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Invertebrate Biomass and Richness in Various Food Plot Types in East Texas

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As northern bobwhite (*Colinus virginianus*) chicks are dependent on invertebrates for food, land managers often use spring/summer food plots to meet these needs. We examined invertebrate production in native vegetation and 6 different food plot types (i.e., fallow disking only; fallow disking and fertilizing; or disking, fertilizing, and planting a single species [browntop millet, iron and clay peas, or sorghum] or a multi-species mix [browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet]) in the Pineywoods of east Texas. Invertebrates were collected weekly during the summers of 1997 and 1999 and for 5 weekly sampling periods during summer, 1998. For each food plot type, invertebrates were separated from debris, air dried, and weighed as a group. Bi-weekly, a 100-invertebrate sub-sample was randomly selected from each sample and sorted to order with weight and number of individuals recorded. When spring precipitation was sufficient, multi-species food plots produced greater ($P < 0.05$) invertebrate biomass than fallow or native vegetation plots, and all cultivated plots had more ($P < 0.05$) biomass than native vegetation. Likewise, all cultivated plots had more ($P < 0.05$) biomass than fallow plots in early summer but not in mid- and late summer. A combination of multi-species (with legumes) food plots and fallow disking should provide bobwhite chicks with invertebrates throughout most summers.

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Key words: *Colinus virginianus*, east Texas, food plots, invertebrate biomass, invertebrate richness, northern bobwhite

Introduction

Invertebrates are a critical component of the diet of northern bobwhites (*Colinus virginianus*; hereafter bobwhite). For hens, insects are a source of protein which is necessary for laying (Rosene 1969). More importantly, bobwhite chicks need 28% protein during the first 10 weeks of life (Rosene 1969) and are dependent on invertebrates for this protein (Handley 1931). As with most species, juvenile recruitment is critical in maintaining or increasing bobwhite populations. However, in the southeastern United States, recruitment has not replaced mortality for many years. In attempts to improve recruitment, managers and biologists use prescribed burning, fallow disking, and spring/summer food plots to increase invertebrate abundance.

In managing for bobwhites, fallow disking has long been recommended (Stoddard 1931). However, while disking may improve the structure of brood habitat (Olinde 2000), its impact, as compared to undisked native vegetation, on invertebrate production is unknown. Although disking is less expensive than planting food plots (Stoddard 1931, Brennan et al. 2000), food plots provide greater invertebrate biomass than native vegetation, either disked (Brennan et al. 2000) or undisked (Parsons et al. 2000*a*).

Some research has investigated invertebrate communities in food plots established using various combinations of fertilizer and plant species. In Mississippi, there were no differences in invertebrate density or biomass among old field (i.e., 2-year-old rye grass), fertilized old field, and fertilized Kobe lespedeza treatments; some invertebrate orders did differ among treatments, however (Jackson et al. 1987). In Georgia, invertebrate

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biomass did not differ among millet, sorghum, soybean, and wheat food plots, but invertebrate density was highest in millet and lowest in soybean and wheat plots. However, both biomass and density of Coleoptera, Diptera, Hemiptera, and Homoptera did differ among crop types; biomass and density values were generally highest in the millet plots (Maidens and Carroll 2002).

Burger et al. (1993) investigated invertebrate abundance, biomass, and diversity in Conservation Reserve Program (CRP) fields planted to 6 different species or species groups and in conventionally tilled soybean fields. They also tracked changes in the invertebrate community during 4 sampling periods between 1 July and 22 August. With few exceptions, invertebrate abundance, biomass, and diversity were highest in red clover fields and lowest in soybean fields. Likewise, these invertebrate values were generally higher in early July than mid-August.

No studies such as these have taken place in the Pineywoods of east Texas. Likewise, no studies have tracked changes in invertebrate biomass in food plots across the spring/summer brood-rearing period. Our objectives were to examine invertebrate abundance, biomass, and richness in native vegetation and in 6 types of food plots during late spring and summer, 1997, 1998, and 1999. The food plots were established by fallow disking only; fallow disking and fertilizing; or disking, fertilizing, and planting with browntop millet, iron and clay peas, sorghum, or a multiple species mix (browntop millet, Japanese millet, pearl millet, catjang peas, and iron and clay peas). For the purpose of this study, native vegetation was considered a food plot type.

