EVALUATING PHYSIOLOGICAL CONDITION OF BOBWHITE QUAIL

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Abstract: A total of 146 bobwhite quail (*Colinus virginianus*) was collected during the winters of 1972-73 and 1973-74, from 2 study areas in Tennessee and 1 area in Florida. Body weight, levels of body fat, burden of gastrointestinal helminths, and adrenal weights were determined. Quail from the Tennessee areas were significantly ($P < 0.05$) heavier than those from the Florida area. Fat was extracted using a Soxhlet ether extraction apparatus, and was expressed as a percentage of oven-dry body weight. Percentage body fat differed significantly ($P < 0.05$) among all areas, being greatest in east Tennessee (13.7%) and least in Florida (10.4%). Infection rates of gastrointestinal helminths varied among areas and years, with birds from east Tennessee showing markedly lower infection rates (59.5%) than birds from the other two areas (100%). The overall rate of cestode infection (19.3%) was much lower than the rate of nematode infection (88.3%). Heavier adrenals were associated with decreased fat levels. On one area, parasite load had a significant effect on adrenal weight ($P < 0.05$). Percentage body fat, adrenal weight, and parasite burden in combination may provide a good indicator of population condition, once norms, or base values, for that population are established.

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The condition or "general state of health or well-being" of an animal population is often of primary concern in making decisions dealing with habitat manipulation or other management practices. Most efforts to determine condition of a wildlife population have involved ungulates and have utilized some aspect of fat reserves (Harris 1945, Cheatum 1949, Riney 1955, Ransom 1965, Bear 1971, and Nichols and Pelton 1972). Unfortunately, little research has been conducted to evaluate methods for determining condition in avian species. Robel (1972) used the percentage of body weight represented by fat to evaluate the merits of food plots to bobwhites in Kansas. His study stressed the importance of fat reserves for survival of bobwhites during periods of severe winter weather. Moss and Lough (1968) and West and Meng (1968a, b) compared the composition of stored body fats in birds with the composition of fats present in their major food source.

Chronic, sub-lethal infections of parasites in wild animal populations have seldom been shown to be specifically influential on population welfare. Kellogg and Prestwood (1968) stated that in southeastern United States, the parasite burden was usually directly proportional to population density. Eve and Kellogg (1977) reported that numbers and kinds of gastrointestinal parasites of white-tailed deer can be used as indicators of environmental condition. Unfortunately, though the species of parasites which infect bobwhites are well-documented (Kellogg and Doster 1972), little is known about the role of parasites in the high annual losses sustained by wild bobwhite populations. Parmalee (1952) and Blakeney and Dimmick (1971) reported that body weight of bobwhites apparently was not measurably influenced by intensity of gastrointestinal worm infection.

Since the pioneering work of Selye (1956) delineating the role of adrenals in the strees syndrome, adrenal size and weights often have been used as indicators of stress. Neave and White (1968) found a significant positive relationship between adrenal weight and population density in ruffed grouse (*Bonasa umbellus*). Anderson (1969) reported similar findings for ring-necked pheasant (*Phasianus colchicus*).

This study of bobwhites in Tennessee and Florida examined the relationships between body weight, fat levels, parasite burden, and adrenal weight. Differences in these variables among areas with dissimilar habitat characteristics and population histories are also described.

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THE STUDY AREAS

Quail for this study were collected from 3 major areas: Ames Plantation in southwest Tennessee, 2 locations in east Tennessee, and Tall Timbers Research Station in northern Florida. Ames Plantation, in Hardeman and Fayette Counties, Tennessee, is rich farmland with about one-third of its 7,440 ha in forest land. Soybeans, corn, and cotton are major row crops grown on the area. Beef cattle production is also important. The collection sites in east Tennessee varied widely. Some of the birds were collected from farmland, predominantly cattle pastures dominated by grasses. Others were shot on young loblolly pine (*Pinus taeda*) plantations, some of which contained food plots planted specifically for bobwhites and other wildlife. Tall Timbers Research Station in northern Florida is dominated by mature pine forests, principally shortleaf (*P. echinata*) and loblolly which are control-burned each year.

