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INSECTS AND BOBWHITE QUAIL BROOD HABITAT MANAGEMENT

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Recipient of the "Wendell Bever" award presented by the Oklahoma Wildlife Federation to the best paper of the Symposium. The award was in memorium to the late Wendell Bever, former Director of the Oklahoma Department of Wildlife Conservation and Regional Representative of the National Wildlife Federation.

Abstract:

Small insects were the most important foods eaten by quail chicks 2 to 20 days of age. The foods eaten, in order of importance, were beetles, leafhoppers, true bugs, spiders, grasshoppers, ants, larvae, snails, and flies. Important seeds ingested were *Panicum* spp., *Carex* spp., *Scleria* spp., *Paspalum* spp., and *Setaria* sp.

The effect of fire, a major tool in southern quail management, on insect populations was studied by sampling burned and unburned plots with a sweep net and a D-vac machine. On an old-field type of habitat, population densities and biomass of herbivorous insect populations were significantly greater on February-burned plots than on 5-year-old unburned plots. Two peaks in numbers of insects were found. The first peak of ca. 64,000/acre (sweep net) occurred in mid-June. The second peak occurred in mid-August (D-vac) with a density of ca. 90,000/acre. Total insect biomass, excluding individuals over 0.035 g dry weight, averaged 147 g/acre (sweep net) and 128 g/acre (D-vac).

In the second phase of the study, in a longleaf pine forest habitat, grasshoppers were the only species of insect having significantly greater density and biomass on unburned, 3-year-old "roughs" than on annually burned plots. Lack of litter on annually burned plots probably caused this disparity. At peak density, in the period of mid-July to early August, sweep-net density was 19,500/acre and D-vac density was 58,500/acre. Total insect biomass averaged 79 g/acre (sweep net) and 52 g/acre (D-vac).

The major considerations for brood habitat are abundance and availability of insects. In old-field habitat, fire increases insect abundance and removes accumulated litter, opening the area for ease of chick movement. If the soil is fertile, then annual burns are feasible. The interval of burning advocated is 1 or 2 years, but local problems may

modify this. Burning annually in the poor-soil region of the longleaf forest type is not necessary.

The reproductive season is the most important phase of bobwhite quail life history, but little is known about needs of quail chicks. Indeed, the phrase "brood habitat management" is probably new to most game managers. We lack knowledge about the survival of young stages of many wildlife species, so the problems of youth in nature must be studied (12).

A study conducted in Georgia (4) found an average mortality of 50% in quail between hatching and 15 weeks of age. The highest mortality occurred during the first 2 weeks of life. Causes of chick mortality vary, but I believe the abundance and availability of foods should be considered foremost (3,5). Quail chicks have an extremely high demand for protein during the first 2-3 weeks of life; about 28% of their diet must be protein (11). Few data are available concerning the food habits of quail chicks. The most detailed study (5) reported that chicks mainly ate insects in the first 2 weeks posthatching then gradually changed to a diet containing more vegetable matter. One objective of my research was to obtain data on quail chick food habits, emphasizing the ingestion of insects.

In the Coastal Plain region of the South, 2 quail management practices are used widely: controlled burning and food plots. The effects of controlled burning on insect populations have not been studied extensively (8). The second objective of my research was to study the effects of fire on insect populations.

I want to thank Mr. Alton Dunaway for his assistance in the longleaf pine study which was financed by the Bass Pecan Company, of Lumberton, Miss. I wish to particularly thank Mr. Robert Clanton and Mr. Vernon High of that Company.

Many thanks are due various people and organizations who helped with the right-of-way study. Special gratitude is extended Dr. Walter Drapala and Mr. Dave Horton, Department of Experimental Statistics, Mississippi State University. I also want to acknowledge the help of Dr. Dale Arner and others of the Department of Wildlife and Fisheries, MSU. Finally, I thank my wife "Ting" for her many hours of help in the field and sorting insects.

Study Areas

Two study areas are referred to in this paper. The first area is a 150-ft-wide power line right-of-way (ROW) located 10 miles W of Starkville, Mississippi. The land form present is the Interior Flatwoods of the Upper Coastal Plain, in Oktibbeha County. The ROW was originally cleared in 1965 and has not received any maintenance. Second growth mixed hardwoods and pine forest, about 30 years old, border the ROW. The plant community on the ROW is a dense growth dominated by broomsedge (*Andropogon* spp.) and to a lesser extent by panic grasses (*Panicum* spp.). Forbs, such as *Eupatorium* spp. *Helianthus angustifolius*, and Erigeron spp., are numerous, as are many other less abundant herbaceous types, especially various lespedezas (Lespedeza spp.). Soil on the ROW is Prentiss silt loam, with a hard pan at a depth of 8-12 inches and a slope of 0-8%.

