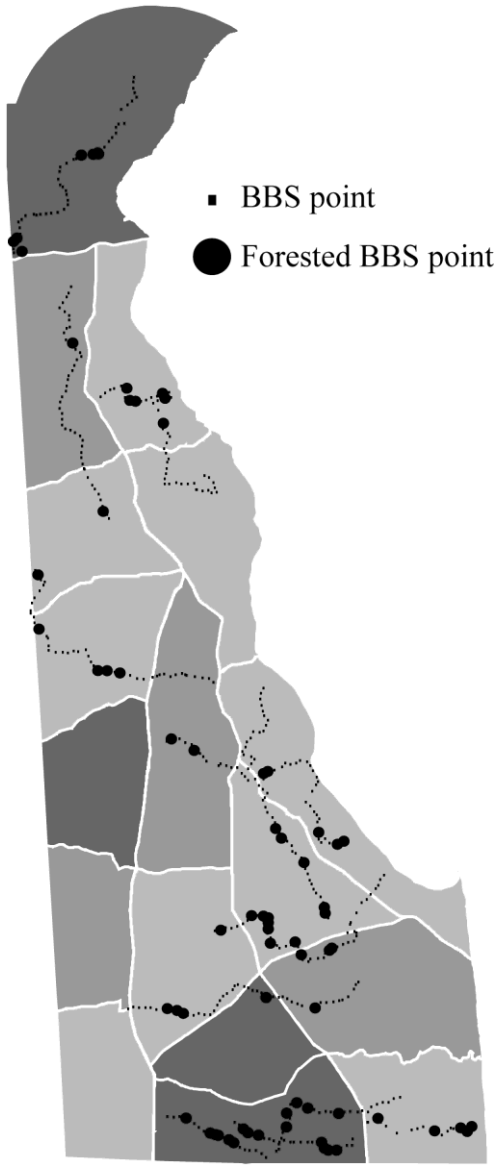
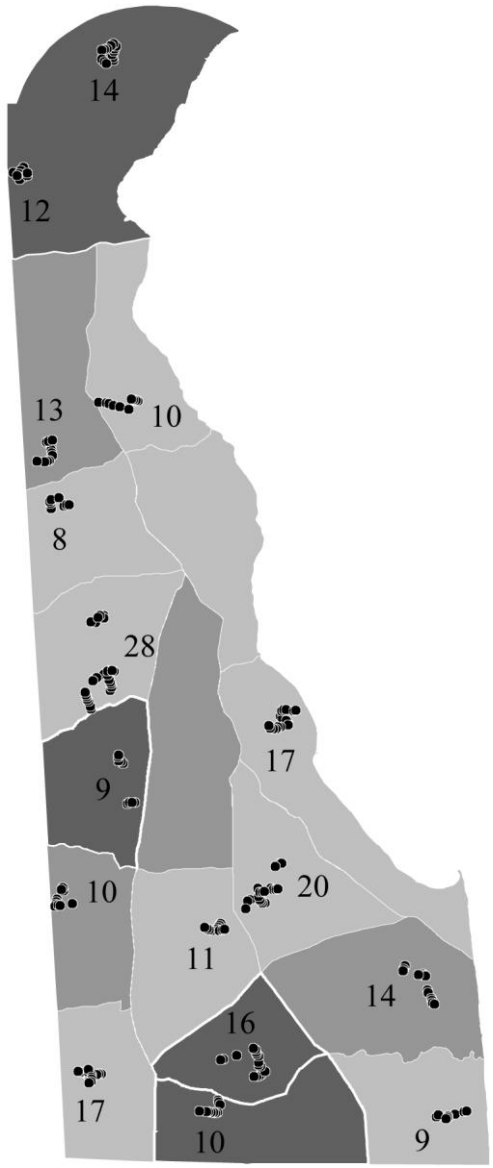


Figure 3. Location of targeted bird survey points in Delaware, 2008-2009, used for comparisons of avian relative abundance and species richness at different deer densities. Labels indicate number of points. Background shading indicates deer density (light = low, medium = moderate, dark = high).



Chapter 3

RESULTS

For the BBS data, most (67%) bird guilds were more abundant at low deer densities (Table 4). Low deer density areas had 1.08 more shrub nesters than high deer density areas and at least 0.56 more neo-tropical migrants than moderate or high deer density areas (Table 4). Low or moderate deer densities had at least 0.52 more individual low canopy foragers than high deer densities. I observed at least 0.61 more ground gleaners at low and high deer densities when compared to moderate deer densities. The abundances of interior forest obligates and ground nesters did not differ by deer density. Species richness also did not differ by deer density for half of the guilds (Table 4). However, low deer densities had 0.54 more species of shrub nesting birds than high deer densities and moderate and low deer densities had at least 0.36 more species of low canopy foragers than high deer densities. The species richness of ground gleaning birds was at least 0.24 species greater at high and low than at moderate deer densities. Only 2 (18%) of the individual species' relative abundances differed by deer density (Table 5). I observed at least 0.29 more Acadian Flycatchers (*Empidonax virescens*) at moderate and low deer densities compared to high densities and at least 0.34 more Wood Thrushes (*Hylocichla mustelina*) at low and high deer densities compared to moderate densities.