Study Area

This study was conducted in the Pineywoods Ecological Region of east Texas (Gould 1975). The study area was on the 4,860-ha South Boggy Slough Hunting and Fishing Club. The club was on lands owned by Temple-Inland Forest Products Corporation and was approximately 16 km southwest of Lufkin, Texas. In 1989, company biologists selected 607 ha within the club to serve as a quail management area (QMA); this research project and several others (e.g., Nedbal et al. 1997, Liu et al. 2000, Parsons et al. 2000*a*) were conducted on the QMA.

Habitat modifications to favor bobwhites took place in the spring of 1989. Basal areas of the mature mixed pine-hardwood forests were reduced from 21-28 m^2/ha to approximately 14 m^2/ha. Sixty-nine food plots, ranging from 0.8 to 2.0 ha in size and totaling 81 ha, were established in the area. Beginning in 1989, approximately 60% of the QMA was burned annually; the remainder was burned biannually. A detailed description of habitat modifications on the QMA may be found in Dietz (1999).

Methods

Field Procedures

In January 1997, we selected 5 blocks on the QMA. Average distance between blocks was approximately 360 m; the shortest distance between any 2 blocks was 200 m. Although all blocks were on upland portions of the QMA, all were on soils classified as wet and/or clayey (Liu 1995).

Within each block, we established 6 cultivated food plots (0.8-2.0 ha in size) and 1 uncultivated food plot in native vegetation. We then randomly assigned 1 of the 6 cultivated food plot types to each food plot. Each spring, the food plots received the assigned treatment as early as possible, usually in early April. In order to maintain plant species homogeneity, each plot received the same treatment each spring. One food plot was fallow disked only; the remainder were disked and fertilized with 13-13-13 at a rate of approximately 220 kg/ha. Single-species plots of browntop millet, iron and clay pea, and sorghum plots were planted at rates of 45, 112, and 32 kg/ha, respectively. In the multi-species plot, browntop millet, catjang pea, iron and clay pea, Japanese millet, and pearl millet were planted at rates of 22, 22, 100, 28, and 22 kg/ha, respectively.

On the QMA, the bobwhite nesting period extended from mid-May into September. Most (70%) nests were initiated in May and June, thus most clutches of eggs hatched in June and July. However,

nest initiation extended into September and at least 1 clutch hatched in October (Parsons et al. 2000*b*). Therefore, if the food plots had adequate vegetation, we began invertebrate sampling in mid-June and continued to do so on a weekly basis through early September. We used a gasoline-powered backpack vacuum machine to collect invertebrates (Ault and Stormer 1983). Starting at a random point, the operator moved in a zig-zag pattern through the food plot. We used the zig-zag pattern rather than designated transects to avoid sampling previously trampled vegetation. As the operator walked, the collecting cone was moved in a side-to-side motion within 15 cm of the soil surface; each food plot was vacuumed for 40 seconds.

Invertebrates and debris gathered in the food plot were immediately transferred to a labeled, self-sealing plastic bag containing an alcohol-soaked cotton ball. In 1997, we began sampling invertebrates on 26 June and gathered 11 weekly samples, ending on 3 September. Although food plots were planted in a timely manner, above-average precipitation in early spring (Table 1) made some plots inaccessible for sampling until late June. In 1998, there was a severe spring and summer drought and the cultivated food plots lacked vegetation until late August, thus we did not sample invertebrates in such plots that summer; invertebrates were collected in native vegetation during July and late August that summer. In 1999, we obtained 12 weekly samples, beginning on 21 June and ending on 14 September; due to equipment problems we were unable to collect invertebrates during the fourth week of July.

Laboratory Procedures

Samples were frozen at 0 °C for at least 48 hours to ensure that all invertebrates were dead. Thereafter, each bag was opened and its contents allowed to air dry for up to 36 hours. When dry, the contents were poured into a number 35 sieve. Obvious debris was carefully searched for invertebrates which were placed in a labeled vial; the debris was discarded. With the aid of a microscope, the contents remaining in the sieve were searched and invertebrates gathered. In doing this, soil particles fell through the sieve, making invertebrates easier to recognize. If necessary, the sieve was gently shaken to expose invertebrates; this was usually unnecessary. Searching continued until all invertebrates $\geq$0.5 mm in length were gathered and placed in the vial.

Contents of each vial were placed in a Petri dish and allowed to further air dry for 24 hours. The sample was then weighed to the nearest 0.0001 g. In order to evaluate taxon richness, samples collected on alternate weeks were sub-sampled to identify invertebrates to order. Contents of each Petri dish were evenly spread on a transparent plastic board with a 400-intersection grid etched on it. One hundred intersections were randomly chosen and the invertebrate nearest each selected intersection was gathered. The sub-sample was weighed and the invertebrates within it were identified to order; the weight and number of individuals of each order were recorded. If a sample contained fewer than 100 invertebrates, all individuals were sorted and weighed.