The second area is located in a longleaf pine (Pinus palustris) forest 10 miles NW of Lumberton, Mississippi. Its land form is Pine Hills (PH) of the Lower Coastal Plain, in Lamar County. The PH area has a long history of grazing by free-ranging cattle and sheep and of burning by annual, wide-sweeping, uncontrolled fires. The 45-year-old longleaf stand had not been cut until the fall of 1968, when Hurricane Camille "thinned" the stand, which had a basal area of 75 sq ft/acre but lacked hardwoods in the overstory. Ground vegetation is dominated by broomsedge and wiregrass (Aristida spp.). The third most important species is hoary pea (Tephrosia spp.), and panic grasses are fourth. PH-area soils are McLaurin fine sandy loam on the hill tops and McLaurin-Lucy association on the slopes; these soils are very low in natural fertility. Slope varies from 0-25%.

The PH study area was divided into 2 parts. The first part was located in an area burned annually for an unknown number of years. The fires usually were set in late winter or early spring, but some summer or fall burns also have occurred. The first part is devoid of hardwoods and is essentially a grassland-pine woods pasture. The second part, a 3-year-old "rough" (3-YOR), located about 1 mile from the first part, has not been burned since the fall of 1968. This second part contains many young hardwoods about 2-3 ft high.

Methods

The ROW study was based on 10 plots, each 0.4 acre in size, located along 1 mile of the right-of-way. Plots were adjacent or continuous in some cases, but were separated by dirt roads or small, temporary creeks in 4 cases. Insects on the plots were sampled, 5 sweep net (SN) and 4 D-Vac Vacuum insect net (DV), in the summer of 1968. An analysis of variance of the total insect dry weights on the plots showed the plots to be comparable. The 10 plots were then subdivided into 20 0.2-acre subplots. In February 1969 one subplot, selected randomly, of each plot was burned. In the summer of 1969, from early June to late August, the subplots were sampled again, including 4 SN and 3 DV.

The PH study contained 2 study areas located about 1 mile apart but in the same longleaf pine forest. In 1 study area there were 3 1-acre plots which had been burned annually (AB) for years, the last burn having taken place in February, 1971. In the other study area there were also 3 1-acre plots. These latter plots were 3-year-old "roughs" (3-YOR) and had not burned since the fall of 1968. In both study areas the plots were from 100 to 200 yards apart and were subdivided into 0.25-acre subplots to allow subsampling. Insects on the subplots were sampled, 4 SN and 3 DV, from mid-June to mid-September, 1971.

A completely randomized design was used in the ROW study. An analysis of variance (AOV) compared numbers and dry weights of major species of insects on the 10 burned plots versus those on the 10 unburned plots. An AOV was also used to compare total dry weight of insects on the treated (burned) plots versus total weight on unburned plots. The total numbers of insects collected on burned and on unburned plots were compared statistically by a 2 x 3 and a 2 x 4 factorial AOV.

When all samples had been completed, a multiple AOV was used to determine significance for the lumped samples, 3 DV and then 4 SN, each type of sample being analyzed separately. Duncan's New Multiple Range Test (DNMRT) was used to distinguish significant means.

A randomized complete block design with subsampling was used in the PH study. An AOV was used to compare quantities and dry weights of the major species of insects on the AB plots versus those on the 3-YOR. Total dry weight of insects in the samples was included in the AOV. Factorial analysis for total insect numbers was not performed due to unequal sample size.

Admittedly, sampling of insect populations is not a precise science. In an attempt to gain valid results, I used 2 different sampling techniques. Sampling was done by 1 technique every 2 weeks. The SN consisted of a 19-inch handle, 30-inch deep heavy-duty net, and a hoop diameter of 15 inches. A SN sample consisted of 144 strokes per 0.2 acre (ROW) and 72 strokes per 0.25 acre (PH). Sample size was reduced in the PH study because the vegetation was not as dense and was more uniform than in ROW. A stroke was made so as to strike as near the ground as possible and to remain parallel to the ground for 50 inches. I moved at a fast walk (28-32 sec to take 36 strokes). The strokes were taken on straight lines from 1 end of a subplot to the other, 36 strokes per line (ROW) and 24 strokes per line (PH). A different starting point was chosen randomly for each sample. A single SN stroke was calculated to have a volume of 8,831 cu. inches, a 15 inch circle traveling 50 inches. Therefore, 144 strokes (ROW) would be 6.83% of the total possible volume within 15 inches over 0.2 acre. The PH sample (SN) was calculated to be 3.75% of the total possible volume within 15 inches over 0.25 acre.