Immediately prior to the study these areas contained respectively, high (Ames), low (east Tennessee), and very high (Tall Timbers) population densities. Population changes during the study reduced some of the differences in population density which previously existed. Quail numbers on Tall Timbers declined from 1 bird per 0.2 ha in February of 1972 to 1 bird per 0.6 ha in February of 1974. Density on the Ames area dropped slightly from 1 bird per 0.5 ha in 1972-73 to 1 bird per 0.7 ha in 1973-74 (Dimmick, unpublished data). The population on the east Tennessee areas increased from an average of 1 bird per 3.8 ha in 1972-73 to 1 bird per 2.2 ha in 1973-74, with one localized unit supporting a population of 1 bird per 0.7 ha, comparable to the Ames and Tall Timbers areas (Brown 1974). Because of the changes in density during the study, relationships between population density and physiological condition of the birds were somewhat obscured.

METHODS

Quail were collected during the months of December through March by shooting or trapping. The following information was collected from all birds: date collected, area, sex, age, total body weight, body weight minus crop weight, adrenal weight, species and number of gastrointestinal helminths, and the percentage of fat based on oven-dry weight.

Birds were thawed overnight before dissection. The crop and its contents were removed to eliminate variability in body weight due to differing amounts of material in the crops. The gastrointestinal tract was then removed, and the adrenals were removed and weighed as a pair. The gastrointestinal tract, posterior to the crop, was examined for parasites using the technique described by Blakeney and Dimmick (1971). All parasites were stored in 70 percent ethanol.

After dissection, the bird along with the viscera was refrozen for 24 hrs. The frozen birds were then processed through a Hobart Model 4722 meat grinder, reducing the bird to the consistency of ground beef. The macerated birds were dried in a forced air oven at 100 C for 24 hrs. to determine oven-dry weight. The oven-dried samples were placed in a large Soxhlet either extraction apparatus and fat was extracted for 18 hrs in a 5:1 mixture of petroleum ether and chloroform to determine body fat as a percentage of body weight.

Data were analyzed by least square analysis of variance and covariance as outlined by Harvey (1960).

RESULTS

A total of 146 quail was collected from the three study areas; 80 were collected in the winter of 1972-73, and 66 in the winter of 1973-74. Relationships were considered to be significant if probability was less than 0.05. However, in some cases, biological considerations dictated that levels of probability greater than 0.05 be considered significant. In such cases, the level at which such relationships were considered statistically significant is given in the text.

Body Weight Relationships

The mean body weight for 146 birds was 165.0 g (Table 1). The mean on the east Tennessee and Ames areas were 170.8 g and 169.0 g respectively. Each was significantly greater than the mean for Tall Timbers (156.6 g), but not significantly different from each other. Females were not heavier than males, nor were adults heavier than juveniles.

Table 1. Mean body weight[a] of bobwhite quail by sex, age, and area, 1972-74.

	Age[b]				Sex[c]						
	Adult		Juvenile		Male		Female		TOTAL		
Area	(n)	wt. (g)	(n)	wt. (g)	(n)	wt. (g)	(n)	wt. (g)	(n)	wt. (g)	Range
East Tennessee	(7)	171.0	(36)	170.6	(29)	171.4	(14)	170.1	(43)	170.8	150.8 - 191.2
Ames Plantation	(16)	167.9	(33)	169.4	(26)	170.0	(23)	167.2	(50)	169.0	152.7 - 200.9
Tall Timbers	(18)	159.5	(35)	155.8	(33)	155.5	(20)	159.8	(53)	156.6	139.8 - 180.2
Total	(42)	165.8	(104)	164.9	(89)	165.6	(57)	166.2	(146)	165.0	139.8 - 200.9

[a]Body weight represents total wet weight of bird less the crop and its contents.

[b]Means adjusted for sex and parasite burden.

[c]Means adjusted for age and parasite burden.

A positive relationship occurred between body weight and fat percentage. For each 1 percent increase in fat, body weight increased approximately 1.2 g ($r = 0.39$)[a].

Body weight was affected by parasite burden on 1 of the areas. On the Tall Timbers area body weight decreased as number of parasites increased ($P < 0.15$).

Body Fat

Fat percentage was determined for all 146 quail examined during this study; mean for all birds was 12.17 percent. The mean for each area was: east Tennessee, 13.73; Ames, 12.77; and Tall Timbers, 10.40 percent (Table 2). The percentage of body fat was significantly different among all 3 areas.

Table 2. Mean fat percentages observed in bobwhite quail by area and year, 1972-74.