Statistical Procedures

We compared invertebrate biomass collected in native vegetation during July and August among the 3 years using a 2-way (week*year) univariate analysis of variance (ANOVA) and a Tukey test (Zar 1999, SAS Institute, Inc. 2006). We used a univariate ANOVA to determine if invertebrate biomass from 1997 and 1999 could be pooled. Biomass differed between years, so we used a 2-way ANOVA with a Tukey test to examine differences among food plots and among weeks for each year. When tests indicated differences, we used univariate ANOVAs with Tukey tests by week or food plot type to separate means. Invertebrate richness data were examined using a 2-way ANOVA and Tukey test of differences among food plots and weeks for each year. Finally, all biomass data were square root transformed and richness data log transformed (original values are reported) before analyses, with $\alpha = 0.05$.

Table 1: Precipitation (cm) at Lufkin, Texas, approximately 20 km northeast of the Quail Management Area in the Pineywoods of east Texas (National Oceanic and Atmospheric Administration 2006).

	Month								
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1997	8.18	17.37	13.16	15.29	8.59	8.48	5.16	5.94	82.17
1998	22.99	13.74	6.86	7.47	0.03	2.03	5.11	12.34	70.57
1999	21.21	1.17	12.12	4.14	21.87	16.28	8.94	0.43	86.16
30-year $\bar{X}$	11.30	8.05	8.97	7.95	13.44	10.62	6.60	7.82	74.75

Results

Invertebrate Biomass

We identified 16 invertebrate taxa as potential food items. Araneida and insect orders comprised >90% of the total biomass in 1997 and 1999. The orders Hemiptera and Homoptera comprised >50% of the biomass each year. Only in native vegetation did these taxa not comprise the majority of the biomass (Table 2).

When we compared invertebrate biomass collected in native vegetation during July and August, 1997, 1998, and 1999, there was a week*year interaction ($F_{5,59} = 3.35$, $P < 0.001$; Figure 1); biomass differed among years ($F_{2,59} = 38.37$, $P < 0.001$) but not weeks ($F_{4,59} = 1.31$, $P = 0.278$). Mean weekly biomass in native vegetation in 1997 (0.1804 g) was higher than in 1998 (0.0498 g) or 1999 (0.07654 g). However, although differences were not significant, 1997 and 1999 biomass declined from 9 July values of 0.2094 g and 0.1215 g, respectively, to 29 August values of 0.1193 g and 0.0199 g, respectively. Conversely, in 1998, values on those dates increased from 0.0186 g to 0.0884 g.

Biomass of invertebrates collected in 1997 differed from that collected in 1999 ($F_{1,749} = 40.51$, $P < 0.001$). For 1997 data, there was no week ($F_{10,297} = 1.04$, $P = 0.407$) nor week*food plot interaction ($F_{60,297} = 0.76$, $P = 0.901$; Figures 2a, b). However, there were differences among food plot types ($F_{60,297} = 18.71$, $P < 0.001$). Overall, multi-species food plots produced more invertebrate biomass than did native vegetation, fallow, or fallow with fertilizer food plots (Table 3). However, invertebrate biomass differed among food plot types for only 4 weekly samples. Multi-species food plots produced more invertebrate biomass than either native vegetation or fallow plots in late June. By late July, biomass produced by fallow plots did not differ from that produced by multi-species plots (Table 3). Although values did not significantly differ, by early September fallow food plots produced 40% more invertebrate biomass than did multi-species plots. In fact, multi-species plots produced less ($P > 0.05$) biomass than did any other food plot type except native vegetation in early September (Table 3).

In the summer of 1999, there was week*food plot type interaction ($F_{66,327} = 1.41$, $P = 0.029$). Invertebrate biomass differed among weeks by food plot type ($F_{11,327} = 50.72$, $P < 0.001$) and among food plot types by week ($F_{6,327} = 48.23$, $P < 0.001$). Each food plot type significantly differed among weeks (fallow, $P = 0.026$; all other types, $P < 0.001$). Without exception, each food plot type produced much more invertebrate biomass in early summer than in late summer (Table 4; Figures 3a, b).

