FOREST BIRD RESPONSE TO REGENERATION PRACTICES IN CENTRAL HARDWOOD FORESTS

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Abstract: We studied breeding songbird populations in a managed, predominantly forested landscape, in southeastern Missouri. We determined differences in the relative abundance of breeding birds in forest stands that had been harvested by the clearcut ($n = 12$), shelterwood ($n = 12$), group selection ($n = 12$), and single-tree selection ($n = 10$) forest regeneration methods, and mature even-aged stands ($n = 12$). Five migrant songbirds, the blue-winged warbler (*Vermivora pinus*), prairie warbler (*Dendroica discolor*), rufous-sided towhee (*Pipilo erythrophthalmus*), white-eyed vireo (*Vireo griseus*), and yellow-breasted chat (*Icteria virens*), were more abundant in clearcut treatments than other treatments ($P < 0.001$). Indigo buntings (*Passerina cyanea*) and field sparrows (*Spizella pusilla*) were more abundant in clearcut and shelterwood treatments than other treatments ($P < 0.001$). Hooded warblers (*Wilsonia citrina*) and northern parulas (*Parula americana*) were more abundant in the selection treatments than other treatments ($P < 0.001$). Ovenbirds (*Seiurus aurocapillus*) and wood thrushes (*Hylocichla mustelina*) were most abundant in mature sites ($P < 0.001$). Acadian flycatchers (*Empidonax virescens*) and red-eyed vireos (*Vireo olivaceus*) were more abundant in group and single-tree selection treatments and mature stands than in clearcut or shelterwood treatments ($P < 0.02$). Numbers of brown-headed cowbirds (*Molothrus ater*) were greater in clearcut treatments than in other treatments ($P < 0.001$). The abundances of 2 avian nest predators, the blue jay (*Cyanocitta cristata*), and the American crow (*Corvus brachyrhynches*), were not significantly greater in any of the 5 treatments ($P > 0.30$). Nest success of species nesting in clearcut and shelterwood treatments was 18–50%. The percent of the site in gaps, shrub stem density, and tree-diameter distribution differed among forest regeneration methods ($P < 0.001$). We believe habitat requirements of birds in managed forests can be best met by a mixture of even- and uneven-aged forest management that creates a range of disturbance sizes.

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Key words: central hardwoods forest, clearcut, group selection, Missouri Ozarks, nesting success, shelterwood, single-tree selection, songbirds.

The possible decline of forest songbird populations, and the effects of land use practices, such as forest management, on declining songbird populations is a growing concern (Robbins et al. 1989, Askins et al. 1990, Hagan and Johnston 1992, Finch and Stangel 1993). Our knowledge of the effects of forest harvesting and regeneration methods on songbird communities in central hardwood forests is incomplete. Songbird response to the clearcut method has been comparatively well researched (Conner and Adkisson 1975, Evans 1978, Conner et al. 1979, Titterington et al. 1979, Crawford et al. 1981, Thompson et al. 1992), but there is little information on other practices.

Silvicultural practices modify forest structure and in turn affect bird communities (Thompson et al. 1995). The magnitude and scale of change in vegetation structure brought about by timber harvest typically determines the degree of change in the bird community. Partial or selective harvests may produce small changes in the bird community and continue to provide habitat for those species found in mature stands (Webb et al. 1977, Szaro and Balda 1979, Medin and Booth 1989). The removal of groups of trees or whole stands, however, results in the replacement of late successional forest species with early-successional forest species and species associated with edges (Conner and Adkisson 1975, Webb et al. 1977, Conner et al. 1979, Dickson and Segelquist 1979, Crawford et al. 1981). As the stand matures, the bird species composition changes. This overlapping replacement of species is characteristic of regeneration practices in most forest types (Franzreb and Ohmart 1978, Crawford et al. 1981).

Forest management practices should be evaluated in landscape and regional contexts (Freemark et al. 1993, Thompson et al 1993*a*). Processes such as forest fragmentation may be an important factor structuring bird communities

(Blake and Karr 1984). Timber harvesting may change forest age-class distribution, but might not have the same effects on bird communities as fragmentation of forest by non-forest land uses. The effects of timber harvesting also can vary in different landscape contexts. In forested contexts young forest stands or openings created by harvest provide important habitat for early-successional migratory forest birds (Thompson et al. 1995), some of which are currently of high management concern in the midwestern United States (Thompson et al. 1993).

Clearcut and shelterwood methods regenerate even-aged stands. The clearcut method removes an entire stand in 1 harvest. In central hardwood forests these stands regenerate from advanced, natural tree reproduction that is usually dense and fast-growing. The shelterwood method retains part of the canopy to shelter and to encourage tree reproduction. The outcome is a stand with moderately dense understory and about 40% of the original overstory (Smith 1986). Group and single-tree selection regeneration methods maintain stands with 3 or more age- or size-classes of trees (Smith 1986). In central hardwoods the recommended opening size for the group-selection method is 0.04–0.20 ha (Law and Lorimer 1989). Single-tree selection results in many single-tree and some multiple-tree openings. Selection cutting results in high within-stand habitat diversity due to the presence of tree reproduction and small and large diameter trees (Thompson et al. 1995).

The clearcut, shelterwood, group selection, and single-tree selection forest regeneration methods are all used in the central hardwood region. We determined differences in the relative abundance of breeding birds in forest stands regenerated by these 4 regeneration methods and mature even-aged stands in the Missouri Ozarks. We also determined nesting success of common migrant songbirds breeding in young forest stands regenerated by the clearcut and shelterwood methods.

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STUDY AREA

We conducted our study in 1993 and 1994 on the Doniphan, Poplar Bluff, and Salem Ranger districts of the Mark Twain National Forest, and Pioneer Forest, a privately-owned forest, located on the Ozark Plateau in southeast Missouri (Carter, Ripley, Shannon, and Wayne counties). The region was mostly forested (>85%) with pastureland in valleys and on broad ridges. Landscapes were characterized by steep, highly dissected slopes adjacent to major streams, interspersed with rolling hills and abundant narrower streams (Miller 1981). Elevations ranged from 134 to 396 m above sea level.