For targeted point count data collected in deer density FLIR transects, the relative abundance and species richness of most (58%) bird guilds did not differ by deer density (Table 6). Low deer densities had at least 0.59 more individual neo-tropical migrants compared to moderate or high deer densities. Similarly, low deer densities had at least 0.49 more migrant species than higher densities. However, I detected at least 0.29 more individual ground gleaners

at high and low deer densities compared to moderate densities and at least 0.18 more ground gleaning species at high and low compared to moderate deer densities. Most (63%) individual species, again, did not differ by deer density (Table 7). Of those that were, the majority (80%) were most abundant at lower deer densities. Low deer densities had 0.18 more Great Crested Flycatchers (*Myiarchus crinitus*) than high densities, and at least 0.17 more Ovenbirds (*Seiurus aurocapillus*) compared to high and moderate deer densities. Moderate or low density areas had at least 0.31 more Red-eyed Vireos (*Vireo olivaceus*) and at least 0.16 more Chipping Sparrows (*Spizella passerina*) than high deer densities. The exception was the Pine Warblers (*Dendroica pinus*), with high deer density areas having 0.18 more individuals than moderate density areas.

I was able to analyze 21 species using Program PRESENCE, after eliminating those with small sample size and lack of convergence. Of these, 16 species had top models where occupancy was not constant (and thus affected by one of the occupancy variables; Tables 3, 8). Eight species had deer density as a factor affecting occupancy (the 95% CI of the odds ratio did not overlap 1), 6 of which were negatively affected by deer (Table 8). The most strongly affected was the Yellow-billed Cuckoo (*Coccyzus americanus*), which had 15 times greater odds of being found in low than high deer densities. Common Yellowthroats (*Geothlypis trichas*) and Great Crested Flycatchers both had 3 times greater odds of being found in low deer density areas than in high density areas, while Acadian Flycatchers, Red-eyed Vireos, and Chipping Sparrows all had 2 times greater odds of being found in low deer density areas than high deer density areas. Conversely, high deer density areas had 3 times greater odds of being occupied by Worm-eating Warblers (*Helmitheros vermivorus*) and 14 times greater odds of being occupied by Gray Catbirds (*Dumatella carolinensis*; Table 8).

High deer density areas had at least 2% more bare soil in the groundcover compared to points at low densities. Exotic species made up at least 9% more of the midstory at high deer density areas than at moderate or low deer density areas. The same trend was seen with the vertical vegetation cover, which had at least 8% more midstory cover at high and moderate deer densities than at low densities. All other vegetation variables did not differ by deer density (Table 9).

DISCUSSION

I did not observe an effect of deer density on just over half (52%) of all songbird guilds or species analyzed from BBS and targeted point count data. These results are in line with what DeCalesta (1994), McShea and Rappole (2000), and Casey and Hein (1983) documented in similar studies. However, deer density did affect certain sensitive birds. Almost all sensitive bird guilds that were affected by deer density, were affected negatively. Similarly, almost all individual species that had significant results were also present at greater numbers at lower deer densities. Although not all comparisons were significant, examining the trends in the other guilds and species revealed the same pattern of birds faring better in low and moderate deer density areas, and perhaps with a larger sample differences would have been detected for these species.

Neo-tropical migrants and shrub nesting birds, as guilds and the individual species, were consistently found with greater species richness and greater abundances in low deer densities. Many of the species in these guilds have been shown to be sensitive to deer density in past studies. Supporting my findings, Casey and Hein (1983) detected a lack of shrub nesters at high deer densities. Additionally, McShea and Rappole (2000) saw an increase in the abundance of Acadian Flycatchers and Great Crested Flycatchers, both neo-tropical migrants, after the

exclusion of deer from an area. As individual species, I also found that these Flycatchers were most abundant at lower deer densities.

Alternatively, birds associated with the low canopy seemed to have a greater threshold tolerance for deer density. The relative abundance and species richness of this guild were still least at high deer densities, but were similar between low and moderate densities. DeCalesta (1994) observed a marked decrease in the abundance and richness of these birds at the highest deer densities, as well as a decrease in the abundance of Yellow-billed Cuckoos, a low canopy forager. Deer have been shown to greatly affect the regeneration rates of eastern hardwood trees at high densities (Tilghman 1989, Harlow and Downing 1970). In areas with high deer densities, deer could have sufficiently overbrowsed saplings so they never became tall enough to become a part of the lower canopy; thus reducing habitat for this guild.

