Improving Northern Bobwhite Brood Rearing Habitat in Tall Fescue Dominated Fields

L. Andrew Madison, *Department of Forestry, University of Kentucky, Lexington, KY 40546*
Thomas G. Barnes, *Department of Forestry, University of Kentucky, Lexington, KY 40546*
Jeffery D. Sole, *Kentucky Department of Fish and Wildlife Resources, No. 1 Game Farm Road, Frankfort, KY 40601*

Abstract: Tall fescue (*Festuca arundinacea*)-dominated fields provide poor northern bobwhite (*Colinus virginianus*) brood rearing habitat. Burning, disking, and herbicide applications have been recommended to improve bobwhite habitat within fescue-dominated fields. We implemented fall burning, fall disking, spring burning, spring disking, spring herbicide application, summer burning, and summer disking in fescue-dominated fields on 4 wildlife management areas across Kentucky. We sampled invertebrate populations and vegetative structure in summers 1992 and 1993 to determine if bobwhite brood rearing habitat quality was improved. We considered forb-dominated fields with high plant species richness, high invertebrate populations, and sufficient bare ground as providing the best brood rearing habitat. Fall disked plots provided significantly greater invertebrate abundance ($\bar{x}$ = 2199.4 ± 331.5; $p \leq 0.05$) than control plots ($\bar{x}$ = 824.0 ± 264.5) in 1992. In 1993, herbicide treated plots had greater invertebrate abundance ($\bar{x}$ = 1126.8 ± 229.5; $p \leq 0.05$) than control plots ($\bar{x}$ = 327.3 ± 63.2). Plant species richness ($\bar{x}$ = 12.8 ± 1.2), forb coverage ($\bar{x}$ = 70.2 ± 12.5%), and bare ground ($\bar{x}$ = 48.5 ± 8.2%) were significantly greater ($p \leq 0.05$) on fall disked plots in 1992 than on control plots. In 1993, herbicide treated plots had greater ($p \leq 0.05$) plant species richness ($\bar{x}$ = 14.1 ± 1.4), forb coverage ($\bar{x}$ = 59.3 ± 12.0%), and bare ground ($\bar{x}$ = 41.0 ± 10.2%) than control plots. Fall disked plots provided the best bobwhite brood rearing habitat in 1992, while herbicide treated plots provided the best habitat in 1993.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 49:525–536

Quality of brood rearing habitat for northern bobwhite is dependent on invertebrate abundance and vegetative structure. Bobwhite chicks consume >80% invertebrates during the first 2–3 weeks after hatching, providing essential nutrients for growth and survival (Handley 1931, Nestler 1940). Survival of galliform chicks has been directly related to the invertebrate biomass in brood rearing habitat (Southwood and Cross 1969, Erikstad 1985, Hill 1985). Invertebrate populations are highest in fields containing diverse, broad-leaved plant communities (Shelton and Edwards 1983). Optimal brood rearing habitat generally occurs in fields <3 years old with high plant species richness, favoring broad-leaved herbaceous plants (Burger et al. 1990). Areas with dense vegetation and insufficient bare ground can entangle and exhaust chicks attempting to move and find invertebrates (Hurst 1972).

Kentucky-31 tall fescue is the predominant cool-season perennial grass planted in pastures throughout the central and mid-central United States (Buckner et al. 1979). Fields dominated by tall fescue lack vegetative structure and composition for bobwhite brood rearing habitat (Barnes et al. 1995). These fields are dense monocultures providing little bare ground and low plant species richness (Madison 1994). We examined the effectiveness of using fire, disking, and herbicide to increase invertebrate populations and improve vegetative structure in fescue-dominated fields.

We gratefully acknowledge the Kentucky Department of Fish and Wildlife Resources and the University of Kentucky Agricultural Experiment Station for funding this project. We appreciate the efforts of C. Logsdon, M. Cramer, B. Clark, and R. Mauro and their technicians for implementing treatments on the wildlife management areas. We also extend appreciation to M. Lacki, B. Arnett, M. Schuster, R. Wells, M. Hamilton, and M. Adam for assistance with field and lab work. This is a contribution of the Kentucky Agricultural Experiment Station.