We selected sites in mixed oak (*Quercus* spp.) and oak-pine (*Pinus* spp.) forests. Mixed oak forests were dominated by black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*), post oak (*Q. stellata*), and hickories (*Carya* spp.). Oak-pine forests were dominated by black oak, white oak, post oak, hickories, and short-leaf pine (*P. echinata*). Dogwood (*Cornus florida*), sassafras (*Sassafras albidum*), and black gum (*Nyssa sylvatica*) were scattered throughout both forest types. Common shrubs were fragrant sumac (*Rhus aromatica*), black raspberry (*Rubus occidentalis*), early low blueberry (*Vaccinium vacillans*), and greenbriar (*Smilax tamnoides* var. *hispida*).

Most forest land in southeast Missouri is managed for timber production. These areas are a mosaic of forest size-classes originating from even-aged management practices. About 20% of the forest in the 4-county study area was seedling-sapling size (<12.7 cm), 21% poletimber (12.7–27.9 cm), and 35% sawtimber (>27.9 cm). Existing mature forest stands in the Missouri Ozarks are mostly even-aged resulting from clearcutting during 1900–28. Forest regeneration after clearcutting is natural and occurs rapidly. Trees reach pole-size within roughly 25 years. The low site quality and xeric soil conditions tend to promote oak reproduction, and as a result there is little evidence of succession to more shade tolerant tree species such as beech (*Fagus* spp.) or maple (*Acer* spp.)(Johnson 1992).

Timber management on the Mark Twain National Forest is dominated by even-aged silvicultural systems, but uneven-aged silvicultural systems are being used with increasing frequency. The clearcut, shelterwood, group-selection, and seed-tree methods are used to regenerate forest stands. Forest regulations limit clearcut size to 16 ha, and a minimum of 15 trees per ha must be left as residual standing timber. Shelterwood method treatments leave a residual shelter of 3–4 m^2/ha basal area. The group-selection method creates 2–5 openings, 0.2–0.4 ha, about every 8 ha, and single-tree selection is generally used to remove trees between the groups. Clearcutting was the dominant regeneration method on the Doniphan, Poplar Bluff, and Salem Ranger districts from 1984 to 1994 (Fig. 1); however, use of the shelterwood and group selection methods has increased greatly in the last few years.

Pioneer Forest uses the single-tree selection method throughout their ownership of 64,750 ha. From 1984 to1994 Pioneer Forest harvested 25,892 ha by the single-tree selection method (Fig. 1). During the 1950s–60s the dominant practice was diameter-limit cutting of mostly white oak for the barrel-making industry. Currently, harvest entries are applied in 260-ha sections, and a section is treated about every 20 years. Harvests leave, on average, 60% of the original basal area in a stand. Selection is determined on a tree-by-tree basis, and those with limited potential for future growth are harvested. The diameter distribution of the forest now mimics the reverse J-shaped distribution of an all-aged forest (E. Loewenstein, pers. commun.).

METHODS

We studied bird communities at 58 stands (sites). Twelve sites were treated by the clearcut method, 12 by the shelterwood method, 12 by the group-selection method, 10 by the single-tree selection method, and 12 were mature even-aged stands. Treated sites were regenerated between 1988 and 1990 and had abundant natural tree reproduction. Mature sites had not received any silvicultural treatment for at least 50 years. Sites ranged from 7.2 to 29.6 ha and mean size for each treatment ranged from 10.5 to 15.3 ha. While the mean size of treated sites was similar across all treatments, the size of patches of forest regeneration varied as a function of the treatment. Clearcut and shelterwood treatments result in a large patch encompassing the entire site, while the selection treatments created smaller patches within the site.

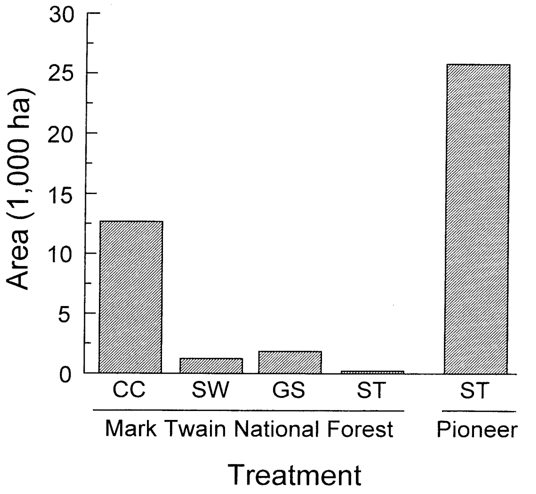

Fig. 1. Application of 5 forest-regeneration methods on the Doniphan, Poplar Bluff, and Salem ranger districts of the Mark Twain National Forest, and Pioneer Forest, in the Missouri Ozarks from 1984 to 1994. CC=Clearcut, SW=Shelterwood, GS=Group selection, ST=Single-tree selection, MA=Mature.

We surveyed bird communities by the point-count method (Verner 1988). At each site we located 4 point-count stations along a transect that sampled upper- and lower-slope positions. Point-count stations were at least 150 m apart and at least 60 m from the edge of the site. Bird populations were surveyed between 19 May and 18 June in 1993 and between 16 May and 22 June in 1994. Each point was surveyed by 3 different observers for 10 minutes on different days to reduce observer bias (Verner and Milne 1989) in both years. We recorded all birds heard or seen that were within the study site.

We searched for active nests in the clearcut and shelterwood treatments during May, June, and July of both years. Nests were monitored every 3–5 days until fledging or depredation occurred. For each nest, we recorded the number of host and brown-headed cowbird eggs, nestlings, fledglings of both host and brown-headed cowbird, and any physical evidence of nest depredation.

We measured the habitat structure of each stand in July 1993 with techniques modified from Noon (1981). Four 0.08-ha vegetation plots were established 30 m from each point count location in each of the 4 cardinal directions, resulting in 16 plots per site. We averaged 4 spherical densiometer readings taken at the center of the plot to estimate canopy closure. We recorded the species and diameter of trees >3 cm at 1.3 m aboveground (dbh) that were selected with a 2-factor metric prism. The height of 1 dominant tree was measured with a clinometer. We counted the number of live woody stems <3-cm dbh and >1.3 m tall along 4 10- × 2-m transects in the 4 cardinal directions from the plot center. Average tree seedling height was estimated visually. Percent cover of live woody and herbaceous vegetation <1.3 m was visually estimated within a 2-m radius circle at plot center. We estimated average seedling regeneration height.