Only ground gleaners showed a different trend, having greater relative abundance and species richness at both high and low deer densities compared to moderate densities. Close examination of the individual species in this guild offers potential explanations for this pattern. I analyzed 6 ground gleaners but only 2 (Wood Thrush and Ovenbird) are found at abundances great enough to influence the guild as a whole. Two ground gleaners, the Kentucky Warbler (*Oporornis formosus*) and the Louisiana Waterthrush (*Seiurus motacilla*), were rare birds and were seldom encountered in Delaware. The Northern Flicker (*Colaptes auratus*) and the Worm-eating Warbler were more common than the warblers mentioned above, but still not common in Delaware. The Flicker is a ground feeding species that can adapt to open, park-like settings (Hess et al. 2000), so areas with high deer densities that have a degraded understory could create this sort of habitat. If flickers are consistently being found in high deer density areas the relative

abundance and species richness of the guild they are a part of would be greater in these places. Worm-eating Warblers are mainly found in southern Delaware (Hess et al. 2000), which is where all but 1 of the high deer density zones are located (Figure 1). I think this species is responding to other cues that determine its presence (e.g. patch size; Robbins et al 1989), rather than deer density. The last 2 species are very common and are most likely the main drivers of abundance patterns seen in the ground gleaning guild. Wood Thrushes, like the guild as a whole, were most abundant at both low and high deer densities. Wood Thrushes are more adaptable than many songbirds and are less sensitive to forest fragmentation than most (Hess et al. 2000, Roth and Johnson 1993). Perhaps they are also not as sensitive to the quality of the forest midstory, so it is possible that Wood Thrushes are able to utilize exotic shrubs better than other species. Because Wood Thrushes were so numerous, they could easily affect the overall pattern of ground gleaner abundance. Conversely, Ovenbirds, the most common ground gleaner, were most abundant at low deer densities. The combination of the abundance patterns of Ovenbirds (greatest at low deer densities) and Wood Thrushes (greatest at high and low densities), plus the less abundant species (both greatest at high deer densities) could account for the odd trend seen in the ground gleaner guild.

Only 3 species (14%) were only positively influenced by deer density, and all 3 have restricted ranges in Delaware. The Worm-eating Warbler, discussed above, is found only in southern Delaware where most high deer density areas are located (Figure 1). The Pine Warbler is also restricted to southern Delaware, due to the abundance of pine habitat. Finally, Gray Catbirds live almost exclusively in the Piedmont portion of Delaware. I only had 1 route on the Piedmont and it was in a high deer density area. None of these species are categorized in more

than 2 sensitive guilds, so their restricted ranges are probably the reason they were found in high deer density areas, not their response to deer density, per se.

Despite the negative effects I saw in the bird community, I did not observe the expected trend of sparse vegetation cover in the midstory in areas with a high deer density. These areas did, however, have a greater percentage of exotic species compared to lower deer density areas. Eschtruth and Battles (2009) have shown that white-tailed deer can facilitate the spread of exotic and invasive plants in eastern forests. High deer density areas (particularly zone 1) have proportionally more exotic species which are potentially compensating for the decrease in native species; therefore, the midstory layer appears to be thicker in areas of high deer density. This thicker midstory could be due to the greater number of deer preferentially browsing native species. Exotic species have been shown to support far fewer insects and birds than native shrubs (Burghardt et al. 2009), so even though the midstory appears intact, it may not provide sufficient resources for birds. If birds cannot get the food resources they need or adequate nesting spots in a midstory dominated by exotic plants, then one would expect fewer of them in these areas, even when the midstory looks dense.

MANAGEMENT IMPLICATIONS

Most guilds and species were not impacted by deer density in Delaware, so I do not recommend any change in the current deer management goals. Only certain sensitive birds were affected when densities exceeded 20 deer/km^2, and not many areas in Delaware surpass that density. However, managers in these areas may want to consider reducing deer densities to below 20 deer/km^2 in order to provide adequate conditions for these sensitive avian species. Knowing how and why deer are impacting these birds is clearly important. More research needs

to be done on the methods by which deer are affecting certain songbirds. The increase in exotic invasive species in high deer density areas is particularly interesting and warrants further research.

Table 4. A comparison of mean relative abundance and species richness of guilds counted in the Delaware Breeding Bird Survey (BBS) during 2005-2009 among low, moderate and high deer densities. Values sharing the same letter within each row are not different.

