Effects of Red-cockaded Woodpecker Management on Vegetative Composition and Structure and Subsequent Impacts on Game Species

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Abstract: To facilitate recovery of the endangered red-cockaded woodpecker (RCW), management priorities and practices on >800,000 ha of Forest Service land in the Southeastern United States have been realigned to restore the pine-grassland system to which the RCW is adapted. Management regimes for RCW involve fire and mechanical suppression of hardwood understory and midstory. As such, RCW management practices might be expected to alter plant communities and associated wildlife populations. We examined differences in vegetation composition and structure between mature pine stands managed for red-cockaded woodpeckers and similarly-aged stands not managed specifically for RCWs on 2 national forests in southern Mississippi. During the growing seasons of 1997 and 1998, 123 vegetation plots were sampled on both study areas using nested circular plots. Pine sawtimber stands under RCW management differed in structure and composition from those under traditional U.S. Forest Service (USFS) management. Hard mast production was reduced by RCW management, while soft mast production, forb canopy cover, and grass canopy cover increased. Although differences were detected between study areas for several vegetative characteristics, RCW management had similar effects on composition and structure of the vegetative communities. We documented potential effects of RCW management for game species.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 53:220–234

Red-cockaded woodpeckers *(Picoides borealis)* (RCWs) are a federally-endangered species endemic to mature pine ecosystems of the southeastern United States (U.S. Fish and Wildl. Serv. 1970, Jackson 1994). RCW populations respond well to intensive habitat management (Hooper et al. 1991, Richardson and Stockie 1995, Walters et al. 1995). Intensive management for the RCW includes long timber rotations (≥70 years), 2- to 3-year prescribed burn rotations, and aggressive removal of hardwood midstory stems using mechanical and herbicidal methods (U.S. For. Serv. 1995).

Although management for RCW has produced encouraging results, the potential effects of intensive habitat alteration on game and non-game species must be considered (Wilson et al. 1995, Masters et al. 1996). Brennan et al. (1994) noted that information on effects of RCW management practices on non-target vertebrates is limited, although, in recent years, several studies have examined the effects of intensive habitat alteration on vertebrate communities. Positive responses to RCW management have been reported for white-tailed deer *(Odocoileus virginianus)* forage production (Masters et al. 1996), northern bobwhite *(Colinus virginianus)* populations (Fuller 1994, Burger et al. 1998), small mammal populations (Masters et al. 1998), and migratory and resident avian communities (Wilson et al. 1995, Burger et al. 1998). Hunter et al. (1994) suggested that high priority temperate migrants and resident bird species might benefit from RCW management practices. Responses (positive or negative) of vertebrates to RCW management are presumably attributable to changes in the plant community in response to management activities. Therefore, information on effects of RCW management regimes on plant communities is fundamental to predicting responses by vertebrate populations.

This study examined the differences in vegetation composition and structure between areas under RCW management and mature pine stands not managed specifically for RCWs on 2 sites in central Mississippi. We discuss potential impacts on several game species including white-tailed deer, wild turkey *(Meleagris gallopavo silvestris)*, fox squirrel *(Sciurus niger)*, gray squirrel *(S. carolinensis)*, eastern cottontail *(Sylvilagus floridanus)*, northern bobwhite, and black bear *(Ursus americanus)*.

We thank J. Baker, G. Berryhill, D. Coggin, W. McKinley, and P. Owens for field assistance. Editorial comments were provided by M. Chamberlain, B. Strickland, and J. Jones. Funding was provided by the Mississippi Department of Wildlife, Fisheries and Parks through Federal Aid in Wildlife Restoration Funds (W-48, Study XXXXIII), Mississippi GAP Analysis, Boone-Crockett, and Camp Fire Conservation Fund. Approved for publication as Journal Article Number WF105 of the Forest and Wildlife Research Center, Mississippi State University.