Methods

The study was conducted on 4 Kentucky Department of Fish and Wildlife Resources Wildlife Management Areas (WMAs) representing different physiographic regions and bobwhite densities across Kentucky. Study sites were established in tall fescue-dominated fields at the Grayson Lake, Clay, Taylorsville Lake, and West Kentucky WMAs. Fields had been abandoned for >3 years and vegetative structure was similar between fields prior to implementation of treatments. More detailed descriptions of the study areas can be found in Madison (1994) and Barnes et al. (1995).

The study field at each WMA was divided into 16 0.1-ha plots and randomly assigned 1 of 7 treatments (fall burning, fall disking, spring burning, spring disking, spring herbicide application, summer burning, and summer disking) and a control. Experimental design was a randomized complete block with each treatment replicated once at each WMA, except at the Grayson Lake WMA where 1 control plot was inadvertently destroyed. Fall disking was implemented in late September 1991; fall burning in early November 1991; spring burning and disking in early March 1992; spring herbicide applications in late April to early May 1992; and summer burning and disking in mid July 1992.

Prescribed burns were performed in late afternoon to achieve hot fires and a harrowing disk was used to disk plots. Herbicide treated plots were mowed, allowed to regrow for 2 weeks, and sprayed with glyphosate (Round-up™) at a rate of 3.5 l/ha. Treatment plots were allowed to revegetate naturally.

Invertebrate populations were sampled using sweep nets (Southwood 1966) in summer 1992 (26–30 July) and summer 1993 (28 Jul–2 Aug). Sweep nets provide relative estimates of invertebrate populations (Evans et al. 1983, Schotzdo and O'Keeffe 1989). Invertebrate sampling began in late morning, after dew had evaporated from vegetation. Nets were swept over the entire surface area of treatment plots and were beat close to the ground to provide consistent sampling between treatment plots. Collected invertebrates were either preserved in 10% ethanol or frozen. Invertebrates were identified to taxonomic order, oven-dried for 24 hours at 80 C, and weighed. Invertebrates were not sampled in summer disked or summer burned plots in 1992 because these plots had been recently disturbed.

Following invertebrate sampling, percentage vegetation canopy cover, bare ground, and canopy cover by individual plant species in each treatment plot were estimated by randomly establishing one 1.0-m^2 rectangular quadrat/plot (Daubenmire 1959). Plant species richness and percentage cover of forbs and grasses were derived from these estimates. Overhead canopy cover protection was estimated by adding percentage vegetation cover to percentage bare ground and subtracting 100%.

A randomized block analysis of variance supplemented with a control and Tukey's honest significant difference mean comparison tests were used to detect differences in all vegetation and invertebrate analyses by year, WMA, and treatments (Steele and Torrie 1980). All statistical computations were performed using SAS (SAS Inst. 1990).

Results

Mean invertebrate abundance across treatments was significantly greater ($P \leq 0.05$) in 1992 ($\bar{x}$ = 1244.4 ± 118.5) than 1993 ($\bar{x}$ = 570.7 ± 51.7). Invertebrate biomass also was greater ($P \leq 0.05$) in 1992 ($\bar{x}$ = 3.7 ± 0.4 g) than 1993 ($\bar{x}$ = 1.3 ± 0.1 g). Significant interaction ($P \leq 0.05$) was detected between years and treatments among all vegetation analyses. Therefore, treatment effects on invertebrate populations and vegetation structure were analyzed separately by years.

Summer 1992

Mean invertebrate biomass was higher ($P \leq 0.05$) on fall disked ($\bar{x}$ = 6.0 ± 1.1 g) and spring burned ($\bar{x}$ = 4.4 ± 0.8 g) plots than control plots ($\bar{x}$ = 2.3 ± 0.8 g) in 1992 (Table 1). Mean invertebrate abundance was greater ($P \leq 0.05$) on fall disked plots ($\bar{x}$ = 2199.4 ± 331.5) than control plots ($\bar{x}$ = 824.0 ± 264.5), but invertebrate abundance on all other treatment plots was similar ($P > 0.05$) to control plots. Higher invertebrate abundance on fall disked plots was

Table 1. Mean invertebrate abundance (*N*/plot) and biomass (g/plot) by treatment sampled with sweep nets in summer 1992 among 4 wildlife management areas in Kentucky.