	Low		Moderate		High			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$F_{2,190}$	*P*
Relative abundance								
Interior obligates	1.60a	0.141	1.26a	0.300	1.22a	0.208	3.13	0.046
Ground nesters	0.74	0.082	0.29	0.095	0.47	0.094	0.23	0.794
Shrub nesters	4.92a	0.267	4.39ab	0.492	3.84b	0.323	2.40	0.094
Ground gleaners	1.25a	0.114	0.65b	0.151	1.25a	0.174	4.17	0.017
Low canopy foragers	2.08a	0.144	1.90a	0.229	1.39b	0.145	12.14	<0.001
Neo-tropical migrants	4.98a	0.274	4.16b	0.578	3.60b	0.309	2.69	0.070
Species richness								
Interior obligates	1.10	0.085	0.90	0.209	0.89	0.122	0.28	0.754
Ground nesters	0.47	0.047	0.26	0.080	0.37	0.066	1.26	0.287
Shrub nesters	3.28a	0.145	3.06ab	0.258	2.73b	0.186	2.64	0.074
Ground gleaners	0.79a	0.059	0.55b	0.121	0.93a	0.113	3.02	0.051
Low canopy foragers	1.45a	0.085	1.48a	0.179	1.10b	0.101	11.03	<0.001
Neo-tropical migrants	3.45	0.157	3.06	0.307	2.77	0.203	1.47	0.233

Table 5. A comparison of mean relative abundance of bird species counted in the Delaware Breeding Bird Survey (BBS) during 2005-2008 among low, moderate and high deer densities. Species counted on at least 25% of points. Values sharing the same letter within each row are not different.

	Low		Moderate		High			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$F_{2,190}$	*P*
Acadian Flycatcher	0.41a	0.060	0.42a	0.166	0.12b	0.036	19.44	<0.001
American Goldfinch	0.53	0.067	0.65	0.158	0.31	0.064	0.49	0.612
Blue Grosbeak	0.34	0.051	0.42	0.090	0.25	0.076	0.32	0.724
Carolina Wren	0.38	0.050	0.42	0.111	0.39	0.074	0.78	0.462
Indigo Bunting	0.73	0.077	0.52	0.160	0.76	0.098	0.08	0.922
Northern Cardinal	0.59	0.063	0.87	0.216	0.46	0.085	0.38	0.685
Ovenbird	0.56	0.069	0.19	0.086	0.36	0.080	0.80	0.453
Pine Warbler	0.32a	0.049	0.32a	0.117	0.37a	0.076	3.08	0.049
Red-eyed Vireo	0.47	0.063	0.45	0.201	0.25	0.060	0.04	0.965
Tufted Titmouse	0.47	0.065	0.58	0.166	0.25	0.079	1.78	0.172
Wood Thrush	0.56a	0.073	0.13b	0.077	0.47a	0.090	2.69	0.071

Table 6. A comparison of mean relative abundance and species richness of guilds encountered in Delaware on point counts during 2008-2009 among low, moderate and high deer densities. Values sharing the same letter within each row are not different.

	Low		Moderate		High			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$F_{2,418}$	*P*
Relative abundance								
Interior obligates	2.20a	0.095	1.92a	0.163	1.98a	0.160	2.48	0.085
Ground nesters	1.19	0.063	1.01	0.104	0.98	0.083	2.10	0.123
Shrub nesters	5.40	0.137	5.23	0.228	5.34	0.182	0.20	0.821
Ground gleaners	1.49a	0.082	1.20b	0.082	1.58a	0.139	5.10	0.007
Low canopy foragers	3.30	0.116	3.14	0.177	3.18	0.166	0.36	0.699
Neo-tropical migrants	5.24a	0.155	4.65b	0.281	4.47b	0.230	3.79	0.023
Species richness								
Interior obligates	1.83a	0.071	1.58b	0.122	1.63b	0.106	3.02	0.050
Ground nesters	0.95	0.045	0.84	0.077	0.82	0.069	1.75	0.175
Shrub nesters	4.26	0.102	3.88	0.176	4.13	0.146	1.50	0.224
Ground gleaners	1.14a	0.052	0.96b	0.085	1.23a	0.096	4.66	0.010
Low canopy foragers	2.57	0.080	2.50	0.134	2.42	0.121	1.33	0.267
Neo-tropical migrants	4.26a	0.117	3.77b	0.210	3.77b	0.183	3.76	0.024

Table 7. A comparison of mean relative abundance of birds counted in Delaware on point counts during 2008-2009 among low, moderate and high deer densities. Species counted on at least 25% of points. Values sharing the same letter within each row are not different.