Methods

Study Area Description

Bienville National Forest.—This 70,931-ha forest is located in south-central Mississippi in Jasper, Newton, Scott, and Smith counties. Annual average maximum and minimum temperatures were 25 C and 11 C, respectively (Natl. Oceanic and Atmos. Admin. [NOAA] 1994). The area experienced high humidity and an average rainfall of 154 cm (NOAA 1994). Three cover types dominated this area: pine (54,786 ha), mixed pine-hardwood (3,912 ha), and hardwood (12,233 ha). Our study focused on pine sawtimber stands (37,515 ha). These stands had dominant overstories of loblolly *(Pinus taeda)*, shortleaf *(P. echinata)*, and longleaf *(P. palustris)* pines. Other common overstory species were red maple *(Acer rubrum)*, mockernut hickory *(Cayra tomentosa)*, flowering dogwood *(Cornus florida)*, sweet gum *(Liquidambar styraciflua)*, black gum *(Nyssa sylvatica)*, white oak *(Q. alba)*, southern red oak *(Q. falcata)*, water oak *(Q. nigra)*, and post oak *(Q. stellata)*. Midstories were dominated by red maple, flowering dogwood, common persimmon *(Diospyros virginiana)*, sweet gum, black gum, water oak, post oak, and muscadine grape *(Vitis rotundifolia)*. Understories were dominated by sassafras *(Sassafras albidum)*, saw greenbrier *(Smilax bonanox)*, common greenbrier *(S. rotundifolia)*, and muscadine grape.

Homochitto National Forest.—This 76,069-ha forest is located in southeast Mississippi in Adams, Amite, Copiah, Franklin, Jefferson, Lincoln, and Wilkinson counties. Annual average maximum and minimum temperatures were 25 C and 13 C respectively (NOAA 1994). The area experienced high humidity and an average rainfall of 156 cm (NOAA 1994). Three cover types dominated this area: pine (60,103 ha), mixed pine-hardwood (11,106 ha), and hardwood (4,851 ha). Our study focused on pine sawtimber stands (36,425 ha). These stands had dominant overstories of loblolly, shortleaf, and longleaf pines. Other common overstory species were red maple, flowering dogwood, sweet gum, black gum, sourwood *(Oxydendron arboreum)*, white oak, southern red oak, water oak, post oak, black oak *(Q. velutina)*, and winged elm *(Ulmus alata)*. Midstories were dominated by American beautyberry *(Callicarpa americana)*, flowering dogwood, tree sparkleberry *(Vaccinium arboreum)*, and muscadine grape. Understories were dominated by cat greenbrier *(S. gaucus)* and muscadine grape.

We examined the differences in vegetation composition and structure between traditional USFS and RCW management of pine sawtimber stands. Prescribed burning (dormant season) was conducted on a 3- to 5-year rotation for RCW management, whereas traditional pine stands were burned every 5–10 years. Traditionally managed stands were randomly selected using USFS geographic information systems (GIS) databases and plot center coordinates were randomly assigned within these stands. Plots were located using global positioning system (GPS) and US Geologic Survey (USGS) quadrangles. RCW managed stands were randomly selected from a list provided by the USFS. A random azimuth and distance were used to select plot center. All vegetation plots were >50 m from an edge to prevent adjacent stands from influencing vegetative characteristics of sampled plots. Plots were sampled May–June 1997 and 1998.

Sampling

Vegetation was sampled in nested circular plots. Overstory vegetation was measured in 0.04-ha circular plots (Noble and Murphy 1975). Every tree taller than

5m was measured (U.S. Natl. Park Serv. [USNPS] 1990). Species, diameter-at-breast height (dbh), and crown class (dominant, codominant, intermediate, or overtopped) were recorded for each tree. Midstory vegetation was measured in 0.004-ha circular plots (Noble and Murphy 1975). Every plant between 1–5 m in height and all vines 1 m, even if they extended beyond 5 m, were considered midstory vegetation (USNPS 1990). In each midstory plot, the species and number of individuals of each species were recorded (USNPS 1990). Understory vegetation was measured in 0.0004-ha circular plots (Noble and Murphy 1975). All vegetation <1 m was considered understory vegetation (USNPS 1990). In each understory plot, the following data were recorded: species of soft mast producers; *N* stems of each soft mass species; and coverage of grasses, sedges, forbs, vines, mushrooms, organic litter, woody debris, mineral soil, and rock (USNPS 1990). Canopy cover of overstory and midstory plots were ocularly estimated and placed into 1 of 5 classes (1=0%, 2=1%–25%, 3=26%–50%, 4=51%–75%, 5=76%–100%). Canopy cover for understory plots was calculated by adding percent coverage of grasses, sedges, forbs, vines, and mushrooms. Additionally, to assess vertical vegetation density, a Nudds Board was used at the 4 cardinal directions 15 m from plot center (Nudds 1977, van Manen 1991). A running mean was used to determine the number of sample plots within each cover type (Mueller-Dumbois and Ellenber 1974).