		Invertebrate			
		Abundance		Biomass	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	993.6 b[a]	195.5	3.8 bc	1.0
Fall disk	8	2199.4 a	331.5	6.0 a	1.1
Spring burn	8	1165.4 ab	182.9	4.4 ab	0.8
Spring disk	8	1316.0 ab	318.5	3.9 bc	1.0
Herbicide	8	980.9 b	215.9	1.9 d	0.3
Control	7	824.0 b	264.5	2.3 cd	0.8

[a]Means within columns followed by different letters significantly differ at $P \leq 0.05$.

a function of greater dipteran and homopteran abundance. Dipteran abundance on fall disked plots ($\bar{x}$ = 383.9 ± 114.50) was significantly higher ($P \leq 0.05$) relative to fall burned and spring burned plots (Table 2). Fall disked plots also supported higher ($P \leq 0.05$) homoptera abundance ($\bar{x}$ = 767.0 ± 180.4) relative to herbicide treated, fall burned, and control plots. Mean abundance of all other invertebrate orders was similar ($P > 0.05$) among treatment plots.

Plant species richness was higher ($p \leq 0.05$) on fall disked ($\bar{x}$ = 12.8 ± 1.2) and spring disked ($\bar{x}$ = 12.5 ± 0.8) plots during 1992 relative to control plots ($\bar{x}$ = 6.0 ± 0.9) (Table 3). Forbs, primarily common ragweed (*Ambrosia artemissifolia*), were favored on fall disked plots in 1992 ($\bar{x}$ = 70.2 ± 12.5%) with grasses comprising 37.2 ± 12.2%. Grasses, primarily nodding foxtail (*Setaria geniculata*) and giant foxtail (*S. glauca*), dominated spring disked plots ($\bar{x}$ = 70.2 ± 8.3%), whereas forb coverage averaged 39.4 ± 10.9%. Mean percentage bare ground was higher ($P \leq 0.05$) in fall disked ($\bar{x}$ = 48.5 ± 8.2%) and spring disked ($\bar{x}$ = 49.1 ± 7.9%) plots relative to control plots ($\bar{x}$ = 0.0 ± 0.0%), but canopy coverage protection was only higher ($P \leq 0.05$) on fall disked plots ($\bar{x}$ = 22.9 ± 8.2%). On fall burned, spring burned, and herbicide treated plots in 1992, plant species richness, bare ground, and canopy coverage protection were similar ($P > 0.05$) to control plots and grasses dominated the plant community.

Summer 1993

Invertebrate biomass was higher ($P \leq 0.05$) on herbicide treated ($\bar{x}$ = 2.3 ± 0.4 g) and fall disked ($\bar{x}$ = 2.0 ± 0.4 g) plots than control plots ($\bar{x}$ = 0.9 ± 0.2 g) in 1993 (Table 4). Mean invertebrate abundance was higher ($P \leq 0.05$) only on herbicide treated plots ($\bar{x}$ = 1126.8 ± 229.5) than control plots ($\bar{x}$ = 327.3 ± 63.2). A greater abundance of hemiptera, homoptera, and lepidoptera explained the higher invertebrate abundance observed on herbicide treated plots. Herbicide treated plots supported significantly higher ($P \leq 0.05$) homopteran abundance ($\bar{x}$ = 353.1 ± 87.46) relative to all other treatment plots (Table

Table 2. Mean abundance (*N*/plot) of insect orders and araneida by treatment sampled with sweep nets in summer 1992 among 4 wildlife management areas in Kentucky.

		Orthoptera		Homoptera		Hemiptera		Coleoptera	
Treatment	N	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	234.9 a[a]	88.9	270.9 b	85.3	72.5 a	27.2	124.0 a	28.2
Fall disk	8	326.1 a	117.9	767.0 a	180.4	214.4 a	86.9	234.4 a	49.8
Spring burn	8	211.8 a	67.1	403.1 ab	84.0	87.8 a	26.6	138.0 a	30.6
Spring disk	8	218.6 a	70.9	320.3 ab	97.0	204.8 a	76.9	180.5 a	41.0
Herbicide	8	113.5 a	33.7	292.5 b	94.8	80.3 a	27.2	253.9 a	60.3
Control	7	74.9 a	23.4	200.6 b	70.7	49.6 a	28.1	199.1 a	83.4
		Lepidoptera		**Diptera**		**Hymenoptera**		**Araneida**	
Treatment	N	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	4.9 a	1.2	118.8 b	45.7	67.5 a	15.1	93.4 a	24.4
Fall disk	8	8.8 a	2.4	383.9 a	114.5	123.9 a	39.0	124.9 a	26.9
Spring burn	8	7.3 a	1.5	118.3 b	22.1	60.9 a	15.4	134.0 a	35.9
Spring disk	8	5.9 a	2.3	212.8 ab	57.1	83.4 a	47.2	85.6 a	36.7
Herbicide	8	3.5 a	1.4	142.8 ab	37.8	51.5 a	10.4	36.6 a	7.2
Control	7	5.6 a	2.1	126.1 ab	40.2	46.0 a	15.8	119.1 a	41.6

[a]Mean within columns followed by different letters differ significantly at $P \leq 0.05$.