In July 1994 we measured canopy gaps along 12 100-m transects at each site. Transects were perpendicular to the slope and located at each point count station and 30 m uphill and 30 m downhill from each station. We measured the width of all gaps >3 m intercepting the transect by pacing the distance along the contour of the slope.

Data Analysis

We estimated the mean relative abundances of breeding birds in each of the 58 sites in 1993–94. All detections (aural and visual, male and female) were used in abundance calculations. We assumed all species had the same detectability across all habitats. We calculated the mean number of detections of a species at a point from the 3 visits within a field season, and calculated the average abundance of a study site as the mean of the 4 point means. Relative abundance of species on sites was expressed as the mean number of detections at a point during a 10-minute visit.

We used a repeated measures analysis of variance (ANOVA) to test for treatment effects, year effects, and treatment-year interactions. Error rates were controlled for all treatment comparisons for a bird species, but not experiment-wide for all species. We defined tests with $P \leq 0.05$ as significant and calculated post-hoc statistical power for these tests as well as power for this design based on a large effect size (Cohen 1988). We used Tukey-Kramer's mean separation procedure to identify significant ($P \leq 0.05$) differences between treatments based on the mean of the 1993–94 values; this masks treatment-year interactions but rejects average effects during the time period.

We calculated mean total bird detections in each site by averaging total detections of all species in a 10-minute point count from each point in a site. Species richness was calculated as the total number of species detected during all visits to all points in a site.

We used the Mayfield (1975) method to estimate daily survival on a per nest basis. We were able to find only sufficient numbers of nests for analysis in clearcut and shelterwood treatments. Nests found in clearcut and shelterwood treated sites were pooled for each species. We chose not to examine treatment differences for nest success, but to look only at nest success in sites treated by even-aged management. Nests were classified as successful (at least 1 host-young fledged) or failed. Nests failed due to depredation (all eggs or nestlings disappeared before predicted fledge date), abandonment (all eggs or nestlings left exposed to die), parasitism (only brown-headed cowbird nestlings fledged), or natural causes. Observation days were counted from the first day of egg-laying (if found during nest-building stage) or first day observed (if already active) through the day of fledging or failure. We assumed daily survival was constant through the entire nest cycle. Nesting success, the probability a nest will survive the entire nest cycle to fledge 1 nestling, was calculated as the daily survival estimate raised to a power equal to the number of days in a species nesting cycle (Ehrlich et al. 1988).

We calculated 11 vegetation-structure variables from the field measurements. We used 1-way ANOVA to test for differences ($P < 0.05$) in each variable among treatments. Error rates were controlled for all treatment comparisons for each vegetation variable. Tukey-Kramer's mean separation procedure was used to identify differences ($P < 0.05$) between treatments.

RESULTS

Our results focus on 14 species that collectively represent the 5 most abundant species in each treatment (Fig. 2), though the data are reported for all species (Tables 1 and 2). Of the 36 species, 30 showed treatment effects ($P < 0.05$; Table 1). Tests of treatment effects for 25 of 36 species had an observed statistical power >0.80 (Table 1). Power values based on observed treatment differences, however, will be small when tests are non-significant; the power of our design to detect large treatment effects (as defined by Cohen 1988) was 0.653, 0.843, and 0.653 for treatment, year, and treatment-year interactions, respectively. Species numbers varied greatly among the 5 treatments (Table 2). Prairie warblers and field sparrows were recorded only in the clearcut and shelterwood