Vegetative characteristics of interest were vertical density (<0.5 m, <1.0 m, <3.0 m), pine basal area/hectare, hard mast producers basal area (m^2/ha), *N* hard mast producers/hectare, oak basal area (m^2/ha), number of oaks/hectare, Shannon-Weaver Index (Hair 1980) for soft mast species, overstory canopy closure, midstory canopy closure, understory canopy closure, grass in understory (%), forbs in understory (%), woody in understory (%), and vines in understory (%). Vertical vegetative density was measured at 3 heights because the height of protective cover varies by species. Pine basal area (m^2/ha) for trees >5" dbh was a measure of successful RCW management. Hardwood (included hickories) and oak basal area for trees >50 years of age was a measure of potential mast production. Van Manen (1991) indicated that most hard mast species do not produce optimal amounts of hard mast until at least 50 years of age. Number of hard mast species and oak species/hectare >50 years of age was a measure of hard mast diversity. Van Manen (1991) hypothesized that as the number of hard mast producing species increased, the probability of mast crop failure decreased. The Shannon-Weaver Index (Hair 1980) of soft mast diversity measured species richness and evenness. Large numbers of soft mast producing plants are important for soft mast production and richness of soft mast species alleviates concern about soft mast failures. Canopy cover was a measure of sunlight available to each canopy layer. Percent composition of the understory by life form was a measure of change in structure of the understory.

A 2-way analysis of variance (ANOVA) was used to detect differences in vegetative characteristics for the main effects of management type and study area. Vertical vegetative density was arcsine transformed and pine basal area was square-root transformed to normalize residuals and equalize variances (Sokal and Rohlf 1981). All other vegetative variables would not meet normality. These variables were rank transformed and analyses were conducted on transformed variables (Conver and Iman 1976). Fisher's Protected LSD multiple comparison procedure was used to determine differences between means when a significant result was detected (Conover 1980).

Results

We compared 123 vegetation plots on the study areas (Bienville traditional management $N=27$, Bienville RCW management $N=33$, Homochitto traditional management $N=23$, Homochitto RCW management $N=40$). Traditional and RCW management stands on Bienville had the same species dominating their overstories (Table 1). Relative frequency of hardwood species on Bienville in the overstory was less in RCW managed stands when compared to traditional management (Table 1). However, the relative frequency of post oak was greater for RCW management (Table 1). Most common midstory woody species at Bienville had lower relative frequencies (i.e., red maple, sweet gum, black gum, and water oak), but common persimmon, white oak, and post oak had greater relative frequencies (Table 2). Additionally, forb, grass, and vine midstory relative abundance was greater for andropogon (*Andropogon* spp.), eupatorium (*Eupatorium* spp.), poison ivy *(Rhus radicans),* and muscadine grape (Table 2) for RCW management. The only common woody understory species on Bienville, sassafras, was absent under RCW management (Table 3). Additionally, 2 species of greenbrier (saw and common) and muscadine grape had lower relative frequencies under RCW management (Table 3). Four common understory species on Bienville had greater relative frequencies under RCW management, winged sumac *(Rhus copallina),* poison ivy, blackberry *(Rubus argutus),* and pigeon grape *(Vitis cinerea)* (Table 3).

Relative frequency of species reflected similar trends on Homochitto, but several differences existed. Traditional and RCW managed stands on Homochitto had the same species dominating their overstories (Table 1). Relative frequency of hard-

Table 1. Frequency and relative frequency of species with >5% relative frequency in overstory plots under traditional and RCW management in pine sawtimber stands on Bienville and Homochitto National Forests, Mississippi, 1997–1998.