Table 3. Mean plant species richness (*N*/plot), percentage broad-leaved herbaceous plants, percentage grasses, percentage bare ground, and percentage canopy coverage protection (%-vegetation cover + %-bare ground − 100%) by treatment in summer 1992 among 4 wildlife management areas in Kentucky.

Treatment	N	Richness		Broad-leaved Plants		Grasses		Bare Ground		Canopy Coverage	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	10.1 ab[a]	0.9	28.9 ab	9.2	81.7 a	6.4	11.1 b	4.2	2.6 b	1.2
Fall disk	8	12.8 a	1.2	70.2 a	12.5	37.2 b	12.2	48.5 a	8.2	22.9 a	8.2
Spring burn	8	10.5 ab	1.0	38.6 ab	9.6	76.4 a	9.3	14.8 b	6.7	2.8 b	1.2
Spring disk	8	12.5 a	0.8	39.4 ab	10.9	70.2 ab	8.3	49.1 a	7.9	15.4 ab	7.2
Herbicide	8	8.9 ab	1.5	34.3 ab	13.4	66.0 ab	15.1	32.0 ab	8.9	4.4 b	1.7
Control	7	6.0 b	0.9	7.2 b	2.4	96.3 a	2.6	0.0 b	0.0	0.0 b	0.0

[a]Means within columns followed by different letters differ significantly at $P \leq 0.05$.

Table 4. Mean invertebrate abundance (*N*/plot) and biomass (g/plot) by treatment sampled with sweep nets in summer 1993 among 4 wildlife management areas in Kentucky.

		Invertebrate			
		Abundance		Biomass	
Treatment	N	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	397.6 b[a]	90.7	0.9 c	0.2
Fall disk	8	554.1 b	104.9	2.0 ab	0.4
Spring burn	8	406.0 b	71.0	1.2 bc	0.3
Spring disk	8	642.8 ab	175.5	0.8 c	0.1
Herbicide	8	1126.8 a	229.5	2.3 a	0.4
Summer burn	8	382.1 b	54.5	1.0 c	0.1
Summer disk	8	644.9 ab	91.2	1.3 abc	0.2
Control	7	327.3 b	63.2	0.9 c	0.2

[a]Means within columns followed by different letters differ significantly at $P \leq 0.05$.

5). Hemipteran abundance ($\bar{x}$ = 348 ± 165.20) was greater ($P \leq 0.05$) on herbicide treated plots relative to all other treatment plots, except summer disked plots. Lepidopteran abundance on herbicide treated plots ($\bar{x}$ = 12.6 ± 3.68) was significantly greater ($P \leq 0.05$) than summer burned plots. All other invertebrate orders were similar ($P > 0.05$) across treatment plots in 1993.

Plant species richness was higher ($P \leq 0.05$) on herbicide treated ($\bar{x}$ = 14.1 ± 1.41), summer burned ($\bar{x}$ = 11.5 ± 1.18), and summer disked ($\bar{x}$ = 11.8 ± 2.22) plots than control plots ($\bar{x}$ = 4.6 ± 0.5) during 1993 (Table 6). Dominant plant species on herbicide treated plots included foxtails, common ragweed, blue vervain (*Verbena hastata*), and sericea lespedeza (*Lespedeza cuneata*), yielding a nearly 50–50 mixture of forbs ($\bar{x}$ = 59.3 ± 12.0%) and grasses ($\bar{x}$ = 49.0 ± 13.0%). Grasses, primarily tall fescue, dominated summer burned ($\bar{x}$ = 94.6 ± 3.4%) and summer disked ($\bar{x}$ = 85.0 ± 7.1%) plots. Mean percentage bare ground was higher ($P \leq 0.05$) on herbicide treated ($\bar{x}$ = 41.0 ± 10.2%) and summer disked ($\bar{x}$ = 38.8 ± 9.0%) plots than control plots ($\bar{x}$ = 1.4 ± 0.8%). Canopy coverage protection was higher on herbicide treated plots ($\bar{x}$ = 21.9 ± 7.6%) than control plots ($\bar{x}$ = 0.0 ± 0.0%), but the difference was not statistically significant. Fall burned, fall disked, spring burned, and spring disked plots were dominated by grasses, primarily tall fescue, in 1993. Percentage bare ground and canopy coverage protection on these treatment plots were similar ($P > 0.05$) to control plots.