Similar to 1997, multi-species food plots produced more invertebrate biomass over the entire 1999 summer than did native vegetation or fallow plots (Table 4). However, different from 1997, invertebrate biomass differed among food plot types each

Table 2: Percent composition by weight of invertebrate orders collected in native vegetation (NaV) and food plots established by fallow disking only (FwD), fallow disking and fertilizing (FwF), or disking, fertilizing and planting a single species (i.e., browntop millet [BTM], iron and clay peas [ICP], or sorghum [SGM]), or a multi-species mix (i.e., browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet [MSP]) in the Pineywoods of east Texas during spring and summer, 1997 and 1999. The others category included Acarina, Anoplura, Coleoptera, Lepidoptera, Neuroptera, Odonata, Plecoptera, Psocoptera, Thysaboptera, and Trichoptera.

		Food plot type							
Year	Order	NaV	FwD	FwF	BtM	SGM	ICP	MSP	% composition $\bar{X}$
1997	Araneida	14	9	11	10	4	11	5	9.2
	Diptera	6	7	11	7	8	6	9	7.8
	Hemiptera	13	26	28	41	34	33	37	30.4
	Homoptera	25	23	23	23	33	23	26	25.2
	Hymenoptera	8	2	4	2	3	3	8	4.4
	Orthoptera	27	24	13	11	13	12	10	15.2
	Others/unknown	7	9	10	6	5	12	5	7.8
1999	Araneida	17	11	11	8	6	9	6	9.7
	Diptera	8	6	8	0	8	6	7	6.2
	Hemiptera	15	32	25	44	31	19	18	26.3
	Homoptera	25	26	26	30	34	47	46	33.4
	Hymenoptera	8	2	3	2	5	3	7	4.3
	Orthoptera	20	15	9	10	9	9	10	11.7
	Others/unknown	7	8	18	6	7	7	6	8.4

week except the last week of the 1999 study period. As with 1997, by mid-July, biomass values for fallow food plots were similar to values for food plots which had been cultivated (Table 4).

Invertebrate Richness

In 1997, the mean number of taxa per sample was 6.45 (range 4.6-7.4). There was no week*food plot interaction ($F_{30,159} = 1.55$, $P = 0.059$), but mean numbers of taxa did differ among food plot types ($F_{6,159} = 2.66$, $P = 0.017$) and among the 6 weekly samples ($F_{5,159} = 3.62$, $P = 0.004$). More taxa were recorded in samples from fallow plots ($\bar{x} = 6.9$) than from multi-species plots ($\bar{x} = 5.8$); means from the remaining food plot types overlapped both values. Taxon richness was lower the week of 9 July ($\bar{x} = 5.1$) than the weeks of 26 June, 23 July, 6 and 20 August, and 3 September (range 6.5-7.2).

The mean number of taxa per sample in 1999 was 6.55 (range 5.4-7.0). There was a week*food plot interaction ($F_{30,159} = 1.79$, $P = 0.012$). Taxon richness differed among food plot types ($F_{6,159} = 2.44$, $P = 0.028$) and among weeks ($F_{6,159} = 4.15$, $P = 0.001$). Taxon richness was higher in native vegetation ($\bar{x} = 6.8$) than in the fallow food plot types ($\bar{x} = 6.3$). As with 1997, values for the remaining food plot types overlapped both native vegetation and fallow values. Taxon richness in the week of 21 June ($\bar{x} = 6.1$) was lower than in the weeks of 6 and 20 July ($\bar{x} = 6.7$ for each) and 10 August ($\bar{x} = 6.8$), but similar to the weeks of 24 August ($\bar{x} = 6.5$) and 6 September ($\bar{x} = 6.5$).

Table 3: Mean biomass (g) of invertebrates collected in native vegetation and food plots established by fallow disking only, fallow disking and fertilizing, or disking, fertilizing, and planting a single species (i.e., browntop millet, iron and clay peas, or sorghum), or a multi-species mix (i.e., browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet) in the Pineywoods of east Texas during spring and summer, 1997. Within rows, means followed by the same letter did not differ $P > 0.05$).