	Bienville				Homochitto			
	Traditional		Red-cockaded		Traditional		Red-cockaded	
Species	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq
Acer rubrum	37.04	5.95	3.03	1.11	39.10	5.60	2.50	1.02
Carya tomentosa	37.04	5.95	15.15	5.56	17.39	2.48	2.50	1.02
Cornus florida	33.33	5.36	6.06	2.22	56.52	8.07	7.50	3.06
Liquidambar styraciflua	55.56	8.93	3.03	1.11	52.17	7.45	2.50	1.02
Nyssa sylvatica	40.74	6.55	12.12	4.44	26.09	3.73	7.50	3.06
Pinus echinata	51.85	8.33	30.30	11.11	47.82	6.83	50.00	20.41
P. palustris	11.11	1.79	12.12	4.44	26.09	3.73	45.00	18.37
P. taeda	88.89	14.29	90.91	33.33	86.96	12.42	80.00	32.65
Quercus falcata	29.63	4.76	12.12	4.44	47.82	6.83	10.00	4.08
Q. stellata	51.85	8.33	36.36	13.33	26.09	3.73	2.50	1.02

Table 2. Frequency and relative frequency of species with >5% relative frequency in midstory plots under traditional and RCW management in pine sawtimber stands on Bienville and Homochitto National Forests, Mississippi, 1997–1998.

	Bienville				Homochitto			
	Traditional		Red-cockaded		Traditional		Red-cockaded	
Species	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq
Acer rubrum	59.24	11.68	12.12	2.56	17.39	5.33	32.50	8.28
Andropogon spp.	0.00	0.00	24.24	5.13	0.00	0.00	0.00	0.00
Callicarpa americana	18.52	3.64	6.06	1.28	21.74	6.67	22.50	5.73
Cornus florida	22.22	4.38	3.03	0.64	39.13	12.00	17.50	4.46
Diospyros virginiana	29.63	5.84	36.36	7.69	17.39	5.33	45.00	11.46
Eupatorium spp.	0.00	0.00	24.24	5.13	0.00	0.00	0.00	0.00
Liquidambar styraciflua	37.04	7.30	15.15	3.21	39.13	12.00	40.00	10.19
Magnolia macrophylla	0.00	0.00	0.00	0.00	17.39	5.33	2.50	0.64
Nyssa sylvatica	40.74	8.03	24.24	5.13	0.00	0.00	0.00	0.00
Quercus alba	3.70	0.73	24.24	5.13	0.00	0.00	2.50	0.64
Q. falcata	7.41	1.46	18.18	3.85	8.70	2.67	22.50	5.73
Q. nigra	29.63	5.84	9.09	1.92	8.70	2.67	0.00	0.00
Q. stellata	25.93	5.11	27.27	5.77	0.00	0.00	0.00	0.00
Rhus copallina	18.52	3.65	21.21	4.49	0.00	0.00	20.00	5.10
R. radicans	3.70	0.73	27.27	5.77	0.00	0.00	0.00	0.00
Vaccinium arboreum	7.41	1.46	3.03	0.64	26.09	8.00	17.50	4.46
Vitis rotundifolia	37.04	7.30	36.36	7.69	13.04	4.00	30.00	7.64

wood species on Homochitto in the overstory was less under RCW management when compared to traditional management (Table 1). Most common midstory species, American beautyberry, flowering dogwood, sweet gum, bigleaf magnolia *(Magnolia macroophylla),* and tree sparkleberry in the Homochitto had lower relative frequencies, but red maple, common persimmon, southern red oak, winged sumac, and

Table 3. Frequency and relative frequency of species with >5% relative frequency in understory plots under traditional and RCW management in pine sawtimber stands on Bienville and Homochitto National Forests, Mississippi, 1997–1998.

	Bienville				Homochitto			
	Traditional		Red-cockaded		Traditional		Red-cockaded	
Species	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq	Freq	Rel freq
Callicarpa americana	7.41	2.27	0.00	0.00	17.39	8.00	10.00	3.77
Diospyros virginiana	11.11	3.41	6.06	1.98	8.70	4.00	15.00	5.66
Rhus copallina	7.41	2.27	18.18	5.94	0.00	0.00	22.50	8.49
R. radicans	11.11	3.41	42.42	13.86	8.70	4.00	0.00	0.00
Rubus argutus	18.51	5.68	75.76	24.75	13.04	6.00	40.00	15.09
Sassafras albidum	22.22	6.82	0.00	0.00	4.35	2.00	2.50	0.94
Smilax bonanox	29.63	9.09	15.15	4.95	8.70	4.00	17.50	6.60
S. glaucus	11.11	3.41	0.00	0.00	30.43	14.00	12.50	4.72
S. rotundifolia	25.93	7.95	3.03	0.99	13.04	6.00	10.00	3.77
Vaccinium arboreum	7.41	2.27	12.12	3.96	17.39	8.00	22.50	8.49
Vitis aestivalis	0.00	0.00	18.18	5.94	0.00	0.00	0.00	0.00
V. rotundifolia	55.56	17.05	33.33	10.89	43.48	20.00	32.50	12.26