				Average Fat	Range	
Area	Year		(n)	Percent[a]	Low	High
East Tennessee	1972-73		31	13.84	8.11	20.35
	1973-74		12	13.33	6.34	19.84
Subotal			33	13.73	6.34	20.35
Ames Plantation	1972-73	(Early)	12	13.55	6.83	19.67
	1972-73	(Late)	12	9.57	6.05	13.74
Subotal			24	11.56	6.05	19.67
	1973-74	(Early)	13	19.14	13.32	25.12
	1973-74	(Late)	13	8.82	6.32	14.14
Subotal			26	13.98	6.32	25.12
Subtotal	(Early)		25	16.37	6.83	25.12
	(Late)		25	9.18	6.32	25.12
Subotal			50	12.77	6.32	25.12
Tall Timbers	1972-73		25	10.61	4.32	17.72
	1973-74		28	10.09	6.26	13.75
Subotal			53	10.40	4.32	17.72
Total			146	12.17	4.32	25.12

[a]Average fat percentage adjusted for age and sex.

When birds from all areas were combined in a single sample, females (13.12%) had significantly more fat than males (11.72%). Neither sex, however, had significantly more fat when the areas were analyzed separately. Age of bird was unrelated to percentage of body fat.

On Ames Plantation mean fat percentage of birds collected in December and January was 16.37 percent, while those collected in March had a mean of 9.18 percent (Table 2). This relationship was evident in both years of the study. The relationship between season of year and body fat was not examined on the other areas.

[a]Partial, age, sex, and fat held constant.

Parasite Burden

The rate of infection by nematodes for all birds was 88.3 percent (Table 3). The infection rate was 59.5 percent for birds from east Tennessee, while 100 percent of those from Ames and Tall Timbers were infected with at least 1 species.

Table 3. Incidence of parasites found in bobwhite quail on three major study areas, 1972-74.

		Nematodes			*Cestodes*		
			No. Birds			*No. Birds*	
Area	*Year*	*n*	*Infected*	%	*n*	*Infected*	%
East Tennessee	1972-73	31	17	54.8	31	0	0.0
	1973-74	11	8	72.7	11	2	18.2
Subtotal		42	25	59.5	42	2	4.8
Ames Plantation	1972-73	24	24	100.0	24	3	12.5
	1973-74	26	26	100.0	26	4	15.4
Subtotal		50	50	100.0	50	7	14.0
Tall Timbers	1972-73	25	25	100.0	25	7	28.0
	1973-74	28	28	100.0	28	12	42.9
Subtotal		53	53	100.0	53	19	35.8
Total		145	128	88.3	145	28	19.3

The mean number of gastrointestinal nematodes per bird for the 3 areas was: east Tennessee, 11.7; Ames, 244.6; and Tall Timbers, 209.9 (Table 4). A cecal worm, *Heterakis bonasae,* was the only species common to all 3 areas. The intensity of infection by *H. bonasae* for all 3 areas is given in Table 5.

Table 4. Mean numbers of nematode parasites found in bobwhite quail by sex, age, area, and year, 1972-74.

		Age[a]		*Sex*[a]		*All birds*[b]	
Area	*Year*	*Adult*	*Juvenile*	*Male*	*Female*	$\bar{x}$	*Range*
East Tennessee	1972-73	16.9	9.2	12.9	13.2	7.9	1 - 85
	1973-74	74.8	3.9	30.8	47.9	15.7	1 - 145
Subtotal		45.9	6.6	21.9	30.5	11.7	
Ames Plantation	1972-73	294.6	158.3	213.0	239.8	209.4	21 - 576
	1973-74	263.3	294.9	229.6	328.6	279.7	46 - 1,583
Subtotal		279.0	226.6	221.3	284.2	244.6	
Tall Timbers	1972-73	450.7	206.1	347.6	309.2	276.9	22 - 979
	1973-74	142.4	150.3	134.2	158.4	142.8	55 - 353
Subtotal		296.5	178.2	240.9	233.8	209.9	

[a]Means adjusted for sex, age, date of collection.

[b]Arithmetic means.

Nineteen percent of the quail examined were infected with cestodes (Table 3). Tall Timbers had the highest rate of infection, 35.8 percent (19/53), while Ames had 14.0 percent (7/50), and east Tennessee only 4.8 percent (2/42). On the Ames area no cestodes were found in birds collected in December or January.