	Food plot type									
Week	Native vegetation	Fallow	Fallow with fertilizer	Browntop millet	Sorghum	Iron and clay peas	Multiple species	$\bar{x}$	F	P
26-Jun	0.2108b	0.2421b	0.3245ab	0.5352ab	0.5787ab	0.4810ab	0.7197a	0.4417	4.06	0.005
3-Jul	0.2377	0.2762	0.3213	0.4136	0.4983	0.3331	0.6372	0.3882	2.35	0.059
9-Jul	0.2070	0.2094	0.2753	0.3485	0.5528	0.3085	0.5788	0.3543	1.50	0.227
16-Jul	0.2314	0.3785	0.3918	0.4871	0.6529	0.4047	0.7151	0.4659	2.29	0.064
23-Jul	0.1730b	0.3092ab	0.3698ab	0.4531ab	0.5221ab	0.4345ab	0.5674a	0.4042	3.17	0.017
30-Jul	0.2167	0.3717	0.3425	0.3644	0.4318	0.5218	0.5177	0.3952	1.25	0.313
6-Aug	0.1884	0.3445	0.4284	0.4021	0.4363	0.3432	0.4160	0.3655	1.59	0.186
13-Aug	0.1710	0.5016	0.4163	0.3502	0.4110	0.3934	0.4516	0.3850	1.51	0.211
20-Aug	0.1310	0.5509	0.4631	0.4455	0.4121	0.3390	0.4981	0.4057	2.21	0.072
27-Aug	0.1193b	0.5671a	0.4784ab	0.4785ab	0.4504ab	0.5512a	0.5125a	0.4511	3.24	0.015
3-Sep	0.1132b	0.6038a	0.4490ab	0.5488ab	0.7234a	0.6259a	0.4319ab	0.4994	3.36	0.014
$\bar{x}$	0.1818c	0.3959b	0.3873b	0.4388ab	0.5154ab	0.4306ab	0.5496a			

Table 4: Mean biomass (g) of invertebrates collected in native vegetation and food plots established by fallow disking only, fallow disking and fertilizing, or disking, fertilizing, and planting a single species (i.e., browntop millet, iron and clay peas, or sorghum), or a multi-species mix (i.e., browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet) in the Pineywoods of east Texas during spring and summer, 1999. Within rows, means followed by the same letter did not differ ($P > 0.05$).

	Food plot type									
Week	Native vegetation	Fallow	Fallow with fertilizer	Browntop millet	Sorghum	Iron and clay peas	Multiple species	$\bar{x}$	F	P
21-Jun	0.0867c	0.2061bc	0.4792ab	0.6177a	0.5060ab	0.4834ab	0.6681a	0.4353	7.77	<0.001
28-Jun	0.1155b	0.4066ab	0.5339ab	0.6748a	0.3823ab	0.5242ab	0.5304ab	0.4525	3.39	0.012
6-Jul	0.1215c	0.3207bc	0.4902abc	0.6645ab	0.5326ab	0.5500ab	0.8556a	0.5050	6.06	<0.001
13-Jul	0.1051c	0.3482bc	0.4695ab	0.5248ab	0.5721ab	0.4886ab	0.8207a	0.4756	9.06	<0.001
20-Jul	0.0893b	0.2510a	0.4337a	0.4072a	0.3542a	0.4181a	0.4326a	0.3409	11.70	<0.001
4-Aug	0.0515b	0.4754a	0.3825a	0.5760a	0.3893a	0.4890a	0.6249a	0.4269	11.64	<0.001
10-Aug	0.0810b	0.2854a	0.3042a	0.2857a	0.3151a	0.3078a	0.3487a	0.2754	3.77	0.007
17-Aug	0.0328b	0.2394a	0.2186a	0.2882a	0.2502a	0.2798a	0.2756a	0.2264	6.55	<0.001
24-Aug	0.0289b	0.1864a	0.1232ab	0.1446ab	0.1540ab	0.1398ab	0.1843a	0.1373	2.91	0.025
31-Aug	0.0199b	0.0749ab	0.0943ab	0.1264a	0.1128ab	0.0835ab	0.1161a	0.0897	2.78	0.030
6-Sep	0.0179b	0.1502a	0.0467ab	0.1335a	0.0877ab	0.1185ab	0.0572ab	0.0874	3.35	0.018
14-Sep	0.0192	0.0676	0.0550	0.1507	0.0779	0.0851	0.0713	0.0753	2.08	0.088
$\bar{x}$	0.0641f	0.2500cde	0.3026acde	0.3828abc	0.3112acde	0.3307abcd	0.4155ab			