muscadine grape showed greater relative frequencies (Table 2). Four common understory species had lower relative frequencies under RCW management, American beautyberry, cat greenbrier, and muscadine grape (Table 3). Additionally, 5 common Homochitto understory species had greater relative frequencies under RCW management, common persimmon, winged sumac, blackberry, saw greenbrier, and tree sparkleberry (Table 3).

We observed no area by management type interaction for vertical vegetation densities, but detected differences for management type and study area (Table 4). Traditional management had greater vertical vegetation density at all heights compared to RCW management (Table 5). Additionally, Bienville had greater vertical vegetation density <0.5 m than Homochitto, whereas Homochitto had greater vertical vegetation density at <1.0 m. and <3.0 m.

We observed an area by management type interaction for pine basal area (Table 4). Fisher's Protected LSD grouped RCW management at Bienville (23.85±1.40 m^2/ha), traditional management at Bienville (22.12±2.17 m^2/ha), and traditional management at Homochitto (24.38±2.89 m^2/ha) together, but RCW management on Homochitto (13.72±1.02m^2/ha) was significantly lower. We observed no area by management type interaction for hard mast species basal area, number of hard mast species, oak basal area, and number of oaks, but detected differences for management type and study area (Table 4). Hard mast species basal area, number of hard mast species, oak basal area, and number of oaks were greater under traditional management than for RCW management (Table 5). Hard mast and oak basal areas were

Table 4. Two-way ANOVA on vegetative characteristics for the main effects of management type and study area, Bienville and Homochitto National Forests, 1997–1998.

	Type*Area		Area		Type	
Vegetative characteristic	$F_{1,119}$	*P*	$F_{1,119}$	*P*	$F_{1,119}$	*P*
Vertical vegetation density <0.5m (%)	0.07	0.7947	4.27	<0.0001	97.75	<0.0001
Vertical vegetation density <1.0m (%)	1.19	0.2783	57.20	<0.0001	57.20	<0.0001
Vertical vegetation density <3.0m (%)	2.43	0.1217	12.83	0.0005	12.83	0.0005
Pine basal area (m^2/ha)	13.38	0.0004	6.90	0.0097	5.53	0.0203
Hard mast species basal area (m^2/ha)	0.03	0.8714	0.00	0.9853	14.84	0.0002
Number of hard mast species/ha	0.01	0.9161	0.00	0.9550	15.10	0.0002
Oak basal area (m^2/ha)	0.16	0.6881	0.02	0.8824	15.02	0.0002
Number of oaks/ha	0.01	0.9161	0.00	0.9550	15.10	0.0002
Shannon-Weaver Index of soft mast species						
Overstory	0.42	0.5167	0.08	0.7819	12.76	0.0005
Midstory	0.86	0.3565	1.12	0.2921	0.00	0.9715
Understory	0.91	0.3409	5.14	0.0252	4.73	0.0317
Overstory canopy closure (cover class 1–5)	1.84	0.1771	6.46	0.0123	70.66	0.0001
Midstory canopy closure (cover class 1–5)	4.71	0.0319	6.27	0.0136	4.27	0.0410
Understory canopy closure (%)	1.37	0.2438	9.94	0.0020	20.96	<0.0001
Percent coverage by life form in understory						
Grass (%)	1.39	0.2400	3.26	0.0734	18.40	<0.0001
Forb (%)	0.51	0.4767	5.29	0.0231	42.68	<0.0001
Woody (%)	0.19	0.6632	12.20	0.0007	3.82	0.0530
Vine (%)	3.15	0.0784	14.97	0.0002	1.89	0.1722

Table 5. Mean and standard errors of vegetative characteristics for traditional and RCW management on Bienville and Homochitto National Forests, 1997–1998. Letters after mean and standard error denote whether means were different based on Fisher's Protected LSD.