The DV machine having an intake nozzle diameter of 6.5 inches, was held about 6 inches from the ground or litter. A DV sample consisted of carrying the machine in a straight line, 4 lines per 0.2 acre (ROW) for a total of 525 ft and 4 lines per 0.25 acre (PH) for 420 ft. I moved at a fast walk (25-30 sec to travel 100 ft). The lines went from one end of a subplot to the other end, with a starting point being randomly chosen for each sample. The DV sample was trapezoid in shape, the top being 6.5 inches wide, the bottom 12 inches wide., and 6 inches high. A DV sample was calculated to be 4.67% of the total possible volume within 6 inches over 0.2 acre, and 3.40% within 6 inches over 0.25 acre.

Insects in a sample were killed by spraying them with carbon tetrachloride after which they were sorted manually from the debris, identified, counted, dried at 83 C for 7 hr, and weighed on a top-loading balance. All weights listed are oven-dry. Individual insects weighing more than 0.035 g were discarded as they were considered too large to be ingested by quail chicks.

The 2 sampling methods give quite different results for total number and total insect weight. The SN is more efficient at collecting large, fast-escaping types, especially grasshoppers. Therefore, this method collects greater total dry weight of insects. The DV captures considerably more of the extremely small insects, thus it collects a much higher quantity of insects. The DV represents best what is available for quail chicks because it samples in the feeding zone of chicks, up to 6 inches above ground, collects tiny insects of the size usually eaten by chicks, and collects the types (slow moving) usually eaten by chicks.

The main objective of the research was to determine if the insect total weight or total number, by insect type, differed between burned and unburned subplots. Thus the 2 types of sampling methods would have to agree in capture characteristics in order for the results to be acceptably comparable. Regarding the question of insect density and biomass, the differences in the sampling methods must be remembered. The results of the sampling can be converted because sampling of the same plots on the same day showed the following ratios, DV:SN, to exist as far as number caught: spiders 3:1, flies 5:1, ants 4:1, and homopterans 1.6:1. The SN and DV collected beetles and hemipterans at about the same ratio. The SN collected twice as many orthopterans as did the DV. The total dry weight of insects in the SN was about twice as much as in the DV.

Newly hatched quail chicks, 126 in the ROW and 38 in the PH study, were placed with a broody bantam hen. When adoption was complete, a brood containing 7-20 chicks was released on a burned plot in the ROW study and on both 3-YOR and AB plots in the PH study. Fewer chicks were used in the PH study than in the ROW study due to a lack of time and personnel. Also, chicks not eating anything were not included in the results, and there were a greater number of noneating chicks in the PH study. The chicks, age 1-20 days, were able to move about the entire plot in search for food items. Each brood remained on the plot for 5-10 hr, then was picked up and killed immediately at dusk. Crop and gizzard contents were combined for the ROW study, but in the PH study only crop contents were counted to reduce a possible bias.

Three criteria were used to arrive at a relative-importance value for the insects eaten: average number of a given species of insect per chick, frequency of occurrence, and my ocular estimate of the weights of the insects eaten. Having weighed the same insects many times from the insect samples, I could estimate quite accurately relative weights of the insects eaten by chicks. Weight estimates were ranked from 1 to 8, with 1 being the heaviest. The relative importance of seeds found in chick crops, or in crops and gizzards combined, was based on the average number of certain species per chick.

Results

Quail Chick Food Habits-Insects

Adopted Quail Chicks

A total of 126 quail chicks, age 2-15 days, was used on the ROW plots. Table 1 presents the 3 relative-importance criteria for insects eaten by these chicks from early June to late August.

Table 1. Average numbers of insects in crops and gizzards of 126 quail chicks, age 2-15 days, released on the ROW burned plots.

Criterion	Type of insect						
	Spider	Ant	Fly	Leaf-hopper	True bug	Grass hopper	Beetle
Avg. No./ chick	1.2	3.6	0.7	1.7	2.2	1.2	3.6
% Frequency occurrence	27	74	9	21	61	12	83
Rank of wt. importance	4	6	7	3	2	5	1

Combining the 3 criteria, and emphasizing weight, insect types rank from most important to least important as follows: beetles, true bugs, leafhoppers, spiders, ants, grasshoppers, and flies. Chicks ate some larval forms (lepidopterans), tiny hymenopterans, snails, and moths, but did not eat any type of insect that was not collected by the SN or DV sampling techniques.

Beetles eaten were mostly small weevils (Curculionidae) and leaf beetles (Chrysomelidae). The important true bugs included a herbivorous lygaeid (*Oedancala* spp.), the negro bug (*Corimelaena* spp.), and stink bug nymphs (Pentatomidae). Ants consumed were mostly fire ants (*Solenopsis* spp.), whereas spiders eaten were ground spiders (Lycosidae). Grasshoppers taken as food were first or second instar stages of *Conocephalus strictus* and *Melanoplus* spp.

Chicks less than 1 week old ate more insects than did older chicks. Younger chicks averaged 9 beetles each, whereas older chicks averaged only 2.8 each. The other comparisons, presenting first in each case the average numbers in younger chicks, were: ants 7-3.1, spiders 4-0.8, true bugs 5-1.8, leafhoppers 4-1.4, grasshoppers 2.4-1.1, and flies 2-0.5. Frequency of occurrence percentages were also higher for the younger chicks.