	Low		Moderate		High			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$F_{2,418}$	*P*
Acadian Flycatcher	0.48	0.039	0.49	0.080	0.30	0.058	1.51	0.222
American Goldfinch	0.77	0.045	0.97	0.110	0.78	0.074	1.95	0.144
Carolina Chickadee	0.69	0.064	0.76	0.096	0.72	0.085	0.35	0.702
Carolina Wren	0.56	0.041	0.58	0.072	0.64	0.065	0.61	0.543
Chipping Sparrow	0.50a	0.046	0.51a	0.082	0.34b	0.059	3.91	0.021
Eastern Towhee	0.28	0.034	0.36	0.068	0.26	0.049	0.84	0.432
Eastern Wood-Pewee	0.37	0.035	0.34	0.059	0.34	0.052	0.10	0.909
Great Crested Flycatcher	0.41a	0.046	0.31ab	0.066	0.23b	0.048	3.15	0.044
Indigo Bunting	0.51	0.047	0.35	0.071	0.61	0.075	1.71	0.182
Northern Cardinal	1.02	0.054	1.07	0.089	1.17	0.078	0.89	0.410
Ovenbird	0.85a	0.051	0.65b	0.080	0.68b	0.071	3.60	0.028
Pine Warbler	0.38ab	0.040	0.27b	0.065	0.45a	0.075	4.11	0.017
Red-eyed Vireo	0.88a	0.048	0.89a	0.105	0.57b	0.060	3.82	0.023
Tufted Titmouse	1.03	0.055	0.99	0.101	1.02	0.104	0.12	0.889
White-eyed Vireo	0.35	0.034	0.28	0.062	0.31	0.046	0.39	0.675
Wood Thrush	0.37	0.048	0.27	0.073	0.43	0.081	1.26	0.284

Table 8. Parameter estimates (ß) and standard errors (SE) of occupancy models for species counted in Delaware, 2008-2009. Models are listed by ΔAIC or ΔQAIC when there was more than one well-supported model (ΔAIC or ΔQAIC ≤ 2) for a species. Species are listed by increasing deer density ß, followed by species whose occupancy was not affected by deer and those with constant occupancy.

Species	Parameter							
	Deer density		Forest		Year		Intercept	
	ß	SE	ß	SE	ß	SE	ß	SE
Yellow-billed Cuckoo	-1.31	0.327	0.02	0.008			-0.15	1.092
	-1.44	0.431					2.33	1.268
Common Yellowthroat	-0.57	0.187	-0.02	0.005			0.97	0.506
Great Crested Flycatcher	-0.54	0.209					1.10	0.553
	-0.56	0.211	<-0.01	0.005			1.47	0.688
Acadian Flycatcher	-0.41	0.138	0.02	0.003			-1.52	0.323
Chipping Sparrow	-0.37	0.160	-0.02	0.003	0.22	0.269	1.80	0.560
	-0.33	0.154	-0.01	0.003			1.81	0.390
Red-eyed Vireo	-0.36	0.157	0.02	0.005	0.43	0.275	-0.53	0.654
Scarlet Tanager			0.03	0.005			-2.61	0.471
	-0.23	0.233	0.02	0.005			-2.11	0.655
Ovenbird			0.04	0.836			-2.19	0.718
	-0.22	0.165	0.03	0.008			-1.73	0.825
	-0.20	0.160	0.03	0.007	-0.18	0.287	-1.49	0.821

Table 8. cont.

	Deer density		Forest		Year		Intercept	
	ß	SE	ß	SE	ß	SE	ß	SE
White-eyed Vireo					-0.85	0.254	0.87	0.422
	-0.11	0.150	-0.01	0.003	-0.91	0.258	2.05	0.561
Pine Warbler	-0.09	0.175	0.03	0.004	-0.40	0.311	-1.47	0.687
Black-and-white Warbler			0.027	0.005			-3.23	0.479
	0.19	0.236	0.03	0.005			-3.65	0.611
House Wren			-0.03	0.014			0.41	1.101
	0.28	0.252	-0.03	0.015			-0.25	1.470
Northern Flicker			-0.82	0.007			81.16	0.695
	0.44	0.389	-0.03	0.007			0.78	1.023
					-2.10	2.736	3.77	8.627
Worm-eating Warbler	0.46	0.185	0.02	0.004	-0.89	0.326	-2.05	0.655
Gray Catbird	1.30	0.287	-0.04	0.008	-0.24	0.450	0.51	1.020
Eastern Wood-Pewee					-0.87	0.249	0.98	0.413
Blue Grosbeak					-0.50	0.321	0.34	0.585
							-0.42	0.267

Table 8. cont.