Vegetative characteristic	Traditional ($\bar{x}$ ± SE)	RCW ($\bar{x}$ ± SE)
Vertical vegetation density <0.5m (%)	0.76±0.03a	0.73±0.03b
Vertical vegetation density <1.0m (%)	0.62±0.03a	0.57±0.03b
Vertical vegetation density <3.m (%)	0.41±0.03a	0.34±0.02b
Pine basal area (m^2/ha)	23.16±1.76[1]	18.30±1.03[1]
Hard mast species basal area (m^2/ha)	1.99±0.66a	0.37±0.26b
Number of hard mast species/ha	3.60±0.85a	0.55±0.27b
Oak basal area (m^2/ha)	1.86±0.65a	0.35±0.26b
Number of oaks/ha	3.20±0.78a	0.41±0.23b
Shannon-Weaver Index of soft mast species		
Overstory	0.10±0.02a	0.03±0.01b
Midstory	0.19±0.03a	0.17±0.02a
Understory	0.17±0.03a	0.24±0.02b
Overstory canopy closure (cover class 1–5)	4.58±0.10a	3.21±0.11b
Midstory canopy closure (cover class 1–5)	2.60±0.17[1]	2.18±0.11[1]
Understory canopy closure (%)	45.4±2.99a	62.7±2.91b
Percent coverage by life form in understory		
Grass (%)	11.12±2.17a	20.96±2.26b
Forb (%)	5.12±1.13a	12.86±1.15b
Woody (%)	10.62±1.31a	13.23±1.10a
Vine (%)	18.34±1.94a	14.77±1.50a

1. Means are listed for completeness and should not be interpreted because a 2-way interaction was detected for the ANOVA; thus, type by study means were compared for differences and are listed in the results.

greater on Homochitto than Bienville, but number of hard mast and oaks species were greater on Bienville than Homochitto (Table 6).

We observed no area by management type interaction for Shannon-Weaver Index of soft mast species in the overstory, midstory, and understory (Table 4). Additionally, no differences were detected for study area for the overstory, but differences were detected by management type (Table 4). Diversity of soft mast in the overstory was less for RCW management (Table 5). No effect of management type or area was detected for midstory soft mast diversity (Table 4). However, management type and area did affect understory soft mast diversity (Table 4). RCW management had greater soft mast diversity than traditional management (Table 5). Additionally, Bienville had greater soft mast diversity than Homochitto (Table 6).

We observed no area by management type interaction for overstory and understory canopy cover (Table 4). However, we observed an area by management type interaction for midstory canopy cover (Table 4). Fisher's Protected LSD grouped RCW management at Bienville (2.21±0.12), RCW management at Homochitto (2.15±0.17), and traditional management at Homochitto (2.13±0.19) together, but traditional management on Bienville (3.00±0.24) was significantly higher. Type of management and area did affect the canopy cover for the overstory and understory (Table 4). The overstory had greater canopy cover under traditional management than under RCW management (Table 5). In contrast, the understory had greater canopy

Table 6. Mean and standard errors of vegetative characteristics for Bienville and Homochitto National Forests, 1997–1998. Letters after mean and standard error denote whether means were different based on Fisher's Protected LSD.

Vegetative characteristic	Bienville ($\bar{x}\pm$SE)	Homochitto ($\bar{x}\pm$SE)
Vertical vegetation density <0.5m (%)	0.77 ±0.03a	0.35 ±0.02b
Vertical vegetation density <1.0m (%)	0.62 ±0.03a	0.74 ±0.03b
Vertical vegetation density <3.m (%)	0.41 ±0.03a	0.56 ±0.03b
Pine basal area (m^2/ha)	23.08 ±1.24[1]	17.61 ±1.39[1]
Hard mast species basal area (m^2/ha)	0.99 ±0.40a	1.06 ±0.49b
Number of hard mast species/ha	2.00 ±0.62a	1.59 ±0.52a
Oak basal area (m^2/ha)	0.95 ±0.39a	0.97 ±0.49a
Number of oaks/ha	2.00 ±0.62a	1.59 ±0.52a
Shannon-Weaver Index of soft mast species		
Overstory	0.06 ±0.02a	0.05 ±0.02a
Midstory	0.20 ±0.03a	0.16 ±0.03a
Understory	0.24 ±0.02a	0.18 ±0.03b
Overstory canopy closure (cover class 1–5)	4.05 ±0.14a	3.49 ±0.14b
Midstory canopy closure (cover class 1–5)	2.57 ±0.14a	2.14 ±0.13a
Understory canopy closure (%)	61.2 ±2.90a	50.5 ±3.28b
Percent coverage by life form in understory		
Grass (%)	19.30 ±2.55a	14.73 ±2.12b
Forb (%)	7.2 ±0.85a	12.11 ±1.48b
Woody (%)	14.67 ±1.16a	9.79 ±1.16b
Vine (%)	19.67 ±1.66a	12.94 ±1.62b