Insects eaten by 38 chicks, age 1-20 days, but mostly 6 days, in the PH study, are summarized in Table 2. According to the 3 criteria, rank of importance, from most important to least important would be: beetles, leafhoppers, ants, spiders, larval forms, true bugs, grasshoppers, and flies.

Table 2. Insects in crops and gizzards of 38 quail chicks released on the AB and 3-YOR PH plots.

Criterion	Insect category							
	Spider	Ant	Fly	Leaf-hopper	True bug	Grass-hopper	Bee-tle	Larval* forms
Avg. No./ chick	5.2	6.4	1.9	4.2	1.9	2.5	3.2	2.0
% Frequency occurrence	50	95	32	32	24	10	45	37
Rank of wt. importance	5	3	8	2	6	7	1	4

*Mostly Lepidopterans

Wild Quail Chicks

A summary of food items found in the crops of 6 wild quail chicks is presented in Table 3. Chicks labeled A-C were captured in habitat very similar to the ROW, and chicks D-F were caught in the longleaf pine forest habitat (PH).

Table 3. Insects found in the crops of 6 (A-F) wild quail chicks, age 7-14 days.

Arthropod type	Actual number found in the crop					
	A	B	C	D	E	F
Spider	10	9	2	5	3	44*
Fly	0	1	0	0	0	0
Ant	1	2	0	2	0	0
Grasshopper	2	2	1	0	1	2
True bug	8	7	3	3	0	5
Leafhopper	36	12	9	5	1	12
Beetle	3	3	4	12	3	3
Hymenopteran	0	0	0	0	0	2
Larval form**	3	0	0	3	0	24
Snail	1	0	0	24	0	0

*Including one female with 42 newly hatched young
**Lepidopteran and Coleopteran

Leafhoppers ranked first in number eaten per chick, followed by spiders, beetles, and true bugs. In frequency of occurrence, beetles, spiders, and leafhoppers all rated 100%, followed by true bugs and grasshoppers. According to the 2 criteria above and my weight estimates, the rank of importance, most important to least, is: beetles, leafhoppers, true bugs, spiders, larval forms, grasshoppers, and the other types.

The chicks, whether adopted or wild, ate extremely small insects in most cases. Most food items were <8 mm long and weighed <0.005 g. The largest item eaten was a grasshopper that was 20 mm long and weighed 0.051 g. This individual was partly in the crop and extended all the way into the chick's gizzard. This grasshopper was the only exception to the weight of 0.035 g chosen as being too big for ingestion by quail chicks. Other large examples were a June beetle (0.027 g), a ground beetle (0.022 g), an adult stink bug (0.030 g), and a lepidopteran larval form 20 mm long and weighing 0.021 g.

It is not known how much food, insects and/or seeds, quail chicks eat or need per day. Some preliminary data are presented as indicators. A wild quail chick, about 9 days old, had a total of 0.212 g of insect food in its crop and 0.017 g of seeds in its crop and gizzard combined. The greatest amount eaten by an adopted chick, 14 days old, was 0.203 g of insect food in the crop and 0.014 g of seeds in the crop and gizzard combined. These were the largest amounts found in crops of chicks; most chicks had eaten much less.

Quail Chick Food Habits-Seeds

Estimates of seed abundance and availability on the study areas were not made. Consequently the results of this phase of the chicks' food habits will be restricted to a brief summary of the more important species of seeds found in the chicks' crops. The ROW chicks, age 2-20 days, ate mostly *Panicum lindheimeri* and *Carex cherokeensis* seeds. Other important species were *Scleria* spp. and *Paspalum* spp. *Panicum anceps* became important in August, when the seeds matured. Many seeds of P. *lindhimeri* and Scleria spp. were eaten directly from the plants. Wild quail chicks caught in habitats similar to the ROW had eaten mostly *Panicum* spp. seeds, as well as *Scleria* spp., *Digitaria* spp., and *Setaria* spp. Adopted chicks in the PH study ate *Panicum* spp. seeds mostly, but also consumed *Scleria* spp., *Cardamine* spp., and *Paspalum* spp. Wild quail chicks captured in the PH area had eaten mostly *Panicum* spp. seeds, along with some *Scleria* spp. and *Cardamine* spp. seeds.

Insect Samples-ROW Study

Results of the 7 samples, 4 SN and 3 DV, taken in the summer of 1969 on the ROW plots are presented in Tables 5 and 6. The AOV results for insect mean numbers and mean dry weights are also given.

