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Ralph W. Dimmick, Major Professor

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BOBWHITE QUAIL: I. SOME PHYSIOLOGICAL PARAMETERS DURING LATE BREEDING SEASON; II. WING FAT AS AN INDICATOR OF TOTAL BODY FAT

A Thesis

Presented for the

Master of Science

Degree

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Herbert Eugene Trammell, Jr.

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ABSTRACT

Twenty six bobwhite quail were trapped on Ames Plantation during July and August, 1981. Each bird was analyzed for body weight, body fat, gastrointestinal parasites, food habits and blood plasma biochemical values. Adrenal, pancreas, testes, follicle and oviduct measurements were also taken. Several parameters were compared to values from April/May bobwhite (McRae, 1978).

Adult females were significantly heavier (180.3 g) than adult males (154.7 g) ($P \leq .05$). Mean body weight of juveniles was 140.9 g. The significant July to August increase in adult male body weight ($P \leq .05$) was believed to be associated with changing hormone levels and reduced breeding activity.

Percent body fat was 15.5 in adult females, 12.9 in adult males and 8.4 in juvenile males. Adult male and female values were higher than earlier breeding adults. The 57% fat increase in August males was accompanied by a significantly lower FFA level (as indicated by albumin level).

Plasma triglyceride increased in adult males and decreased in adult females from April/May levels. Plasma glucose also declined and was significantly lower in adult females than in adult males. Lower glucose in females and a substantially increased plasma globulin may have indicated a response to large numbers of gastrointestinal parasites. Plasma uric acid increased in males and decreased in females over summer.

Five nematode, 1 cestode and 2 trematode species were recovered from the gastrointestinal tracts. *Heterakis bonasae* occurred in every bird, averaging 138 worms per adult bird. Female quail harbored significantly more worms than males ($P \leq .05$). *Tetrameres pattersoni* were found in the proventriculus of 50% of the

birds. Cyrnea colini, Cheiliospirura spinosa and Dispharnyx nasuta were recovered from few birds in low numbers. The cestode Rhabdometra odiosa was found in 3 females. Two trematodes, Leucochloridium sp. and Echinoparyphium sp. were recovered from the intestines of 2 hens.

Mean adrenal percent of body weight was 0.105. It was lower than during winter, suggesting that bobwhites were not experiencing stress. Mean pancreas percent was .1226.

The 4 largest ovarian follicles and the oviducts were weighed and measured. Follicles appeared to be in normal hierarchal arrangement. The oviduct length averaged 23.5 cm. The left testis was heavier and larger in adults and juveniles. Juvenile testes were significantly smaller than adults. Mean testis percent of body weight showed a significant negative correlation to increasing body fat in adults ($r=-.66$, $P \leq .01$, $n=17$).

In July, the bobwhite diet contained about equal volumes of animal and plant matter but animal matter dropped to 27% in August. Seeds of Sassafras albidum and grasshoppers were the most abundant plant and animal foods.

Because of the increasing body weight and fat percent, the seemingly unstressed biochemical values and normal gonad development, late summer quail appeared to be in good condition.

Studies to determine the physiologic condition of a population often entail special sampling and lengthy analytical procedures. A simpler method of assessing condition would be needed for yearly evaluations of a managed, wild population. Bobwhite wings are collected annually by some wildlife agencies and represent a potential source of valuable physiologic information.

Twenty six bobwhite quail (Colinus virginianus) were collected from Tall

Timbers Research Station during the winter of 1981. Fat was extracted from the total body, the total feathers, the left wing and the left wing feathers. Fat levels of the wing and the total body were compared. The significance of feathers in the fat comparisons was determined.

Only juvenile males showed a significant correlation between wing and total body fat weights ($r=.87$, $P \leq .05$, $n=6$) and percentages ($r=.79$, $P \leq .06$, $n=6$). A significant correlation was not found between wing and total body fat when data were pooled. There was a significant difference between the fat of the wing and total body when fat was expressed as a percentage of oven-dry weight ($P=.004$). Wing fat proved to be a poor index of total lipid reserves in this study.

Though feather fat contributed significantly to total body and wing fat, it weakened the correlations between the wing and body in the feathered and unfeathered analyses. The left wing feathers comprised 32.5% of total feather fat. The significant variation in wing feather fat (c.v.=1.41) indicated that exclusion of feathers from fat comparisons was preferable.

Fat levels were not significantly affected by variation of wet body weights. Fat weight was significantly correlated to oven-dry weight in the body, but not in the wing.

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CHAPTER I

INTRODUCTION

Perpetuating a viable wild animal population is dependent on maintaining a healthy level of physiological condition among its members. It is a satisfactory state of condition that enables an animal not only to meet the maintenance requirements of daily existence but to respond appropriately to a variety of environmental stresses present in the wild. Knowledge of a population's level of condition should warn of detrimental influences before damage results in a declining population (Kirkpatrick, 1980).

The breeding period is a time of increased physiologic stress. The importance of successful breeding "performance" at a time of heightened natural physiologic stress makes the breeding period key to a species survival. The ability of a population to reproduce is essential to that population and is indeed the essence of that species (Dewsbury, 1978). It is the ability of the animal to endure the physiologic stresses of this period that will result in a successful reproductive effort. Determining condition level during the breeding period gives the wildlife biologist valuable information for managing species.