1. Means are listed for completeness and should not be interpreted because a 2-way interaction was detected for the ANOVA; thus, type by study means were compared for differences and are listed in the results.

cover under RCW management (Table 5). Canopy cover was greater on Bienville for both overstory and understory (Table 6).

We observed an area by management type interaction for percent coverage for the life forms grass, forb, woody, and vine in understory (Table 4). RCW management had greater percentages of grass and forbs than traditional management, but no differences were detected for management type for woody or vine life forms (Table 5). Study area also affected percent of life forms in the understory for forb, woody and vine, but not grass (Table 4). Homochitto had more forbs in the understory, while Bienville had more woody and vine life forms in the understory (Table 6).

Discussion

Generally, we detected differences in vegetation characteristics between pine sawtimber stands under traditional and RCW management regimes. Potential hard mast production was negatively affected by RCW management, while potential soft mast production, forb canopy cover and grass canopy cover benefited. Although differences were detected between study areas for several vegetative characteristics, RCW management had similar effects on composition and structure of the vegetative communities on both study areas. Differences between study areas resulted from different vegetative communities (e.g., longleaf versus loblolly) and management intensity and history.

However, some statistically significant differences may not be biologically significant. An example is the result for vertical vegetative density. The difference between the means was <7% for all 3 heights sampled. We used vertical vegetation density as a measure of protection cover; thus, the importance of this variable is determined by how much the vegetation obscures an animal from a possible predator. Thus, this 7% would translate into a smaller percentage when considering the actual amount of an animal that is obscured.

White-tailed Deer

The white-tailed deer is an important game species on both areas. Masters et al. (1996) documented the benefits of deer forage production in RCW stands. Our results were similar, in that we observed increased abundance of forbs and grasses. The increased production of forbs and grasses was likely due to reduced basal area and canopy cover as Masters et al. (1996) noted in their study. Although we documented increased canopy cover forage plants, a decrease in indices of hard mast production also was noted. Traditionally managed stands had adequate species richness of hard mast producers, but had low basal area of hard mast species (Schroeder and Vangilder 1997). Thus, RCW management significantly lowered species richness and basal area of hard mast producers, but hard mast production under traditional management was already suboptimal. Managers may view RCW management as negatively affecting hard mast production, but hard mast production only moved from poor to very poor.

Wild Turkey

The wild turkey is another important game species on these areas. The impact of RCW management on hard mast production was similar to that for white-tailed deer. The increase in soft mast production on or near ground level increased the benefits to wild turkeys (Hurst 1992, Palmer et al. 1996). Many soft mast producers in the canopy area are not available to turkeys until their fruits fall to the ground (Hurst 1992). In addition to soft mast production, RCW management improved habitat structure for hen turkeys during pre-incubation and nesting activity. Palmer et al. (1996) and Chamberlain and Leopold (1998) both noted that hens preferred areas dominated by grasses and forbs, and with less woody and vine vegetation, which was reflected by our data. Additionally, increased grasses and forbs in the understory should benefit brood habitat.

Tree Squirrels

RCW management would likely affect gray squirrels to a greater degree than fox squirrels. However, both species of squirrels would likely be adversely affected by low hard mast production. Additionally, hardwoods are preferred for denning (Flyger and Gates 1982, Edwards et al. 1989, Edwards et al. 1998); thus, removal of hardwoods, as is common in RCW management, would adversely affect squirrels. Fox squirrels prefer more open habitats than gray squirrels (Allen 1982*a,* Allen 1982*b,* Flyger and Gates 1982, Weigl et al. 1989). In Mississippi, Ross (1996) reported fox squirrels were nearly absent from pine sawtimber stands with dense mid- and understories. Thus, reduction in basal area and canopy cover accompanying RCW management may favor fox squirrels (Flyger and Gates 1982, Weigl et al. 1989).