Discussion

Several factors may have contributed to greater invertebrate abundance and biomass in 1992 than 1993. The 2 most probable reasons were the rapid plant successional changes induced by the treatments or climatic conditions. During 1992, each study site was a mosaic of habitat types among treatment plots which

Table 5. Mean abundance (*N*/plot) of insect orders and araneida by treatment sampled with sweep nets in summer 1993 among 4 wildlife management areas in Kentucky.

		Orthoptera		Homoptera		Hemiptera		Coleoptera	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	22.4 a[a]	4.1	84.5 b	21.3	34.5 b	16.3	81.6 a	24.7
Fall disk	8	36.1 a	11.1	120.8 b	33.7	60.5 b	22.1	104.0 a	18.1
Spring burn	8	22.8 a	5.3	105.5 b	35.2	28.9 b	7.8	118.9 a	25.7
Spring disk	8	20.1 a	6.4	110.4 b	18.2	28.0 b	6.9	309.6 a	169.5
Herbicide	8	35.5 a	5.8	353.1 a	87.5	348.6 a	165.2	117.5 a	45.1
Summer burn	8	29.3 a	5.9	86.0 b	22.8	33.9 b	9.3	62.5 a	15.2
Summer disk	8	36.9 a	7.9	128.8 b	51.3	82.8 ab	20.2	114.0 a	38.1
Control	7	19.4 a	6.1	46.4 b	9.7	8.4 b	0.5	119.1 a	49.4

		Lepidoptera		Diptera		Hymenoptera		Araneida	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	4.6 ab	1.4	45.6 a	20.2	43.5 a	20.2	76.8 a	28.6
Fall disk	8	7.4 ab	2.5	36.3 a	11.6	49.1 a	15.7	138.8 a	36.3
Spring burn	8	4.3 ab	0.8	43.0 a	10.8	35.6 a	7.4	99.8 a	21.4
Spring disk	8	5.1 ab	1.8	45.9 a	15.1	47.6 a	19.6	73.4 a	13.3
Herbicide	8	12.6 a	3.7	37.9 a	12.3	38.4 a	7.8	181.1 a	54.6
Summer burn	8	2.6 b	0.9	47.2 a	17.1	43.1 a	19.8	74.5 a	14.2
Summer disk	8	5.0 ab	0.8	38.9 a	10.7	56.8 a	26.4	107.1 a	6.6
Control	7	4.7 ab	2.0	38.1 a	10.4	20.1 a	4.1	69.9 a	12.5

[a]Means within columns followed by different letters differ significantly at $P \leq 0.05$.

Table 6. Mean plant species richness (*N* species/plot), percentage broad-leaved herbaceous plants, percent grasses, percentage bare ground, and percentage canopy coverage protection (%-vegetation cover + %-bare ground − 100%) by treatment in summer 1993 among 4 wildlife management areas in Kentucky.

		Richness		Broad-leaved Plants		Grasses		Bare Ground		Canopy Coverage	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fall burn	8	8.4 abc[a]	1.2	32.8 b	13.7	91.6 a	6.1	17.0 ab	5.9	1.1 a	0.6
Fall disk	8	10.9 abc	1.3	20.8 bc	5.5	88.2 a	5.0	26.4 ab	8.1	9.8 a	4.3
Spring burn	8	7.8 bc	1.5	35.3 ab	13.4	80.2 a	10.1	11.4 ab	6.0	7.0 a	3.6
Spring disk	8	9.9 abc	1.1	25.2 bc	10.2	83.5 a	8.3	35.0 ab	8.7	17.5 a	6.8
Herbicide	8	14.1 a	1.4	59.3 a	12.0	49.0 a	13.0	41.0 a	10.2	21.9 a	7.6
Summer burn	8	11.5 ab	1.2	14.7 bc	4.4	94.6 a	3.4	29.0 ab	7.5	13.4 a	5.5
Summer disk	8	11.8 ab	2.2	18.8 bc	7.3	85.0 a	7.1	38.8 a	9.0	11.3 a	5.1
Control	7	4.6 c	0.5	6.1 c	2.9	98.4 a	1.6	1.4 b	0.8	0.0 a	0.0