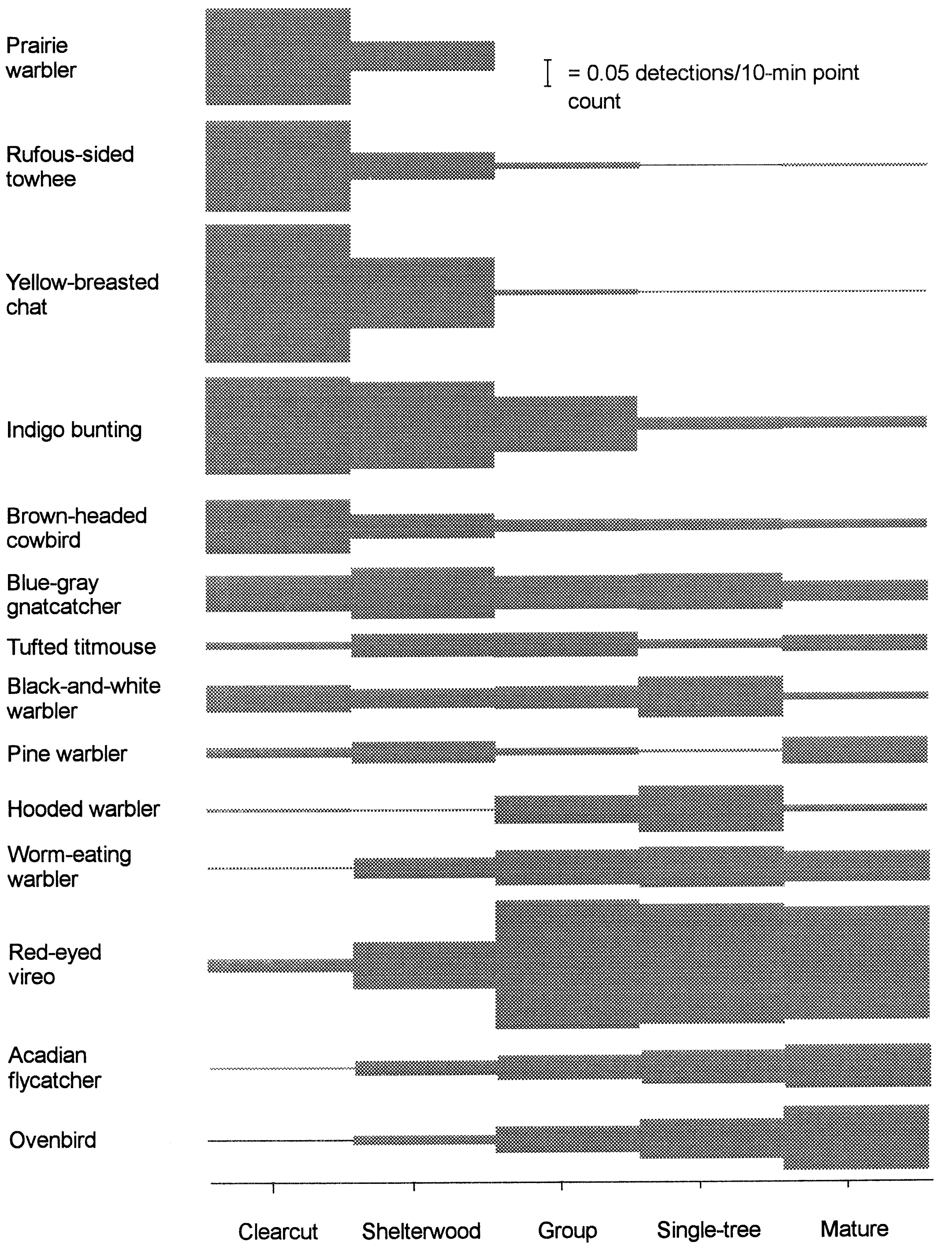

Fig. 2. Distribution of common bird species across sites treated by 5 forest-regeneration methods in the Missouri Ozarks, 1993 and 1994.

method treated sites (Table 2). Five early-successional species (blue-winged warbler, prairie warbler, rufous-sided towhee, white-eyed vireo, and yellow-breasted chat; Fig. 2) were more abundant in clearcut treatments than shelterwood treatments, and more abundant in clearcut and shelterwood treatments than the selection treatments and even-aged stands (Table 2).

Table 1. Statistical significance (*P*) and power[a] for model effects in a repeated measures analysis of variance (type III sum of squares, for all species with >100 detections) of the effects of forest regeneration methods on bird abundance in the Missouri Ozarks, 1993–94.

	Treatment		Year		Treatment × Yr	
Species	*P*	Power	*P*	Power	*P*	Power
Yellow-billed cuckoo (*Coccyzus americanus*)	0.000	1.00	0.379	0.09	0.606	0.12
Red-bellied woodpecker (*Melanerpes carolinus*)	0.504	0.26	0.001	0.68	0.175	0.26
Hairy woodpecker (*Picoides villosus*)	0.554	0.24	0.001	0.65	0.720	0.10
Pileated woodpecker (*Dryocopus pileatus*)	0.000	0.99	0.007	0.50	0.054	0.38
Eastern wood-pewee (*Contopus virens*)	0.046	0.71	0.847	0.05	0.258	0.21
Acadian flycatcher (*Empidonax virescens*)	0.001	0.98	0.543	0.07	0.074	0.36
Great crested flycatcher (*Myiarchus crinitus*)	0.025	0.79	0.760	0.05	0.985	0.06
Blue jay (*Cyanocitta cristata*)	0.383	0.32	0.018	0.39	0.310	0.20
American crow (*Corvus brachyrhynchos*)	0.213	0.45	0.629	0.06	0.524	0.14
Carolina chickadee (*Parus carolinensis*)	0.003	0.93	0.002	0.61	0.055	0.37
Tufted titmouse (*Parus bicolor*)	0.002	0.95	0.648	0.06	0.063	0.36
White-breasted nuthatch (*Sitta carolinensis*)	0.533	0.25	0.000	0.94	0.609	0.12
Carolina wren (*Thryothorus ludovicianus*)	0.001	0.97	0.250	0.13	0.076	0.34
Blue-gray gnatcatcher (*Polioptila caerula*)	0.001	0.89	0.000	0.94	0.401	0.17
Wood thrush (*Hylocichla mustelina*)	0.004	0.92	0.670	0.06	0.779	0.10
White-eyed vireo (*Vireo griseus*)	0.000	1.00	0.248	0.13	0.566	0.13
Yellow-throated vireo (*Vireo flavifrons*)	0.278	0.40	0.342	0.10	0.146	0.27
Red-eyed vireo (*Vireo olivaceus*)	0.000	1.00	0.002	0.62	0.556	0.13
Blue-winged warbler (*Vermivora pinus*)	0.000	1.00	0.341	0.10	0.403	0.17
Northern parula (*Parula americana*)	0.000	1.00	0.012	0.43	0.224	0.23
Yellow-throated warbler (*Dendroica dominica*)	0.001	0.97	0.001	0.68	0.279	0.21
Pine warbler (*Dendroica pinus*)	0.003	0.93	0.208	0.14	0.922	0.07
Prairie warbler (*Dendroica discolor*)	0.000	1.00	0.061	0.26	0.010	0.54
Black-and-white warbler (*Mniotilla varia*)	0.000	1.00	0.131	0.18	0.003	0.65
Worm-eating warbler (*Helmitheros vermivorus*)	0.000	1.00	0.028	0.34	0.006	0.59
Ovenbird (*Seiurus aurocapillus*)	0.000	1.00	0.060	0.26	0.173	0.26
Kentucky warbler (*Opororinus formosus*)	0.050	0.70	0.502	0.08	0.037	0.42
Hooded warbler (*Wilsonia citrina*)	0.000	1.00	0.002	0.62	0.001	0.73
Yellow-breasted chat (*Icteria virens*)	0.000	1.00	0.004	0.55	0.051	0.38
Summer tanager (*Piranga rubra*)	0.030	0.77	0.690	0.06	0.190	0.25
Scarlet tanager (*Piranga olivacea*)	0.000	0.98	0.038	0.31	0.088	0.33
Northern cardinal (*Cardinalis cardinalis*)	0.064	0.67	0.193	0.15	0.807	0.09
Indigo bunting (*Passerina cyanea*)	0.000	1.00	0.252	0.12	0.033	0.43
Rufous-sided towhee (*Piplio erythrophthalmus*)	0.000	1.00	0.984	0.05	0.432	0.16
Field sparrow (*Spizella pusilla*)	0.000	0.99	0.045	0.29	0.169	0.26
Brown-headed cowbird (*Molothrus ater*)	0.000	1.00	0.191	0.15	0.998	0.05

[a] Post-hoc power calculations are based on observed effect size and will be low where differences in treatment means are small. (see text).