Cottontail Rabbits

As compared to tree squirrels, eastern cottontail rabbits are usually considered early successional species (Chapman et al. 1982, Allen 1984). Chapman et al. (1982) characterized cottontail habitat by "weedy forbs and bunch-type perennial grasses." Under RCW management, forb and grass abundance increased. Additionally, blackberry relative frequency at least doubled, and blackberry is often listed as an important component of rabbit habitat (Allen 1984, Chapman et al. 1982). Thus, RCW management should improve rabbit habitat when compared to traditional management of pine sawtimber.

Northern Bobwhite

Fuller (1994) noted that RCW habitat management and northern bobwhite habitat management were very similar in pine forests of the Southeast. Both featured hardwood midstory control, frequent burning, and reduction of overstory basal area (U.S. For. Serv. 1995). Fuller (1994) reported that managed RCW colonies were used by northern bobwhites in greater proportion than their availability within a bobwhite's home range and reported that RCW colony stands had greater arthropod biomass and abundance than unmanaged pine stands which benefited quail chicks during brood-rearing.

Modern forestry practices which maximize the number of overstory stems per hectare and minimize burning frequency have negatively impacted both RCW and northern bobwhites. Burger et al. (1998) noted that RCW habitat management practices maintain open pine forests with forest structure beneficial to many avian species, including northern bobwhites. Our results indicated that RCW habitat management stands had lower canopy cover and more grasses and forbs than traditional management stands. The early successional plant communities of RCW management stands provided higher quality nesting, brood rearing, and foraging habitat than traditional stands. Additionally, increases in forbs, grasses, and soft mass producers in RCW stands should enhance quail food availability.

Black Bear

The black bear is typically considered a forest interior species and generally not thought of as inhabiting pine forest, but bears historically and currently inhabit pine forests in Mississippi and other southeastern states (Pelton 1985, Shropshire 1996). Black bear, like the other species discussed which depend on fall hard mast crops, will not benefit from the low hard mast production associated with traditional and RCW management (Pelton 1982, Pelton 1985). Vertical vegetative density was adequate for protection cover, but it was at the low end of the scale for both types of management (van Manen 1991). The greatest benefit of RCW management to black bears appeared to be soft mast production (van Manen 1991, van Manen 1996). Increases in soft mast in the understory and no decrease in soft mast in the midstory demonstrated that more soft mast would be available for bears. Although bears will climb trees to acquire soft mast, less energy is expended to acquire soft mast near the ground and it is of greater benefit to bears (Pelton 1982). The reduction in hard mast production may not be as important as the increased soft mast production for RCW management if hard mast can be acquired in adjacent stands.

Management Implications

We examined differences in vegetation composition and structure between traditional and RCW management of pine sawtimber stands. Our data demonstrated poor hard mast production for traditional and RCW management. Although pine stands may not provide adequate hard mast production for several game species, these stands can produce other requisites, such as increased soft mast production, and hard mast can be acquired in adjacent hardwood stands (J. L. Bowman, unpubl. data). We do not believe hard mast will be limiting in RCW management areas if they are juxtaposed with hardwood areas. For example, streamside management zones may provide adequate hard mast for species like squirrels and turkeys. However, we recommend managers leave as many large oaks and hickories as allowable under current management guidelines. Currently, guidelines allow ≤25 dominant or codominant hardwoods/hectare and 7 midstory hardwoods/hectare within RCW management areas (U.S. For. Serv. 1995).

We have noted numerous benefits of RCW management. White-tailed deer benefit from increased forage production. Wild turkey hens benefit from improved brood, pre-incubation and nesting habitat, and increased soft mast production. Northern bobwhite benefit from increases in herbaceous ground cover, arthropods, and native legumes which enhance nesting, brood rearing, and foraging habitat quality. Although gray squirrels benefit little under RCW management, fox squirrel habitat will be improved, especially if more hardwoods can be left for mast production and denning sites. By opening the canopy which increases forbs, grasses, and blackberry abundance, RCW management makes previously unsuitable pine sawtimber stands more suitable for rabbits. Although RCW management appears to negatively impact gray squirrel and black bear, it may positively impact certain requisites for most other game species.

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