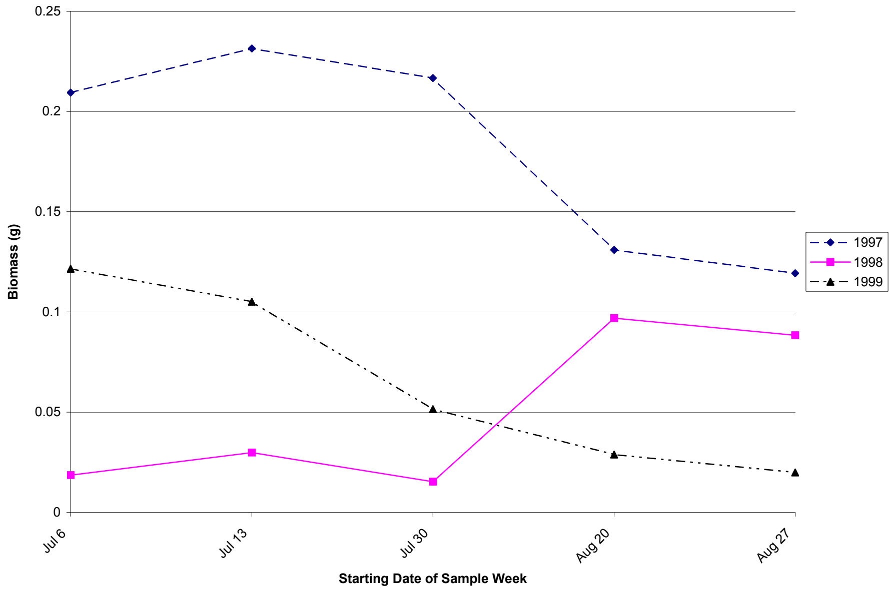

Figure 1: Invertebrate biomass (g) collected in native vegetation in the Pineywoods of east Texas during 5 weekly sampling periods in July and August, 1997, 1998, and 1999.

Discussion

Our results demonstrate the impacts of precipitation on invertebrate biomass in low-growing herbaceous vegetation. June, July, and August 1997 precipitation totals were below the 30-year average each month. However, rainfall was evenly distributed across the 3 months, and biomass remained relatively high throughout the summer. Conversely, the spring drought in 1998 resulted in virtually no vegetation, thus no invertebrates, in cultivated food plots during June and July. However, precipitation in late July and August resulted in relatively high invertebrate biomass in native vegetation by late August. The late July and August 1999 drought resulted in very low invertebrate biomass in late August and early September. These differences among summers are similar to the finding of Burger et al. (1993) in Missouri. They attributed different biomass values from 2 summers to different precipitation regimes. In retrospect, inexpensive rain gauges on each plot may have allowed us to better explain the relationship between the precipitation regime and invertebrate biomass.

When spring rains were sufficient, multi-species food plots consistently produced more invertebrate biomass than either fallow or native vegetation plots during late June and early July. However, by mid-July, vegetation in fallow plots had matured such that invertebrate biomass there equaled or exceeded that in multi-species plots. Although not statistically significant, similar patterns were detected between single-species and fallow plots. Generally, single-species plots had greater biomass than fallow plots in early summer but not late summer, and greater biomass than native vegetation throughout the summer.

With weeks pooled, all cultivated food plot types produced more invertebrate biomass than native vegetation in summer 1997 and 1999. Likewise, cultivated plots generally produced more invertebrate biomass than native vegetation each week. These results parallel those of Parsons et al. (2000*a*), who found greater invertebrate biomass in food plots than in native vegetation on the QMA.

During the summers of 1997 and 1999, invertebrate biomass was generally higher in multi-species food plots than in native vegetation; single-species plots showed similar trends. Likewise, summer-