Indigo buntings were more abundant in the clearcut, shelterwood, and group-selection treatments than in the single-tree and mature sites (Table 2, Fig. 2). Hooded warblers (Fig. 2) and northern parulas were more abundant in the selection treatments than in the clearcut and shelterwood treatments and mature sites (Table 2). Acadian flycatchers were more abundant in mature and single-tree selection treatments than in group-selection and shelterwood treatments, but were more abundant in shelterwood treatments than clearcut treatments (Table 2, Fig. 2). Red-eyed vireos and worm-eating warblers (*Helmitheros vermivorus*) were more abundant in group selection, single-tree selection, and mature sites than clearcut and shelterwood treatments, although both were relatively abundant in shelterwoods (Table 2, Fig. 2). Mature sites had the greatest number of ovenbirds (Table 2, Fig. 2). Wood thrushes were more abundant in mature and single-tree selection sites (Table 2). Pine warblers (*Dendroica pinus*) were more abundant in the mature sites as compared to the other treatments (Table 2, Fig. 2). Black-and-white warblers (*Mniotilta varia*) were more abundant in the single-tree selection treatments than in the other treatments (Table 2, Fig. 2). The relative abundance of tufted titmice (*Parus bicolor*) was greater in group selection and shelterwood treatments but was not significantly different from those found in single-tree selection treatments and mature sites (Table 2, Fig. 2).

Table 2. Mean detections/10-min point count of breeding birds on sites treated by the clearcut, shelterwood, group-selection, and single-tree selection methods and mature even-aged stands in the Missouri Ozarks, 1993 and 1994.

Species	Clearcut		Shelterwood		Group selection		Single-tree		Mature	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Yellow-billed cuckoo	0.18A[b]	0.03	0.27AB	0.05	0.37B	0.05	0.10A	0.02	0.41B	0.04
Red-bellied woodpecker	0.09A	0.02	0.09A	0.04	0.09A	0.02	0.05B	0.02	0.12C	0.03
Hairy woodpecker	0.08A	0.03	0.04A	0.01	0.09A	0.03	0.08A	0.02	0.07A	0.02
Pileated woodpecker	0.03A	0.01	0.19BC	0.03	0.20BC	0.03	0.11AB	0.01	0.24C	0.04
Eastern wood-peewee	0.30AB	0.04	0.51A	0.07	0.36AB	0.06	0.21B	0.05	0.36AB	0.07
Acadian flycatcher	0.02A	0.01	0.24AB	0.11	0.40ABC	0.09	0.54BC	0.10	0.70C	0.17
Great-crested flycatcher	0.20A	0.07	0.17AB	0.04	0.15AB	0.03	0.02B	0.01	0.13AB	0.02
Blue jay	0.17A	0.06	0.10A	0.03	0.10A	0.03	0.13A	0.03	0.14A	0.03
American crow	0.06A	0.01	0.17A	0.07	0.07A	0.02	0.06A	0.02	0.11A	0.03
Carolina chickadee	0.28A	0.04	0.20AB	0.05	0.15AB	0.03	0.12AB	0.03	0.08B	0.04
Tufted titmouse	0.15A	0.02	0.38B	0.05	0.41B	0.04	0.32AB	0.05	0.27AB	0.05
White-breasted nuthatch	0.08A	0.03	0.15A	0.04	0.13A	0.03	0.11A	0.02	0.11A	0.02
Carolina wren	0.31A	0.04	0.35A	0.06	0.23AB	0.03	0.18AB	0.05	0.11B	0.03
Blue-gray gnatcatcher	0.60AB	0.11	0.85A	0.10	0.56AB	0.10	0.61AB	0.06	0.35B	0.06
Wood thrush	0.02A	0.01	0.02A	0.02	0.04A	0.02	0.15AB	0.05	0.26B	0.09
White-eyed vireo	0.83A	0.08	0.40B	0.12	0.02C	0.01	0.03C	0.02	0.01C	0.01
Yellow-throated vireo	0.04A	0.01	0.09A	0.05	0.08A	0.03	0.15A	0.03	0.12A	0.05
Red-eyed vireo	0.22A	0.04	0.77A	0.21	2.10B	0.10	1.95B	0.12	1.84B	0.16
Blue-winged warbler	0.88A	0.08	0.46B	0.14	0.03C	0.02	0.00C	0.00	0.01C	0.01
Northern parula	0.06A	0.02	0.17A	0.04	0.29A	0.08	0.63B	0.13	0.17A	0.05
Yellow-throated warbler	0.33AB	0.05	0.34AB	0.06	0.22A	0.04	0.57B	0.14	0.10A	0.05
Pine warbler	0.17AB	0.04	0.36AB	0.09	0.13A	0.04	0.05A	0.03	0.45B	0.13
Prairie warbler	1.60A	0.24	0.49B	0.25	0.00B	0.00	0.00B	0.00	0.00B	0.00
Black-and-white warbler	0.44A	0.04	0.32AB	0.06	0.37A	0.06	0.67C	0.06	0.13B	0.03
Worm-eating warbler	0.04A	0.02	0.33B	0.10	0.57BC	0.04	0.66C	0.08	0.51BC	0.07
Ovenbird	0.03A	0.01	0.15AB	0.06	0.42BC	0.08	0.64C	0.10	1.03D	0.16
Kentucky warbler	0.15AB	0.03	0.19A	0.04	0.18AB	0.04	0.16AB	0.02	0.06B	0.02
Hooded warbler	0.06A	0.03	0.04A	0.02	0.46B	0.09	0.76C	0.12	0.03A	0.01
Yellow-breasted chat	2.25A	0.11	1.16B	0.30	0.09C	0.05	0.02C	0.02	0.02C	0.01
Summer tanager	0.26AB	0.04	0.28A	0.04	0.20AB	0.05	0.12B	0.03	0.18AB	0.03
Scarlet tanager	0.10A	0.02	0.18AB	0.04	0.23AC	0.04	0.33C	0.04	0.27BC	0.03
Northern cardinal	0.23A	0.05	0.23A	0.05	0.16A	0.07	0.13A	0.02	0.07A	0.03
Indigo bunting	1.60A	0.12	1.42A	0.13	0.91B	0.09	0.21C	0.08	0.19C	0.05
Rufous-sided towhee	1.51A	0.11	0.45B	0.12	0.08C	0.04	0.00C	0.00	0.05C	0.02
Field sparrow	0.27A	0.07	0.15AB	0.07	0.00B	0.00	0.00B	0.00	0.00B	0.00
Brown-headed cowbird	0.89A	0.08	0.41B	0.06	0.21BC	0.05	0.19BC	0.03	0.14C	0.04

[a] Treatment means and SE calculated from mean number of detections for each site from 1993 and 1994.
[b] Means with same letter within rows were not different (Tukey-Kramer multiple comparisons, $P > 0.05$).