Only 5 of the 28 infected birds contained a volume of cestodes greater than 0.4 ml, all from the Tall Timbers area. Volumes less than 0.3 ml were not accurately determined.

Table 5. Mean numbers of *Heterakis bonasae* found in bobwhite quail by sex, age, area and year, 1972-74.

Area	Year	Range per Infected Bird		All birds[a]	Age[b]		Sex[b]	
		Low	High		Adult	Juvenile	Male	Female
East Tennessee	1972-73	1	85	7.8	16.7	9.1	12.7	13.1
	1973-74	1	145	15.7	74.8	3.9	30.8	47.9
Subtotal				11.7	45.8	6.5	21.8	30.5
Ames Plantation	1972-73	21	572	290.3	290.3	155.6	209.8	236.2
	1973-74	44	1,508	254.2	254.2	282.2	216.7	319.8
Subtotal				236.9	272.3	218.9	213.2	278.0
Tall Timbers	1972-73	2	141	45.4	53.8	40.6	56.7	37.7
	1973-74	21	163	66.9	62.6	84.4	48.4	98.6
Subtotal				55.6	58.2	62.5	52.6	68.2

[a]Arithmetic means.

[b]Means adjusted for sex, age, date of collection.

Fat-Parasite Burden Relationship

Parasite burden may have affected body fat significantly ($P < 0.20$) on the Tall Timbers area. The relationship was negative, with fat levels decreasing as parasite burden increased. Parasite burden had little effect on fat levels on either the east Tennessee or Ames areas.

Adrenals

Adrenals from 140 quail were weighed. Weights were adjusted for the body size of each bird, and the values given represent a percentage of body weight. Mean adrenal value for all birds was 0.0131 percent. Mean value for east Tennessee, Ames, and Tall Timbers was 0.0119, 0.0136 and 0.0133 percent, respectively (Table 6).

Table 6. Mean adrenal weights[a] of bobwhite quail by sex, age, and area, 1972-74.

Area	Age[b]						Sex[c]				Range	
	(n)	All birds	(n)	Adult	(n)	Juvenile	(n)	Male	(n)	Female	Low	High
East Tennessee	(40)	0.0119	(4)	0.0127	(36)	0.0121	(28)	0.0117	(12)	0.0132	0.0032	0.0203
Ames Plantation	(47)	0.0136	(15)	0.0158	(32)	0.0127	(26)	0.0132	(21)	0.0154	0.0047	0.0280
Tall Timbers	(53)	0.0133	(18)	0.0135	(35)	0.0130	(33)	0.0136	(20)	0.0129	0.0081	0.0235
Total	(140)	0.0131	(37)	0.0144	(103)	0.0126	(87)	0.0135	(53)	0.0135	0.0032	0.0280

[a]Adrenal weights adjusted for body size, and represent percentage of body weight.

[b]Means adjusted for sex, fat, and total parasite load.

[c]Means adjusted for age, fat, and total parasite load.

When birds from all areas were analyzed in a single group, adrenals of adults (0.0144%) were significantly heavier than those of juveniles (0.0126%). However, when each area was examined separately age was a factor only on the Ames area where adults (0.0158%) had adrenals significantly heavier than juveniles (0.0127%) (Table 6). Again, when all birds were analyzed as a single sample, neither males nor females had larger adrenals, but on the Ames area females had larger adrenals than males (Table 6).

For each one percent decrease in fat, adrenal weight increased significantly ($r = 0.27$) when all birds were grouped together[a]. When the 3 areas were examined separately, only the Ames area exhibited a relationship which was statistically significant.

On the Tall Timbers area adrenal weights increased as the parasite burden increased. However, relationships on the East Tennessee area ($P < 0.15$) and the Ames area ($P < 0.20$) appeared to be negative.

[a]Partial r, age, sex, fat, and total parasite burden held constant.

DISCUSSION

The primary objective of this study was to evaluate several condition factors of the bobwhite which may serve as indicators of its health or general well-being. Differences in the values which we observed among areas for some of the parameters probably reflect evolutionary adaptations to average ecological conditions. Body weight, for example, which was heaviest in east Tennessee (coldest of the 3 areas) and lightest in Florida exemplifies a logical extension of Bergman's rule correlating body size and ambient temperature for endothermic animals. Thus, we would not conclude that quail from east Tennessee were healthier than birds from Florida because they weighed more.