Spiders were most numerous and had the greatest dry weight on the burned plots, but differed from unburned plots significantly in only 2 samples by number and 3 samples by weight. Ants were significantly greatest in number in all 7 samples and significantly heavier in total weight in 5 of the 7 samples on burned plots. Flies were generally more numerous, but not significantly so, on unburned rather than burned plots. Leafhoppers numbered and weighed significantly more on burned plots in all samples. True bugs were more numerous and weighed more on burned plots, but the differences were significant only at peak true-bug density. Beetles were most numerous and totalled greatest weight on the burned plots in 4 of the 7 samples. All families of the Order Orthoptera (grasshoppers, etc.) were significantly more numerous and weighed significantly more on burned than on unburned plots.

Total dry weight of insects was significantly greater on burned plots in all 7 samples. Mean dry weight of insects in the 4 SN samples was 2.657 g on burned and 1.356 g on unburned. The 3 DV samples averaged 1.222 g on burned plots and 0.660 on unburned plots.

The multiple sample AOV, one for each sample type, confirmed the results of the individual sample AOV. In fact, Duncan's New Multiple Range Test disclosed significant differences both in number and in dry weight of some species of insects, on a given date, that the AOV had shown to be nonsignifcant. Significant interactions between treatment (burn) and date of sample were found and were attributed to increase or decrease in insect populations.

The factorial analyses for SN and for DV disclosed significantly more insects on burned plots than on unburned. The mean sample number for SN was 586 on burned and 311 on unburned. The mean sample number for DV was 718 on burned and 432 on unburned.

Insect Samples-PH Study

The results of the PH samples, 4 SN and 3 DV, taken during the summer of 1971, are shown in Table 7. The mean number, mean dry weight, and the AOV results are presented for the major insects by sample date. Most insects were more abundant and heavier in total dry weight on the unburned 3-YOR than on the AB plots. These differences were usually not significant. Only one type of insect, grasshoppers, had significantly more numbers and dry weight, occurring in the 3-YOR, in all 7 samples.

The 3-YOR plots contained greater total dry weight of insects in all samples, the differences being significant in 5 of the 7 samples. Grasshoppers made up 64% of the total insect weight, so they greatly influenced the total insect dry weight, in favor of the 3-YOR. The average of the 4 SN samples, total insect dry weight, was 0.630 g on the 3-YOR and 0.414 g on the AB plots. Total insect dry weight, in the 3 DV samples, averaged 0.375 g on the 3-YOR and 0.174 g on the AB plots.

Insect Density and Biomass

Total insect density and biomass for the 2 studies are presented in Tables 8 and 9. The reader should recall that sampling was conducted from the quail chick's "point-of-view", near the ground, and that large specimens of insects were disregarded. The less numerous types of insects, moths, damselflies, etc. were not included. The expanded figures, insects/acre or biomass/acre, were made on the basis of the calculated volume of a single SN or DV sample. The data for the 2 sampling methods was kept separate, and the reader must remember the great differences between the 2 types of samples.

Table 5. Comparison of mean number and mean dry weight (g) and the statistical significance for arthropods on burned and unburned plots for the 7 ROW samples, 1969.

Sample date & type	Treat-ment	Araneida No.	Araneida Wt.	Formicidae No.	Formicidae Wt.	Diptera No.	Diptera Wt.	Homoptera No.	Homoptera Wt.	Hemiptera No.	Hemiptera Wt.	Coleoptera No.	Coleoptera Wt.
6/3	B[2]	72	.193	67*[3]	.034	68	.035	102**	.106**	83	.152**	38	.073*
DV[1]	U	71	.184	30	.016	53	.035	70	.058	63	.105	28	.050
6/17	B	74	.292*	51*	.026	27	.058	210**	.370**	219**	.395*	174**	.316**
SN	U	64	.200	31	.017	35	.043	84	.131	105	.240	47	.154
7/1	B	90	.206	105**	.041**	42	.026	198**	.243**	104**	.222**	103**	.138
DV	U	87	.177	42	.017	55	.044	90	.134	60	.115	62	.094
7/14	B	61*	.256**	29**	.011*	12	.011	78**	.141**	74	.280	111**	.190
SN	U	41	.126	9	.003	26	.038	52	.092	61	.261	65	.171
7/29	B	61*	.237*	28**	.010*	21	.018	115**	.177**	58	.188	84	.136
SN	U	43	.117	10	.004	22	.023	57	.090	42	.197	55	.101
8/11	B	158	.153	165**	.052**	128**	.027	186**	.150**	58	.102	121	.107*
DV	U	142	.132	51	.017	78	.028	102	.097	46	.078	64	.053
8/29	B	53	.198	61**	.024*	21	.013	119**	.130*	50	.189	127*	.150**
SN	U	40	.142	16	.006	22	.021	52	.091	50	.156	89	.102

1. DV=d-vac and SN=sweep net 2. B=burned and U=unburned 3. *=5% and **=1% level of significance

Table 6. Comparison of mean number and mean dry weight (g) and the statistical significance for families of Orthoptera and the total arthropod sample dry weight on burned and unburned plots for the 7 ROW samples, 1969.