	Deer density		Forest		Year		Intercept	
	ß	SE	ß	SE	ß	SE	ß	SE
Eastern Towhee							-0.49	0.180
			<0.01	0.003			-0.72	0.274
					0.05	0.266	-0.56	0.441
	-0.03	0.157					-0.43	0.322
Indigo Bunting			-0.01	0.003			0.68	0.242
							-0.17	0.130
					-0.30	0.231	0.28	0.376
	0.01	0.136	-0.01	0.003			0.65	0.338
Summer Tanager							-1.33	0.430
					-0.44	0.416	-0.67	0.772
	-0.26	0.248					-0.90	0.600
			0.01	0.006			-2.09	0.497
Tufted Titmouse							1.95	0.321
	-0.42	0.287					2.72	0.727
					0.63	0.542	1.03	0.739

Table 9. A comparison of vegetation characteristics estimated in Delaware, 2008-2009, from low, moderate, and high deer densities. Values sharing the same letter within each row are not different.

	Low		Moderate		High			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$F_{2,207}$	*P*
Groundcover component (%)								
Grass	3.32	1.111	2.69	2.093	5.53	2.286	0.65	0.525
Forbs	6.38	1.264	10.03	3.171	4.92	1.300	1.58	0.208
Woody vegetation	20.85	2.072	18.44	3.625	16.05	2.173	1.08	0.342
Organic matter	69.28	2.598	67.25	5.170	70.10	3.666	0.11	0.892
Soil	0.17b	0.070	1.58b	1.175	3.40a	1.065	7.36	0.001
Vertical vegetation cover	32.60b	1.754	40.10a	3.712	42.40a	3.164	4.80	0.009
Percent exotics	1.57b	0.667	2.93b	1.504	12.13a	3.293	10.00	<0.001
Basal area								
Factor 5	115.18	3.249	110.76	6.752	119.63	5.193	0.66	0.520
Factor 10	152.76	4.123	145.56	9.493	151.50	7.064	0.29	0.748

APPENDICES

Appendix A. Number of detections, by species, from low, moderate and high deer densities, during point counts in Delaware, May-July 2008-2009.

		Deer density			
Common name	**Scientific name**	**High**	**Moderate**	**Low**	**Total**
Northern Cardinal	*Cardinalis cardinalis*	267	193	555	1015
Tufted Titmouse	*Baeolophus bicolor*	222	162	566	950
Ovenbird	*Seiurus aurocapilla*	175	137	536	848
Red-eyed Vireo	*Vireo olivaceus*	119	150	443	712
American Crow	*Corvus brahyrhynchos*	199	104	373	676
American Goldfinch	*Spinus tristis*	138	136	320	594
Brown-headed Cowbird	*Molothrus ater*	136	101	340	577
Carolina Wren	*Thryothorus ludovicianus*	145	90	266	501
Indigo Bunting	*Passerina cyanea*	147	54	280	481
Wood Thrush	*Hylocichla mustelina*	134	71	276	481
Carolina Chickadee	*Poecile carolinensis*	114	81	231	426
Blue Jay	*Cyanocitta cristata*	92	38	149	412
Eastern Wood-pewee	*Contopus virens*	86	79	233	398
Acadian Flycatcher	*Empidonax virescens*	74	81	241	396
Chipping Sparrow	*Spizella passerina*	68	87	224	379
American Robin	*Turdus migratorius*	142	69	155	366
Great Crested Flycatcher	*Myiarchis crinitus*	63	50	205	318
Red-bellied Woodpecker	*Melanerpes carolinus*	70	56	177	303
Blue Grosbeak	*Passerina caerulea*	47	30	104	279
White-eyed Vireo	*Vireo griseus*	71	35	171	277

Common Grackle	*Quiscalus quiscula*	62	56	152	270
Pine Warbler	*Dendroica pinus*	86	31	152	269
Eastern Towhee	*Pipilo erythrophthalmus*	60	67	141	268
Mourning Dove	*Zenaida macroura*	60	33	119	212
Blue-gray Gnatcatcher	*Polioptila caerulea*	89	64	259	181
Yellow-billed Cuckoo	*Coccyzus americanus*	25	22	137	166
Downy Woodpecker	*Picoides pubescens*	38	30	97	165
Common Yellowthroat	*Geothlypis trichas*	25	13	112	150
Scarlet Tanager	*Piranga olivacea*	26	30	92	148
Worm-eating Warbler	*Helmitheros vermivorum*	49	28	66	143
Gray Catbird	*Dumetella carolinensis*	106	4	22	132
Laughing Gull	*Leucophaeus atricilla*	40	35	49	124
Cedar Waxwing	*Bombycilla cedrorum*	22	21	63	106
Northern Flicker	*Colaptes auratus*	28	14	48	90
Prairie Warbler	*Dendroica discolor*	27	36	19	82
Yellow-breasted Chat	*Icteria virens*	18	4	53	75
Hairy Woodpecker	*Picoides villosus*	17	8	42	67
Black-and-white Warbler	*Mniotilta varia*	16	15	33	64
Red-winged Blackbird	*Agelaius phoeniceus*	13	13	36	62
House Wren	*Troglodytes aedon*	28	5	28	61
Field Sparrow	*Spizella pusilla*	14	14	31	59
White-breasted Nuthatch	*Sitta carolinensis*	31	14	14	59
Canada Goose	*Branta canadensis*	20	1	36	57
Fish Crow	*Corvus ossifragus*	6	16	30	52
Summer Tanager	*Piranga rubra*	13	2	37	52
Brown Thrasher	*Toxostoma rufum*	3	15	26	44