Within a general geographical entity, however, there may be merit in monitoring body weight as an indicator of bobwhite condition. On the Tall Timbers area, where parasite burdens were greatest of the 3 areas studied, there appeared to be a negative relationship between parasite burden and body weight. Though this relationship was not statistically significant we feel that it bears additional investigation.

A corollary relationship, and one with perhaps greater implications, was the statistically significant relationship between parasite burden and body fat levels for birds on the Tall Timbers area. The gastrointestinal parasitic fauna of Tall Timbers birds differed from that of Ames birds in the incidence and volume of cestodes and in the species of nematodes. Perhaps one or both of these factors contributed to a relationship which did not appear to exist on either of the other study areas. Unfortunately, little is known of the relative pathogenic effects of the various parasites on bobwhites.

Mean levels of body fat exhibited a clinal trend similar to that for body weight, with lowest fat levels occurring in birds from the warmest climate. On the Tall Timbers area, where winters are mild, mean percent body fat was 10.40; on the Ames area it was 12.77, and in east Tennessee it was 13.72. Robel (1972) reported a mean body fat percent of 17.16 in Kansas, where winters are more severe than in any of the areas we studied in the Southeast. As with body weight, body fat values probably represent adaptations to average ecological conditions, and should not be used to compare condition of quail from disparate ecological regimes. Within an area, however, careful monitoring of body fat levels may provide invaluable insight into the relationship between habitat quality and population welfare. Robel (1972) observed that fat levels in Kansas bobwhites reached a peak in December and January, steadily declining until April or May. He also noted that birds which had access to adequate food supplies maintained higher fat levels than birds which did not. The over-winter decrease in fat levels of bobwhites on Ames Plantation in 1972-73 (29.4%) was similar to that reported by Robel for Kansas (28.2%). Food supplies on Ames during the winter of 1972-73 were considered to be within the range of normal conditions. During 1973-74, however, mean fat levels declined 50.8 percent from December to March on Ames Plantation, a rate of decline which may be abnormal. If this same rate of decline continued on into April or May, the quail could have reached critically low energy reserves at the onset of breeding. That this may have happened is supported by Dimmick's (1974) observations that the breeding population and its reproductive effort were lower in the summer of 1974 than in any of the preceding seven years. Roseberry and Klimstra (1972:273-4) noted that the duration of snow cover during winter accounted for a significant portion of the variation in summer gain. They hypothesized that this may be due to stress placed on the hens, resulting in reduced vigor and consequent delayed nesting and lowered renesting. Klimstra and Roseberry (1975:34) reiterated this conclusion. Two factors were believed to contribute to the rapid decline in fat reserves. First, abnormally warm, damp weather during most of the winter hastened both sprouting and rotting of soybean seeds left in the field. Quail on Ames Plantation are heavily dependent upon the soybean crop for their winter diet (Eubanks and Dimmick 1974). Siginificant reduction in either quality or quantity of soybeans would almost certainly be detrimental to quail. In 1972-73, 54 percent of the birds had fed upon soybeans versus 27 percent in 1973-74. Also, beans eaten by birds during the second winter frequently were blackened and decayed. A second factor contributing to the more rapid decline in fat reserves was a severe ice storm in January 1974. This storm covered virtually all food supplies for several days, undoubtedly putting a stress on the bird's fat reserves.

Adrenals often respond to stress by increasing in size, whether the stress is caused by extreme cold, dense populations, or other factors (Selye 1956:88). Neave and White (1968) reported larger adrenals in ruffed grouse associated with areas of higher population density. Anderson (1969) observed similar relationships with ring-necked pheasants. We observed no significant differences in the adjusted adrenal weights of bobwhites among the 3 areas we studied. Adrenal weights did increase, however, as fat reserves declined.

Consequently, if fat reserves decline in response to stresses of cold and/or starvation, then adrenals also may register the effects of stress by increasing in size.

In conclusion, we believe that each of the factors examined can serve as a useful indicator of condition for bobwhites when placed in perspective for a given population. Establishing norms for each population is extremely important, as different populations may have inherent differences in body weight, fat reserves and/or species composition of its parasite fauna. To achieve a complete assessment of a population's condition or health, all these factors should be evaluated. The one which we regard as the best single indicator is total body fat reserves.

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