Sample date & type	Treat-ment	Orthoptera--Family								Total dry weight of sample
		Tettigoniidae		Gryllidae		Acrididae		Tetrigidae		
		No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	
6/3 DV[1]	B[2]	70**[3]	.144**	6*	.022*	37**	.086**	19.0**	.076*	0.942**
	U	24	.040	4	.010	4	.013	0.5	.002	0.545
6/17 SN	B	65**	.331**	9**	.053	41**	.234**	3.4**	.034*	2.196**
	U	38	.156	6	.030	18	.063	0.3	.003	1.089
7/1 DV	B	43**	.157**	10**	.054*	30	.177**	4.7**	.078*	1.418**
	U	24	.048	5	.022	20	.068	0.3	.004	0.764
7/14 SN	B	40**	.316**	4**	.028*	70**	.769**	3.6*	.055*	2.477**
	U	17	.111	1	.012	31	.240	0.2	.004	1.189
7/29 SN	B	35**	.369**	3**	.016	63**	.984**	3.1**	.067*	2.665**
	U	15	.147	1	.005	27	.364	0.0	.000	1.223
8/11 DV	B	13**	.178**	9**	.009	15**	.230**	0.1	.001	1.305**
	U	6	.060	2	.008	8	.126	0.0	.000	0.673
8/29 SN	B	16	.317**	9**	.014	16**	.268**	0.6	.015	1.414**
	U	12	.198	3	.012	8	.162	0.1	.001	0.954

1. DV=d-vac and SN=sweep net 2. B=burned and U=unburned 3. *=5% and **=1% level of significance.

Table 7. Comparison of mean number and mean dry weight (g) and the statistical significance for arthropods on annually burned and 3-year-old "roughs" (unburned) for the 7 PH samples, 1971.

Sample date & type	Treatment	Spider No.	Spider Wt.	Ant No.	Ant Wt.	Fly No.	Fly Wt.	Orthop. No.	Orthop. Wt.	Homop. No.	Homop. Wt.	Hemip. No.	Hemip. Wt.	Coleop. No.	Coleop. Wt.	Total dry wt.
6/12 SN[1]	UB[2]	21	.103	15	.004	11	.009	40**[3]	.563	17	.021	2	.016	15	.024	.767
	B	14	.035	12	.002	6	.005	15	.287	16	.022	1	.006	18	.030	.459
7/1 DV	UB	56**	.127*	63	.013	69**	.030**	35*	.221**	32	.035	1	.004	21	.028	.478**
	B	23	.027	82	.017	27	.014	15	.076	42	.032	1	.004	16	.018	.209
7/15 SN	UB	39	.134**	20	.007	22	.021*	37**	.570**	22	.042	2	.010	30**	.078*	.862*
	B	27	.058	25	.006	14	.005	20	.209	28	.026	2	.007	16	.036	.568
8/4 DV	UB	89**	.081*	68	.010	205**	.030**	22**	.142**	35	.029	12*	.012	51	.055*	.398**
	B	36	.032	30	.005	89	.011	10	.062	33	.018	2	.011	26	.018	.180
8/18 SN	UB	35	.078	25	.005	39	.019	24**	.372**	13	.022	3	.009	22	.037	.588
	B	27	.053	24	.008	40	.023	12	.179	26	.046**	4	.011	26	.043	.480
9/2 DV	UB	37	.042	55	.010	0[a]	0	10**	.105**	31	0.31	14	.014	17*	.022*	.249**
	B	28	.026	63	.011	0	0	3	.031	50	.039	5	.005	13	.009	.133
9/23 SN	UB	26**	.038**	36	.007	45*	.022*	7**	.117*	20	.029	9	.016	18	.038	.306**
	B	13	.017	32	.005	28	.012	2	.045	22	.027	5	.010	15	.027	.152

1. SN=sweep net; DV=D-vac machine 2. UB=3-year-old "rough"; B=annual burn 3. *=5% level of significance; **=1% level of significance; a/=not counted.

Insect Density

The SN sample of 17 June, with an expanded insect density of about 64,000/acre on burned plots, was significantly greater than the other 3 SN samples and could be considered the peak of insect density. The remaining 3 SN samples showed insect density to be about 35,000/acre. This density was not significantly greater than the 31,000/acre on unburned plots at the peak density, but was significantly greater than the other densities (dates) on unburned plots.

The 3 DV samples on burned plots showed an increase in density, from 59,000/acre to 77,000/acre to about 90,000/acre, in mid-August. DNMRT determined that the last sample, in mid-August, was significantly different from the previous 2 and could be considered as a peak in insect density. Apparently, 2 peaks in insect density occurred on the ROW plots.