Table 3. Nest success for the most common bird species in sites treated by the clearcut and shelterwood methods in the Missouri Ozarks, 1993 and 1994.

Species	No. of nests	Failures	Observation days	Failures due to depredation	Failures due to abandonment	Failures due to parasitism	Daily survival estimate	Nest success (%)[a]
Blue-winged warbler	7	2	72	2	0	0	0.97	0.51
Indigo bunting	16	8	169	4	3	1	0.95	0.31
Prairie warbler	10	4	84	4	0	0	0.94	0.21
Yellow-breasted chat	37	24	330	21	3	0	0.93	0.18

[a] Nest success calculated using Mayfield method (Mayfield 1975).

Blue-gray gnatcatchers (*Polioptila caerula*) were more abundant in treated sites than in the mature even-aged sites; there were no significant differences between treated sites (Table 2, Fig. 2). Brown-headed cowbirds were more abundant in clearcut treated sites followed by shelterwood treated sites and much less common in the group selection, single-tree selection, and mature sites (Table 2, Fig. 2). The 2 important nest predators, blue jay and American crow, occurred in relatively low numbers in all treatments (Table 2).

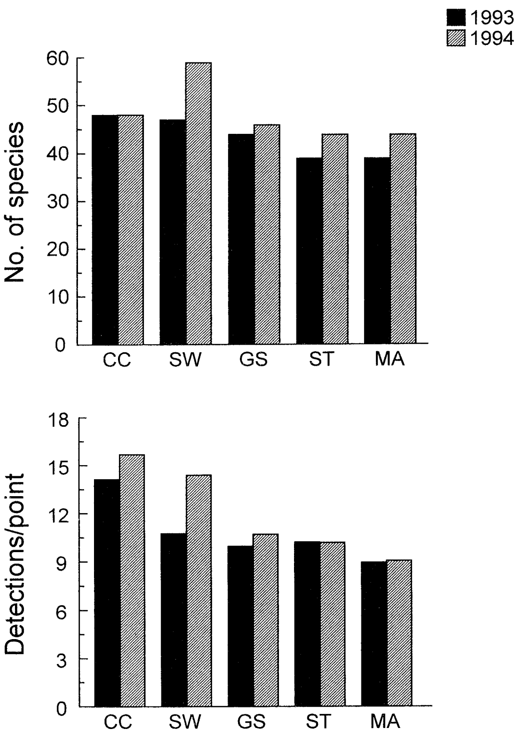

Fig. 3. Species richness and mean total detections/point of all species by year and treatment on sites treated by 5 forest-regeneration methods in the Missouri Ozarks, 1993 and 1994. CC=Clearcut, SW=Shelterwood, GS=Group selection, ST=Single-tree selection, MA=Mature.

Significant year effects in the abundance of field sparrows, red-eyed vireos, and yellow-throated warblers (*Dendroica dominica*) existed (Table 1). Significant treatment-year interaction effects in the abundance of worm-eating warblers and black-and-white warblers existed (Table 1). Significant treatment, year, and treatment-year interaction effects in the abundance of pileated woodpeckers (*Dryocopus pileatus*) existed (Table 1).

Species richness was greater in the clearcut and shelterwood treated sites in 1993, but shelterwoods showed greater richness than all treatments in 1994 (Fig. 3). In 1993 mean total detections of all birds was greater in clearcut treated sites (Fig. 3). No differences in mean total detections between the other 4 treatments existed. In 1994 mean total detections were significantly greater in clearcuts and shelterwood cuts with no significant differences between the 2. No significant differences in mean total detections between the other 3 treatments existed.

Daily survival rates for blue-winged warbler, indigo bunting, prairie warbler, and yellow-breasted chat nests in clearcut and shelterwood treatments were 0.93–0.97. Nesting success was 18–51% (Table 3).

Vegetation structure differed greatly among treatments ($P < 0.0001$) for variables measured (Table 4). Basal area was greatest in the mature even-aged sites. The number of shrub stems/ha was greatest in the clearcut treatments, followed by the single-tree and group-selection treatments. The number of tree stems 3–10 cm and stems 11–25-cm dbh was greatest in the single-tree selection treatments. The number of tree stems >25 cm was greatest in the mature even-aged sites followed by group-selection treatments. Clearcut treatments had the greatest percentage of site occurring in gaps. Mature even-aged sites and single-tree selection treatments had the greatest percent canopy closure. Percent woody and herbaceous ground covers were both greatest in the clearcut treatments followed by the shelterwood treatments. Tree seedling regeneration height was highest in the clearcut and shelterwood treatments.

DISCUSSION

Bird communities differed among the 5 treatments. The clearcut and shelterwood treatments were inhabited predominantly by species associated with shrub or young forest habitats. Shelterwood treatments were also inhabited by high numbers of birds usually associated with mature forest habitats. The 2 selection treatments contained high numbers of forest canopy-gap species, relatively high numbers of all late-successional forest species, and low numbers of early-successional forest species.

The blue-winged warbler, indigo bunting, prairie warbler, rufous-sided towhee, white-eyed vireo, and the yellow-breasted chat were found almost exclusively in the young forest habitats created by the 2 even-aged forest regeneration treatments. This assemblage of species is similar to that reported in other studies of clearcut treatments (Conner and Adkisson 1975, Dickson and Segelquist 1979, Crawford et al. 1981, Thompson and Fritzell 1990). Key features of these 2 habitat types were the large canopy openings and the dense tree reproduction. These species are predominantly shrub and ground nesters (Ehrlich et al. 1988) and probably selected these habitats because of their high shrub stem densities (Rothstein et al. 1986, Thompson et al. 1997). Cowbird numbers were low in all habitats, however, when compared to fragmented landscapes elsewhere in the Midwest (Thompson et al. 1997. Cowbird numbers were probably low due to the scarcity of feeding habitats in this heavily forested landscape.