Pileated Woodpecker	*Dryocopus pileatus*	10	3	25	38
Ruby-throated Hummingbird	*Archilochus colubris*	11	7	20	38
Song Sparrow	*Melospiza melodia*	28	1	2	31
Yellow-throated Vireo	*Vireo flavifrons*	6	12	12	30
Eastern Phoebe	*Sayornis phoebe*	11	2	15	28
Purple Martin	*Progne subis*	10	2	16	28
Northern Bobwhite	*Colinus virginianus*	4	1	22	27
Northern Mockingbird	*Mimus polyglottos*	10	3	13	26
Kentucky Warbler	*Oporornis formosus*	6	0	16	22
Turkey Vulture	*Cathartes aura*	2	5	15	22
Blackpoll Warbler	*Dendroica striata*	1	9	7	17
Wild Turkey	*Meleagris gallopavo*	0	5	12	17
Veery	*Catharus fuscescens*	10	1	5	16
Great Blue Heron	*Ardea herodias*	3	4	8	15
Mallard	*Anas platyrhynchos*	4	4	6	14
Yellow Warbler	*Dendroica petechia*	2	5	7	14
Baltimore Oriole	*Icterus galbula*	8	1	4	13
Double-crested Cormorant	*Phalacrocorax auritus*	1	1	10	12
American Redstart	*Setophaga ruticilla*	6	1	3	10
Chimney Swift	*Chaetura pelagica*	2	4	4	10
House Sparrow	*Passer domesticus*	4	4	2	10
Barn Swallow	*Hirundo rustica*	2	3	4	9
House Finch	*Carpodacus mexicanus*	7	0	2	9
Northern Parula	*Parula americana*	5	0	4	9
Osprey	*Pandion haliaetus*	2	7	0	9
Eastern Kingbird	*Tyrannus tyrannus*	3	0	5	8

European Starling	*Sturnus vulgaris*	3	0	5	8
Killdeer	*Charadrius vociferus*	1	3	4	8
Eastern Bluebird	*Sialia sialis*	3	0	4	7
Louisiana Waterthrush	*Seiurus motacilla*	2	0	4	6
Marsh Wren	*Cistothorus palustris*	0	2	3	5
Prothonotary Warbler	*Protonotaria citrea*	0	1	4	5
Swamp Sparrow	*Melospiza georgiana*	0	0	5	5
Red-headed Woodpecker	*Melanerpes erythrocephalus*	3	0	1	4
Yellow-rumped Warbler	*Dendroica coronata*	3	1	0	4
Black-billed Cuckoo	*Coccyzus erythropthalmus*	1	0	2	3
Cooper's Hawk	*Accipiter cooperii*	2	1	0	3
Red-tailed Hawk	*Buteo jamaicensis*	1	0	2	3
Brown-headed Nuthatch	*Sitta pusilla*	0	1	1	2
Golden Pheasant	*Chrysolophus pictus*	2	0	0	2
Great Horned Owl	*Bubo virginianus*	0	0	2	2
Green Heron	*Butorides virescens*	0	0	2	2
Orchard Oriole	*Icterus spurious*	0	0	2	2
Snowy Egret	*Egretta thula*	0	2	0	2
Swainson's Thrush	*Catharus ustulatus*	0	0	2	2
Tree Swallow	*Tachycineta bicolor*	0	1	1	2
White-throated Sparrow	*Zonotrichia albicollis*	0	0	2	2
Willet	*Tringa semipalmata*	0	0	2	2
Willow Flycatcher	*Empidonax trailii*	1	0	1	2
Bald Eagle	*Haliaeetus leucocephalus*	0	0	1	1
Barn Owl	*Tyto alba*	0	1	0	1

Black-throated Green Warbler	*Dendroica virens*	0	0	1	1
Chuck-will's-widow	*Caprimulgus carolinensis*	0	0	1	1
Great Egret	*Ardea alba*	0	1	0	1
Herring Gull	*Larus argentatus*	0	1	0	1
Hooded Warbler	*Wilsonia citrine*	1	0	0	1
Magnolia Warbler	*Dendroica magnolia*	0	0	1	1
Red-shouldered Hawk	*Buteo lineatus*	1	0	0	1
Sharp-shinned Hawk	*Accipiter striatus*	1	0	0	1
Whip-poor-will	*Caprimulgus vociferus*	0	0	1	1
Wood Duck	*Aix sponsa*	1	0	0	1

Appendix B. Midstory plant species (native and exotic) encountered during vegetation surveys of point count sites in Delaware, July-August 2008-2009.