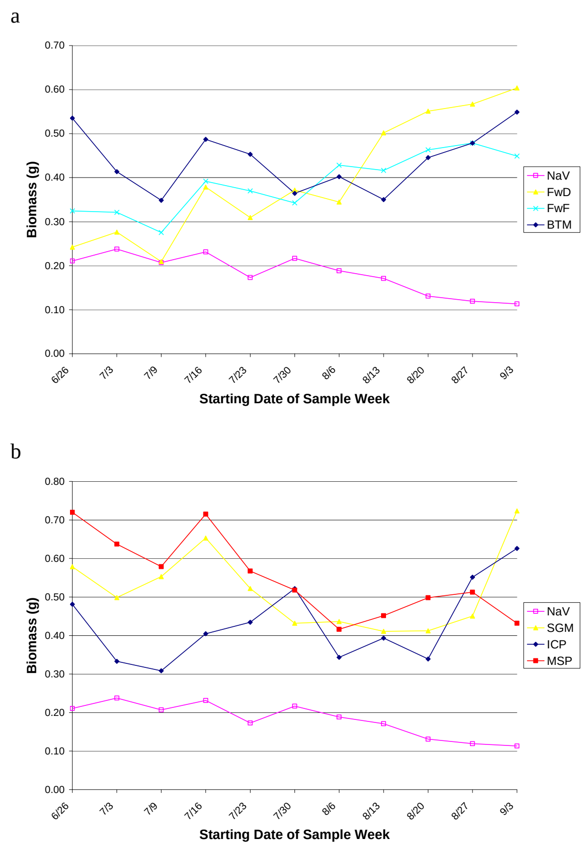

Figure 2: Invertebrate biomass (g) in native vegetation (NaV) and food plots established (a) by fallow disking only (FwD), fallow disking and fertilizing (FwF), or disking, fertilizing, and planting browntop millet (BTM); (b) by disking, fertilizing, and planting a single species (sorghum [SGM], iron and clay peas [ICP]), or a multi-species mix (browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet [MSP]) in the Pineywoods of east Texas during spring and summer,1997.

long biomass was slightly higher in multi-species plots than single-species plots. These differences may have been due to legumes in the multi-species plots. We did not quantify vegetation in food plots, but Burger et al. (1993) recorded more invertebrate biomass in CRP fields planted to red clover than in fields planted to 5 other non-legume species or commercial soybean fields. Conversely, in Mississippi, invertebrate biomass did not differ among Kobe lespedeza, old field, or fertilized old field plots (Jackson et al. 1987).

In early summer, we found few differences in biomass among plots that had been fertilized or fertilized and planted. However, biomass values in such plots were generally higher than biomass in fallow only (i.e., not fertilized) plots. These findings suggest that the application of fertilizer has a greater affect on invertebrate biomass in early summer than

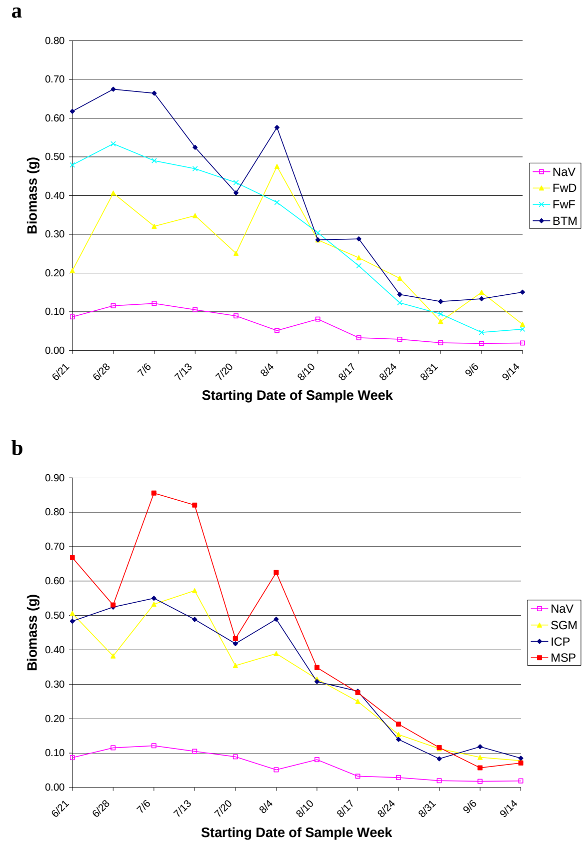

Figure 3: Invertebrate biomass (g) in native vegetation (NaV) and food plots established (a) by fallow disking only (FwD), fallow disking and fertilizing (FwF), disking, fertilizing, and planting browntop millet (BTM); (b) by disking, fertilizing, and planting a single species (sorghum [SGM] or iron and clay peas [ICP]), or a multi-species mix (browntop millet, catjang peas, iron and clay peas, Japanese millet, and pearl millet [MSP]) in the Pineywoods of east Texas during spring and summer,1999.

does the species planted in the food plots.

Although we compared numbers of taxa among food plot types by year, we made no attempt to compare biomass of each invertebrate taxum among food plot types either year. However, Hemiptera and Homoptera dominated biomass samples in cultivated plots and exceeded 50% in all fertilized plot types each year. In Mississippi, fertilized old field and Kobe lespedeza plots produced relatively high biomass of the same orders (Jackson et al. 1987), and in Georgia, millet and sorghum plots had relatively high biomass of Hemiptera, Homoptera, and Hymenoptera (Maidens and Carroll 2002). During a 2-year study in Missouri, Hemiptera and Homoptera biomass values were much higher in red clover fields than in other CRP or soybean fields each year. Within red clover fields, Homoptera made up the highest proportions of biomass each year, while Hemiptera or Orthoptera ranked second (Burger et al. 1993).