In the PH study (Table 9), a comparison of total insect numbers on the 3-YOR and the AB plots was not tested for significance. There seems to be little difference, however, except on 4 August. On the 3-YOR plots, the DV total density varied from about 33,000/acre in early July to a peak of 58,500/acre in early August. It appears that the August total density would be significantly different from the much lower 33,000 in July or the 21,500 in September. There does not appear to be much difference in the SN densities, from 13,300 in 12 June to a high of 19,500 in mid-July. The highest density was recorded just previous to the peak DV density, suggesting that a single peak in insect density occurred in late July and early August.

Insect Biomass

The burned plots (ROW) always held significantly more dry weight of insects than the unburned, so the expanded figures would also be significantly different. The total insect biomass figures were not tested for differences by dates, but with the SN method the differences, 104 g/acre to 195 g/acre, do not appear to be too great. The lower figure in late August was due to most grasshoppers being larger than 0.035 g, and therefore discarded from the sample. The DV method showed an increase from 99 g/acre in early June to 149 g/acre in early July. The mid-August sample is about the same as the early July total.

Total dry weights of PH samples were significantly different, favoring the 3-YOR in 5 of the 7 samples. The expanded figures on total insect biomass were also significantly different. The SN totals on the 3-YOR plots were much alike for the first 3 samples: 82, 92, 63 g/acre, but decreased in late September to only 33 g/acre. The DV method indicated the same trend, about the same biomass in July and August, 56 and 47 g/acre respectively, and then a drop to 29 g/acre in early September. If there was a peak in insect biomass, it occurred in the period of early to mid-July.

Differences in total insect density or biomass on ROW plots versus PH plots were not tested for significance, but the differences appear to be great. The ROW plots produced many more insects. The PH area was particularly devoid of true bugs and had far fewer beetles. These notations were reflected in the number eaten by quail chicks on the respective study areas.

Table 8. Insect density and biomass on ROW burned and unburned plots, 1969.

Sample		Density (No./acre)		Biomass (g/acre)[2]	
Date	Type[1]	Unburned	Burned	Unburned	Burned
Jun 3	DV	36,555	59,034	57	99[3]
Jun 17	SN	31,405	63,982	80	161
Jul 1	DV	46,850	76,681	80	149
Jul 14	SN	22,255	35,360	87	181
Jul 29	SN	19,912	34,553	90	195
Aug 11	DV	52,416	89,706	70	137
Aug 25	SN	21,450	34,627	70	104

1 DV=D-vac machine SN=Sweep net
2 Excluding all individuals over 0.035 g and less numerous types of insects
3 All significantly different at 1% level

Table 9. Insect density and biomass on AB and on 3-YOR plots in the longleaf pine forest (PH).

Sample		Density (No./acre)		Biomass (g/acre)[2]	
Date	Type[1]	3-YOR	AB	3-YOR	AB
Jun 12	SN	13,332	9,387	82	49
Jul 1	DV	33,412	24,706	56**	24
Jul 15	SN	19,520	15,468	92*	60
Aug 4	DV	58,472	28,472	47**	21
Aug 18	SN	18,452	17,920	63	51
Sep 2	DV	21,412	19,884	29**	16
Sep 23	SN	17,812	12,692	33**	16

1 DV=D-vac machine SN=Sweep net
2 Excluding all individuals over 0.035 g dry weight, and less numerous insects
**Significantly different 1% level, * 5% level

Discussion

The results of the study illustrate the great importance of insects in the diet of young quail chicks. The highest rate of chick mortality has been reported to be in the first 2 weeks of life (4), the same period when insects are the most important food items. The survival of chicks might be decreased by a decrease in the quantity of insects in June or July, at which time they are vital (3,6). A greatly lowered insect biomass, due to the use of herbicides in agricultural crops, was thought to be the most important cause of grey partridge (Perdix perdix) chick mortality in England (15).

Quail chicks need an abundance of tiny insects and the insects must be available. The study on the ROW showed significantly more insects and significantly more insect biomass on the burned plots than on the unburned areas. The herbivorous types of insects: beetles, true bugs, leafhoppers, and grasshoppers, were particularly more abundant on the burned plots. These same types of insects were the most important chick foods. The increase in insect density on the burned plots was attributed to the lush, succulent vegetative growth that followed the burn. The abundance of foliage insects is dependent upon the amount of green foliage (7) and the nutritional level and palatability of the plant material (10). The increased palatability and nutritional value of plants on recently burned areas has been documented previously (9).