[a]Means within columns followed by different letters differ significantly at $P \leq 0.05$.

provided diverse plant communities within close proximity. Invertebrate abundance is greatest within fields containing weedy, diverse plant communities (Shelton and Edwards 1983, Burger et al. 1990). Invertebrate biomass and abundance decreased during 1993, when most treatment plots had become similar in vegetation structure. Invertebrates may have also been responding to yearly climatic conditions. Average maximum temperature and precipitation in July 1992 was greater than maximum temperatures and precipitation in July 1993 across Kentucky (Agric. Weather Center 1993).

Bobwhite brood rearing habitat quality is most dependent upon invertebrate abundance (Jackson et al. 1987). Fall disked plots in summer 1992 supported high invertebrate abundance, primarily from greater numbers of dipterans and homopterans. Although dipterans are infrequently consumed by bobwhite chicks, homopterans are an important food (Hurst 1972). One year later, invertebrate abundance was high on herbicide treated plots which supported higher hemiptera, homoptera, and lepidoptera abundance all important foods of bobwhite chicks (Hurst 1972, Jackson et al. 1987).

Brood rearing habitat quality also is dependent on vegetation structure. Invertebrate abundance is greater in weedy, diverse plant communities (Shelton and Edwards 1983), therefore optimal brood rearing habitat should contain high plant species richness favoring forbs (Burger et al. 1993). There must also be sufficient bare ground to allow bobwhite chicks freedom to find invertebrates (Hurst 1972).

Fall disked plots provided the best vegetation structure for brood rearing habitat relative to all other treatment plots in 1992. Fall disked plots supported higher plant species richness than control plots and favored forbs, while all other treatment plots had plant species richness similar to control plots and favored grasses. Schroeder (1985) indicated 30%–60% bare ground should be sufficient for allowing bobwhites to freely move and search for food within winter feeding habitat. If these values apply similarly to bobwhite brood rearing habitat, then fall disked plots provided sufficient bare ground coverage. Fall disked plots also provided overhead canopy coverage protection from predators.

Herbicide treated plots supported vegetation structure of the highest quality for bobwhite brood rearing in 1993. They provided high plant species richness, were dominated by forbs, had sufficient bare ground, and maintained canopy coverage protection.

All other treatment plots lacked either higher invertebrate populations or the proper vegetation structure to provide good brood rearing habitat. Spring burned plots in 1992 did provide greater invertebrate biomass, but available bare ground was similar to control plots. Spring disked plots in 1992 supplied higher plant species richness relative to control plots and had sufficient bare ground, but they favored grasses rather than forbs. Invertebrate abundance and biomass also were similar to control plots on spring disked plots.

Similar trends were detected among treatment plots in 1993. Fall disked plots provided higher invertebrate biomass relative to control plots, but grasses dominated the plant community and bare ground was <30%. Summer disked plots in 1993 did have higher plant species richness relative to control plots and provided an adequate amount of bare ground, but were dominated by grasses rather than forbs. Summer burned plots had higher plant species richness, but were grass-dominated and had insufficient bare ground. Summer burned and summer disked plots also supported invertebrate populations similar to control plots.

Hurst (1972) observed that invertebrate abundance was greater on late-winter burned than unburned fields. Fall, spring, and summer burning in tall fescue-dominated fields did not affect invertebrate abundance, although invertebrate biomass was greater on spring burned plots in 1992. The lack of response by invertebrates may be from vegetation structure and plant species composition being similar between burned plots and control plots during 1992 and 1993. Cancelado and Yonke (1970) determined invertebrate abundance was only greater for several weeks following burning. All burns in this study were completed several months before invertebrate sampling; therefore, possible short-term increases in invertebrate populations caused by burning would not have been detected.