Common name	Scientific name	Exotic
Japanese maple	*Acer palmatum*	**X**
Norway maple	*Acer platanoides*	**X**
red maple	*Acer rubrum*	
sugar maple	*Acer saccharum*	
downy serviceberry	*Amelanchier arborea*	
smooth serviceberry	*Amelanchier laevis*	
porcelain-berry	*Ampelopsis brevipedunculata*	**X**
Hercules club	*Aralia spinosa*	
false nettle	*Boehmeria cylindrical*	
trumpet creeper	*Campsis radicans*	
American hornbeam	*Carpinus caroliniana*	
mockernut hickory	*Carya alba*	
sand hickory	*Carya pallida*	
American chestnut	*Castanea dentate*	
Oriental bittersweet	*Celastrus orbiculatus*	**X**
sweet pepperbush	*Clethra alnifolia*	
silky dogwood	*Cornus amomum*	
flowering dogwood	*Cornus florida*	
witch grass	*Dichanthelium spp*	
persimmon	*Diospyros virginiana*	
spinulose wood fern	*Dryopteris carthusiana*	
autumn olive	*Elaeagnus umbellata*	**X**
strawberry bush	*Euonymus americana*	

American beech	*Fagus grandifolia*	
American holly	*Ilex opaca*	
red cedar	*Juniperus virginiana*	
mountain laurel	*Kalmia latifolia*	
European privet	*Ligustrum vulgare*	**X**
spicebush	*Lindera benzoin*	
sweet gum	*Liquidambar styraciflua*	
tuliptree	*Liriodendron tulipifera*	
Japanese honeysuckle	*Lonicera japonica*	**X**
sweetbay magnolia	*Magnolia virginiana*	
Canada moonseed	*Menispermum canadense*	
Japanese stilt grass	*Microstegium vimineum*	**X**
northern bayberry	*Myrica pensylvanica*	
black gum	*Nyssa sylvatica*	
Virginia creeper	*Parthenocissus quinquefolia*	
mile-a-minute	*Persicaria perfoliata*	**X**
common pokeweed	*Phytolacca americana*	
loblolly pine	*Pinus taeda*	
Virginia pine	*Pinus virginiana*	
large-tooth aspen	*Populus grandidentata*	
American plum	*Prunus americana*	
wild black cherry	*Prunus serotina*	
choke cherry	*Prunus virginiana*	
white oak	*Quercus alba*	
blackjack oak	*Quercus marilandica*	
swamp chestnut oak	*Quercus michauxii*	

water oak	*Quercus nigra*	
willow oak	*Quercus phellos*	
chestnut oak	*Quercus prinus*	
northern red oak	*Quercus rubra*	
post oak	*Quercus stellata*	
black oak	*Quercus velutina*	
swamp azalea	*Rhododendron viscosum*	
winged sumac	*Rhus copallinum*	
multi-floral rose	*Rosa multiflora*	**X**
red rasberry	*Rubus idaeus*	
western raspberry	*Rubus occidentalis*	
wineberry	*Rubus phoenicolasius*	**X**
sassafras	*Sassafras albidum*	
green bristle grass	*Setaria viridis*	**X**
greenbrier	*Smilax spp*	
Johnson grass	*Sorghum halepense*	**X**
American bladdernut	*Staphylea trifolia*	
coral-berry	*Symphoricarpos orbiculatus*	
poison ivy	*Toxicodendron radicans*	
eastern hemlock	*Tsuga canadensis*	
slippery elm	*Ulmus rubra*	
stinging nettle	*Urtica dioica*	**X**
highbush blueberry	*Vaccinium corymbosum*	
early lowbush blueberry	*Vaccinium pallidum*	
maple-leaf viburnum	*Viburnum acerfolium*	
arrow-wood	*Viburnum dentatum*	

exotic arrow-wood	*Viburnum dilatatum*	**X**
smooth black-haw	*Viburnum prunifolium*	
summer grape	*Vitis aestivalis*	
Muscadine grape	*Vitis rotundifolia*	
winter grape	*Vitis vulpine*	

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