Management Implications

Land owners and managers establish food plots for many purposes (e.g., food for other game species, erosion control, road stabilization). As food plots are seldom established solely to benefit bobwhite chicks, our finding and recommendations should be modified to meet other objectives. Regardless of how plots are established or what is planted in

them, the precipitation regime is critical and unpredictable. When spring precipitation is adequate, multi-species food plots provide the greatest invertebrate biomass during the peak hatching period for bobwhite chicks in June and early July. At that time of summer, the mixture of plant species may also provide better overhead protection for hens and chicks than other food plot types. Also, the multi-species plots are more likely to meet other objectives of landowners than are single-species plots. If other factors (e.g., cost, time constraints) are a consideration, single-species and fallow disking with fertilizing food plots produce only slightly less invertebrate biomass than multi-species plots.

During a year of average rainfall, fallow disked food plot types have as much invertebrate biomass as planted and/or fertilized types of plots by mid- to late summer; in dry summers, biomass in fallow disked plots may exceed that in other types of food plots. However, native plant species in fallow plots may provide less overhead protection than is provided by multi-species plots. Regardless, a combination of multi-species (with legumes) food plots and fallow disking should provide invertebrates for bobwhite chicks throughout the summer.

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References

Ault, S. C., and F. A. Stormer. 1983. A suction device for sampling seed availability. Wildlife Society Bulletin 11:63–65.

Brennan, L. A., J. M. Lee, E. L. Staller, S. D. Wellendorf, and R. S. Fuller. 2000. Effects of seasonal fire applications on northern bobwhite brood habitat and hunting success. Pages 66–69 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Burger, L. W., Jr., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1993. Relative invertebrate abundance and biomass in Conservation Reserve Program plantings in northern Missouri. Pages 102–108 *in* K. Church and T. Dailey, editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt, KS, USA.

Dietz, D. R. 1999. Winter food habits and preferences of northern bobwhite in east Texas. Master's thesis, Stephen F. Austin State University, Nacogdoches, TX, USA.

Gould, F. W. 1975. Texas plants: A checklist and ecological summary. Miscellaneous Publication 585, Texas Agricultural Experiment Station, College Station, TX, USA.

Handley, C. O. 1931. Food for the young. Pages 159–164 *in* H. L. Stoddard, editor. The bobwhite quail: Its habitat, preservation, and increase. Charles Scribner's Sons, New York, NY, USA.

Jackson, J. R., G. A. Hurst, and E. A. Gluesing. 1987. Abundance and selection of invertebrates by northern bobwhite chicks. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41:303–310.

Liu, X. 1995. Survival, movements, and habitat selection of relocated and resident northern bobwhite in east Texas. Ph.D. thesis, Stephen F. Austin State University, Nacogdoches, TX, USA.

Liu, X., R. M. Whiting, Jr., B. S. Mueller, D. S. Parsons, and D. R. Dietz. 2000. Survival and causes of mortality of relocated and resident northern bobwhites in east Texas. Pages 119–124 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Maidens, D. A., and J. P. Carroll. 2002. Characteristics of four agricultural crops established as northern bobwhite brood habitat. Proceedings of the National Quail Symposium 5:146–150.

National Oceanic and Atmospheric Administration. 2006. National Weather Sevice. URL `http://www.nws.noaa.gov/`.

Nedbal, M. A., R. L. Honeycutt, S. G. Evans, J. R. M. Whiting, and D. R. Dietz. 1997. Northern bobwhite restocking in east Texas: A genetic assessment. Journal of Wildlife Management 61:855–863.

Olinde, M. W. 2000. Vegetation response to disking on a longleaf pine site in southeastern Louisiana. Pages 32–35 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Parsons, D. S., R. M. Whiting, Jr., X. Liu, and D. R. Dietz. 2000*a*. Food plot use by juvenile northern bobwhites in East Texas. Pages 71–74 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Parsons, D. S., R. M. Whiting, Jr., X. Liu, B. S. Mueller, and S. L. Cook. 2000*b*. Reproduction of relocated and resident northern bobwhites in east Texas. Pages 132–136 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Rosene, W. 1969. The bobwhite quail: Its life and management. Rutgers University Press, New Brunswick, NJ, USA.

SAS Institute, Inc. 2006. Statistical analysis software. SAS Institute, Cary, NC, USA.

Stoddard, H. L. 1931. The bobwhite quail: Its habits, preservation, and increase. Charles Scribner's Sons, New York, NY, USA.

Zar, J. H. 1999. Biostatistical analysis. 4th edition. Prentice-Hall, Englewood Cliffs, NJ, USA.