High relative abundance of brown-headed cowbirds in the clearcut and shelterwood treatments may have been due to the high density of breeding birds found there (Table 2), because cowbirds may select habitats with high host densities (Rothstein et al. 1986, Thompson et al. 1997). Cowbird numbers were low in all habitats, however, when compared to fragmented landscapes elsewhere in the Midwest (Thompson et al. 1997). Cowbird numbers were probably low due to the scarcity of feeding habitats in this heavily forested landscape.

Table 4. Mean vegetation measurements on sites regenerated by the clearcut, shelterwood, group-selection, and single-tree selection methods, and mature even-aged stands in the Missouri Ozarks, 1993.

Variable	Cleacut		Shelterwood		Group selection		Single-tree		Mature		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P[a]
Basal area (m^2)	3.41A	0.22	12.33AB	1.62	17.36A[b]	0.92	17.36AB	0.75	22.20AB	0.98	<0.0001
No. shrubs/ha	8,148.05A	841.86	3,812.40AB	468.12	4,238.70AB	599.61	4,717.19BB	690.45	2,077.13AB	257.03	<0.0001
No. stems 3–10 cm/ha	117.14A	29.19	425.37AB	125.12	729.93BC	82.50	848.00CB	54.18	737.02BC	83.90	<0.0001
No. stems 11–25 cm/ha	69.52A	9.28	237.05AB	42.53	361.29BA	33.90	506.13AB	24.13	320.21AB	24.95	<0.0001
No. stems >25 cm/ha	20.10A	3.04	74.24AB	10.65	95.62AA	5.97	75.42AB	4.87	149.79AB	7.12	<0.0001
Amt. of site in gap (%)	92.91A	1.76	51.01AB	8.90	26.89AA	2.50	25.28AB	3.52	16.19AB	3.69	<0.0001
Canopy closure (%)	29.26A	4.71	71.86AB	5.74	93.38AA	1.05	95.58AB	0.96	96.59AB	0.75	<0.0001
Herb. ground cover (%)	31.16A	2.30	26.80AB	3.34	24.52AA	3.68	18.86AB	3.04	11.04BB	2.69	<0.0001
Woody ground cover (%)	29.95A	2.80	19.64AB	1.71	17.15AB	1.84	15.46AB	1.71	9.58BB	1.25	<0.0001
Canopy height (m)	6.48A	1.22	19.10AB	1.06	21.98AA	0.34	20.97AB	0.43	22.23AB	0.72	<0.0001
Regeneration height (m)	1.68A	0.07	1.71AB	0.10	1.34AB	0.09	1.52AB	0.08	1.26BB	0.15	<0.0001

[a] Means of all variables differed among treatments (1-way ANOVA, $P < 0.001$).
[b] Means with same letter within rows were not different (Tukey-Kramer multiple comparisons, $P > 0.05$).

The hooded warbler and northern parula selected sites treated by the 2 selection methods; they were more abundant in these treatments than in other treatments. Presumably, hooded warblers were attracted to these stands for the small canopy gaps created by the harvest of 1 to as many as 4 trees. Hooded warblers have been found to nest in gaps created by group- and single-tree selection treatments in Illinois (Robinson, unpubl. data). Hooded warblers often select gaps with dense understory vegetation (Morse 1989). Parulas, however, did not appear to use the gaps, and we do not know why their numbers were greater in single-tree selection treatments. Species such as the red-eyed vireo, worm-eating warbler, and Acadian flycatcher, which are usually associated with mature forests, were abundant in group and single-tree selection treatments. A key feature of these habitats for gap species appears to be the interspersion of small canopy openings containing dense patches of shrubs and tree reproduction. The number of shrub stems was greater in the selection treatments than in mature even-aged forest (Table 3). Bird species usually associated with mature forest, however, were likely abundant in the selection treatments due to the presence of intermediate- and large-diameter trees.

Ovenbirds and wood thrushes reached their greatest abundance in the mature even-aged stands. Red-eyed vireos, Acadian flycatchers, and worm-eating warblers were also relatively abundant in these habitats. These species are typically associated with mature deciduous forest habitats (Conner and Adkisson 1975, Crawford et al. 1981, Thompson et al. 1992).

The abundances of the tufted titmouse, black-and-white warbler, blue-gray gnatcatcher, pine warbler, yellow-throated warbler, blue jay, and American crow did not differ greatly among treatments. Tufted titmice, black-and white warblers, blue-gray gnatcatchers, blue jays, and American crow may be forest habitat generalists. Crawford et al. (1981) similarly found tufted titmice and blue-gray gnatcatchers to be tolerant of a wide range of regeneration practices. Both exhibited the lowest numbers of detections in the mature sites, but had relatively high numbers of detections in all the other treatments (Table 2). Black-and-white warblers may be attracted to areas with some open canopy and patches of dense understory (Crawford et al. 1981, Thompson and Capen 1988) which were present in all treatments but the mature sites. Blue jay and crow numbers were generally low, probably because these landscapes are primarily forested. Corvid numbers are positively correlated with the amount of agricultural habitat in European landscapes (Andren 1992). We believe pine warblers and yellow-throated warblers did not show treatment effects because they were associated with habitat features not directly controlled by the regeneration treatments. Both species appeared to be associated with mature pine trees, which were present in all treatments, even as residual trees in clearcut and shelterwood treatments.

Clearcut and shelterwood treatments had the greatest species richness and total detections. Similar patterns exist in other eastern deciduous forests (Conner and Adkisson 1975, Dickson and Segelquist 1979, Thompson and Fritzell 1990). The high bird detections and species richness is probably due to the dense sapling reproduction and patches of ground cover that provided dense and diverse foraging and nesting substrates.