Not only were there more insects on the burned areas, but the insects were more available (21). The question of availability of insects as chick food items is complex, involving insect density, size, type, and vegetative conditions. Quail chicks must be able to move about freely in search of insects. A dense "jungle-like" plant community or a deep layer of accumulated litter renders an area unfit as brood habitat. The chances of a chick becoming entangled, exhausted, lost, preyed-upon, or wet-chilled, are increased by having a dense layer of dead or living plants at the chick's level (2,17). Fire will remove most of the accumulated litter and thus open an area so that quail chicks can use it as brood habitat. In an area with good soil fertility, such as the ROW, annual burning is a must to increase the availability of insects.

At first glance, the results of the PH study appear to contradict the beneficial aspects of fire as a brood habitat management tool. The 3-YOR plots had more insects than did AB plots, but the only significant difference was in the number of grasshoppers. Grasshoppers were not an important chick food, although other studies have found them to be important (5). Grasshoppers were not eaten in proportion to their abundance, or particularly in proportion to their great amount of biomass, which was 64% of the total insect biomass. Grasshopper density was probably lower on the AB plots because litter was lacking. On the Minnesota Prairie, grasshopper density is highest where there is a light-to-medium amount of litter (23). If the litter increases or decreases from optimum, due to fire or grazing or to no fire, grasshopper density decreases. The exact relationship between grasshopper density and litter is not known, but cover, shade, soil temperatures, and oviposition sites must be considered.

Three years of accumulation of litter is too much in the longleaf pine habitat; a 1-to-2-year interval between burning has been recommended (20). This recommendation seems well founded for improving brood habitat. A 1-year-old-"rough" will provide adequate litter so that grasshopper density will increase.

The ROW plots produced much more insect density and biomass than the PH plots. Undoubtedly the difference is due to the rather infertile soils of the longleaf pine habitat and to past history. The "piney woods" were grazed by sheep and cattle for many years, and these herbivores account for a plant community dominated by broomsedge and wiregrass (19) and the lack of a rich flora. Native legumes and palatable grasses have been practically eliminated. Ill-timed fires also contributed to the lack of a more varied flora. Insect density and biomass seems adequate on the ROW plots, but PH habitat has a low carrying capacity as brood habitat.

Another feature of brood habitat carrying capacity is the amount and availability of seeds. The youngest chicks used in my studies ate seeds. A 4-day-old chick ate 165 panic grass seeds. A 6-day-old consumed 240 panic grass, 70 *Carex* spp., and 17 miscellaneous species of seeds in 1 afternoon. The importance of seeds, especially early maturing panic grass species, was reported earlier (5). Fire is routinely used to increase commercial seed production, so this would further add to the advantages of using fire in brood habitat management.

Insect abundance and availability are the prime factors to consider in trying to determine the carrying capacity of an area as brood habitat. Currently, not enough is known about wild quail chick needs, their daily insect consumption, or about availability of insects (16). Insect abundance is influenced by many factors (14), the type of plant community being prominent. Legumes were thought to attract or produce more insects than nonlegumes (17). The attractiveness of certain crops, soybeans, peas, and other developing fields of legumes, for young quail has been noted (13,17). A study in Georgia (1), found that mixed-forb fields, early seral stages of plant succession in the southeast, produced many more insects than did later stages, such as broomsedge fields. From the aspect of insect abundance, brood habitat should favor legumes and mixed forbs. Fire, used properly, will produce a variety of luxuriant vegetation and favors legumes (9,17). When using fire the manager should finish all burning before insect emergence and hatching of the overwintering eggs takes place. Woody-brushy areas, which serve as brood-holding areas, should be saved from burning. Burning in strips or patches is recommended, to leave preferred nest habitat adjacent to brood habitat. The interval of burning will depend on local conditions, but the factors of insect abundance and availability should be considered equally. To have many insects under poor feeding conditions, dense vegetation, or accumulated litter, is worse than having fewer insects under ideal "catching" conditions.

Another way of increasing insect abundance and availability is by planting an agricultural crop or wildlife food plant species; properly fertilized, it will generally produce a lush, green vegetative growth.

So-called "clean" farming is not desired; weedy fields are the goal. A low-growing species is preferred so that insects are concentrated in the chicks feeding zone; 0-8 inches above the ground. Although not completely tested, kobe lespedeza appears to be an excellent species for high insect production, but its density must be controlled by light discing.

During the patch-farm era in the South, quail densities were high. The many small, scattered, cultivated fields and the continued use of fire in the woods combined to produce ideal quail habitat (18). Brood habitat was certainly abundant. High quail densities, 1 or 2 birds to the acre, are found on areas in the South today and these areas use fire and food (brood) plots. While speaking of the needs of wild turkey poults, the Dean of Quail Management, Herbert L. Stoddard, said that "preferred insect catching grounds" should be created (22). These insect or "bugging" habitats can be created by fire or cultivation, or a combination of the two.

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THE RESPONSE OF BOBWHITE COVEYS TO DISTURBANCE DURING FIELD TRIALS

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The characteristically sedentary nature of bobwhites is well documented by intensive research and is generally well known to hunters and