There appeared to be a direct relationship between high brood rearing habitat quality and increased invertebrate abundance. Fall disked plots in 1992 supported the highest quality brood rearing habitat structure and had high invertebrate abundance and biomass. Similarly, herbicide treated plots in 1993 had the best brood rearing habitat structure and supported high invertebrate abundance and biomass. Quality of fall disked plots declined after summer 1992 because tall fescue began to dominate the plant community. Combining use of both fall disking and herbicide applications may provide the best strategy for improving bobwhite brood rearing habitat in tall fescue-dominated fields.

Literature Cited

Agriculture Weather Center. 1993. Weather summary for July 1992 and 1993. Univ. of Louisville, Ky.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue dominated fields. Wildl. Soc. Bull. 23: 231–237.

Buckner, R. C., J. B. Powell, and R. V. Frakes. 1979. Historical development. Pages 5–25 *in* R. C. Buckner and L. P. Bush, eds. Tall fescue. Am. Soc. Agron., Crop Sci. Soc. Am., Inc., Madison, Wisc.

Burger, L. W., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Trans. North Am. Wildl. and Nat. Resour. Conf. 55:74–83.

———, ———, ———, and ———. 1993. Relative invertebrate abundance and biomass in conservation reserve program plantings in northern Missouri. Pages 102–108 *in* K. E. Church and T. V. Dailey, eds. Quail III: national quail symposium. Kans. Dep. Wildl. and Parks, Pratt.

Cancelado, R. and T. R. Yonke. 1970. Effect of prairie burning on insect populations. J. Kans. Entomol. Soc. 43:274–281.

Daubenmire, R. 1959. A canopy-coverage of vegetational analysis. Northwest. Sci. 33: 43–64.

Erikstad, K. E. 1985. Growth and survival of willow grouse chicks in relation to home range size, brood movements and habitat selection. Ornis Scandinavica 16:181–190.

Evans, E. W., R. A. Rogers, and D. J. Opfermann. 1983. Sampling grasshoppers (Orthoptera: Acrididae) on burned and unburned tallgrass prairie: night-trapping vs. sweeping. Environ. Entomol. 12:1449–1454.

Handley, C. O. 1931. Food for the young. Pages 159–169 *in* H. L. Stoddard, ed. The bobwhite quail: its habits, preservation, and increase. Charles Scribners and Sons, New York, N.Y.

Hill, D. A. 1985. The feeding ecology and survival of pheasant chicks on arable farmland. J. Appl. Ecol. 22:645–654.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Pages 65–82 *in* J. A. Morrison and J. C. Lewis, eds. Proc. First Natl. Bobwhite Quail Symp., Okla. State Univ., Stillwater.

Jackson, J. R., G. A. Hurst, and E. A. Gluesing. 1987. Abundance and selection of invertebrates by northern bobwhite chicks. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:303–310.

Madison, L. A. 1994. Impacts of disturbance in tall fescue dominated fields on northern bobwhite habitat in Kentucky. M.S. Thesis. Univ. Ky., Lexington. 146pp.

Nestler, R. B. 1940. Feeding requirements of gallinaceous upland game birds. Pages 893–924 *in* Yearbook of agriculture, 1939. U.S. Dep. Agric., U.S. Printing Off., Washington, D.C.

SAS Institute Inc. 1990. SAS/STAT User's Guide, (Version 6, Fourth Ed.), SAS Inst. Inc., Cary, N.C. 1686pp.

Schotzko, D. J. and L. E. O'Keeffe. 1989. Comparison of sweep net, D-vac, and absolute sampling, and Diel variation of sweep net sampling estimates in lentils for pea aphid (Homoptera: Aphididae), nabids (Hemiptera: Nabidae), lady beetles (Coleoptera: Coccinellidae), and lacewings (Neuroptera: Chrysopidae). J. Econ. Entomol. 82: 491–506.

Schroeder, R. L. 1985. Habitat suitability index models: northern bobwhite. U.S. Fish and Wildl. Serv., U.S. Dep. Int., Washington, D.C. 32pp.

Shelton, M. D. and C. R. Edwards. 1983. Effects of weeds on the diversity and abundance of insects in soybeans. Environ. Entomol. 12:296–298.

Southwood, T. R. E. 1966. Ecological methods. Menthen and Co., Ltds., London. 391pp.

——— and D. J. Cross. 1969. The ecology of the partridge. III. Breeding success and the abundance of insects in natural habitats. J. Anim. Ecol. 38:497–509.

Steele, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. Mc-Graw-Hill Book Co., New York, N.Y. 633pp.