We documented abundance patterns across regeneration treatments, but abundance can be a misleading indicator of habitat quality or population status (Van Horne 1983). Productivity measurements may be a better way to assess habitat conditions for sustainable populations (Donovan et al. 1995). In addition to changes in bird densities, lower reproductive success in managed forests could affect populations in these landscapes. Nest success of yellow-breasted chats (0.18) and indigo buntings (0.31) in regeneration openings was greater than that reported for these species in abandoned upland fields (Nolan 1963, Thompson and Nolan 1973). However, these levels of nest success are low compared to species such as the ovenbird (0.38), red-eyed vireo (0.31), and wood thrush (0.41) nesting in mature forest in the same region (Donovan et al. 1995). Why chats experienced such high nest depredation is unclear. Martin (1993) found shrub nesters in forest habitats to be vulnerable to nest depredation as compared to ground and canopy nesters. Clearly, more research is needed to determine the importance of forest openings for breeding birds in managed forests.

We did not determine reproductive success of mature forest species. Donovan et al. (1995) and Robinson et al. (1995) determined nesting success for species in mature forest in the same landscapes we studied. They observed high reproductive rates in this heavily forested landscape compared to more fragmented landscapes elsewhere in the Midwest, and concluded this area was a likely population source.

MANAGEMENT IMPLICATIONS

Our observation that species have different abundances in habitats created by even- and uneven-aged forest management has several important management implications. Where early-successional forest birds or gap species are a management priority, appropriate forest regeneration practices can be used to create habitat. In the Midwest some early-successional forest songbirds, including the yellow-breasted chat, prairie warbler, and blue-winged warbler, are declining and are of high management concern (Thompson et al. 1993). These species had an apparent selection for larger disturbances created by clearcut and shelterwood methods. While about 20 % of the region is in seedling/sapling-size stands (Hahn and Spencer 1991), actual habitat availability is not accurately known because these species are not as abundant in stands in the upper end of this size class (Thompson et al. 1992) and bird abundances in stands of this size class created by private-land management are not known. Early-successional forest habitats created by forest regeneration practices in extensively forested landscapes could be better habitat for these species than edge habitats in more fragmented landscapes (Brooks and Birch 1988, Welsh and Healy 1993). Other species that used small regeneration openings, however, tended to select sites treated by selection harvests. The hooded warbler, also a species of high management concern in the Midwest, occurred almost exclusively in single-tree or group-selection treatments.

There is also management concern for many late successional forest species, such as the wood thrush. Our results have implications for mitigating the effects of timber harvest on these species. Species such as the worm-eating warbler and red-eyed vireo were equally abundant in selectively cut stands and mature even-aged stands. The use of selection cutting could avoid potential reductions in the abundance of these species that might result from even-aged forest management practices. These species, however, probably can be sustained at a landscape level at reduced numbers under even-aged management (Thompson et al. 1992, Thompson 1993). Other species, such as the ovenbird and Acadian flycatcher, were slightly less abundant in selection treatments than in even-aged mature stands. For these species reductions in numbers at a landscape scale could be comparable under regulated even-aged forest management or selection cutting.

Management implications should be viewed within a landscape and regional context (Freemark et al. 1993, Thompson et al. 1995). Our study was conducted in a heavily forested and intensively managed area, and results found here should not be generalized to different types of landscapes. Given the diversity of habitats used by forest birds in general, or even by a group of priority species within a region, we believe land managers should use a variety of regeneration practices in landscapes subject to timber harvest. The use of both even-aged practices and selection methods, regulated for sustained yield, should provide habitat for most forest songbirds. We believe this approach is appropriate from a landscape diversity perspective as well. A managed landscape with areas dedicated to even- and uneven-aged management, as well as areas reserved from harvest, is inherently more diverse than a landscape managed under 1 system. We also believe this is the most reasonable approach given that small changes in assumptions concerning edge effects can result in severe changes in the predicted effects of even- and uneven-aged management (Thompson 1992). Regardless of the management system used, or whether priority species include early- or late-successional species, managers should strive to prevent further fragmentation of landscapes by non-forest land uses.

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BIRD AND SMALL MAMMAL USE OF SHORT-ROTATION HYBRID POPLAR PLANTATIONS

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Abstract: We studied abundance and species composition of birds and small mammals on hybrid poplar (*Populus* sp.) biomass plantations and other nearby land use types in the northcentral United States. There were few differences in mammal abundance or diversity between hybrid poplar plantations and rowcrop or small-grain fields. Avian abundance and species richness were consistently higher on plantations than in rowcrop or small-grain fields. Our findings suggest little negative site-level effect on songbirds or small mammals resulting from replacement of rowcrop or small-grain fields with hybrid poplar; our study did not address fragmentation or other landscape-level issues. Avian and mammalian abundance and diversity generally were considerably lower on plantations than in forests and non-wooded wildlands. Birds appeared to be more strongly attracted to plantations in agricultural regions than in forested landscapes. Limited use of plantations by area-sensitive and long-distance Neotropical migrant bird species may reflect the relatively young age or small size of the plantations we studied. Mammal abundance and species richness were higher in patches where clones had failed or weed control was ineffective, suggesting that incorporating heterogeneity as a specific design feature may be one approach for managing plantations for biodiversity.

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Key words: biomass energy plantations, birds, habitat, hybrid poplar, land use change, Minnesota, Neotropical migrants, northcentral states, *Populus* sp., short-rotation woody crops, small mammals.

The use of biomass (biofuels) is one of several alternatives for producing renewable energy receiving attention in the United States and elsewhere. One option for producing biomass for energy is through dedicated short-rotation herbaceous or woody crops (Ranney et al. 1987, Beyea and Keeler 1991, Cook et al. 1991, Hohenstein and Wright 1994, Ranney and Mann 1994). These crops include hybrid poplar (Hansen et al. 1983, Heilman and Stettler 1985, Blankenhorn et al. 1986, Ranney et al. 1987; Hansen 1991*a*, 1991*b*, 1992), which is being developed extensively in the midwest and other areas of North America as a potential source of both energy and fiber. In Minnesota, demonstration projects involving hybrid poplar were initiated recently, with >400 ha of hybrid poplars planted in 1994 and about 700 ha each in 1995 and 1996, primarily in agricultural areas. Substantial changes in land use will occur if biomass plantations are deployed at a scale that has significant bearing on U.S. energy supplies (Cook et al. 1991, Ranney and Mann 1994); recent evaluations (Graham 1994) have identified more than

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