Bobwhite quail (Colinus virginianus) are particularly dependent on adequate reproductive output because of their high annual mortality rate. Dimmick (1974) speculated that bobwhite production may be more dependent on the condition of breeders than on the numbers of breeders present. Maintaining good condition would be particularly important to a bird such as the bobwhite which may require several nesting attempts before achieving success. An evaluation of physiologic condition of breeding individuals toward the end of the breeding period may reflect stress which these birds are experiencing. Kabat and Thompson (1963) considered physiologic stress of reproduction to be the primary factor influencing late summer and fall quail loss.

This study was undertaken to assess the physiologic condition of wild bobwhite during the latter part of the breeding period as evidenced by several physiologic parameters. The determination of "normal" or "abnormal" physiologic condition would necessitate a comparison of observed parameter values to standardized values with regard to location, sex, age and season of the year. In this study, a comparison is made to a similar survey taken at early breeding to determine what effect, if any, late breeding has on physiologic levels. This study hopes to document a range of "acceptable" physiologic values for bobwhite at this time of the year as well as to identify "abnormal" values and to explain their significance to the bird's physiology.

Several physiologic parameters were measured to indicate bird condition. Wet weight and oven-dry weight were determined for each bird. The amount of body fat has been the most often used condition index in quail and it was also determined in this study. Blood plasma was assayed for levels of triglyceride, free fatty acids (FFA), cholesterol, albumin, globulin, glucose and uric acid. These plasma biochemical constituents were indicators of current metabolic processes. Numbers of parasites were determined by analyzing blood smears and by examining gastroinestinal tracts. The paired adrenal weight was taken as an index of prolonged stress (Siegal, 1980). The weight of the pancreas was also determined. Reproductive status was ascertained by measuring size and weight of the testes and by measuring the 4 largest ovarian follicles and the oviducts. Also, food habits were determined by analyzing crop contents.

CHAPTER II

MATERIALS AND METHODS

I. COLLECTION OF BIRDS

Quail were live-trapped from Ames Plantation during July and August, 1981. Trapping was conducted on 2 areas located immediately northwest and east of plantation headquarters. These areas were comprised of a series of pastured fields (one soybean field) surrounded by a wooded fringe and were accessed by sand or graveled roads. Traps were set around these fields, just within the wooded fringe.

Quail were collected using cock-and-hen traps (McRae 1978). Bait hens were set in the traps at sunrise. The traps were checked every 3 or 4 hours during daylight, and hens were removed from the traps at the end of the day.

Blood samples and smears were taken from each trapped quail at the capture site. Sex, age, trap location, date and time of capture were recorded for captured birds.

II. COLLECTION OF BLOOD SAMPLES

Blood samples were obtained using procedures outlined by McRae (1978), modified so that a collection could be performed by 1 person. Using the palm of the left hand, a quail was restrained on its back (with head toward collector) and its wing extended with the thumb. Blood collection was performed with the right hand.

After feathers were removed from the ventral surface of the wing's humeral region, the exposed flesh was coated with a thin film of vaseline to prevent clotting and the large wing vein was severed with a razor blade. Six or 7 Caraway capillary tubes were filled with blood, sealed, and chilled for later analysis. At least 2 blood smears were made (Schalm 1975) and allowed to air dry. After the collection was completed, the bird was sacrificed, labelled and frozen for laboratory work.

III. LABORATORY PROCEDURES

Plasma Analysis

Plasma was centrifuged from blood tubes at the end of each day's collections. Centrifuged Caraway capillary tubes were broken at the plasma-erythrocyte interface and the plasma portion was emptied into 3 ml vaccutainers and frozen for later analysis. Analysis of plasma was performed using the Technican SMAC System at the Fort Sanders Presbyterian Hospital, Knoxville, Tennessee.

Parasite Recovery and Preservation

After a bird had thawed 4 to 6 hours, the crop was removed, opened and the contents emptied into a container for later examination. The empty crop was then returned to the carcass and the bird's total weight was recorded. The digestive tract, from the pharynx to the cloaca, was then removed for parasite examination. Under 8-15X magnification, each section of tract was systematically opened, washed and scrutinized. The gizzard, intestine and ceca were examined using the technique of Blakney (1970) and the proventriculus was inspected as described by McRae (1978). However, tissue contents were not washed through a screen, as these authors described, but were carefully "picked through" under magnification. This change in procedure was believed to lessen the chance of losing parasites. The trachea and a small portion of bronchii were removed and similarly examined. All fat adhering to the gastrointestinal tract and trachea was carefully removed to maximize the visibility of parasites during examination. All removed fat was eventually returned to the body cavity for later fat analysis. After the removal of the digestive tract and trachea, the body cavity was washed with water and the washing was examined. All parasites were preserved in labelled specimen jars containing alcohol-glycerine.

Parasite Identification

Gastrointestinal helminths. Helminths were initially segregated into Orders by their gross morphological characteristics. Worms were identified to species by using stereo and compound microscopes. Often, nematodes were cleared in glycerine, slide-mounted, coverslipped and examined at up to 400X to detect their minute morphology. All cestodes and trematodes were cleared in xylene, stained in Aceta-Carmine and mounted to aid in viewing of their internal structures. Keys used in parasite identification were Stoddard (1931), Robinson (1947), Yamaguti (1961), Skrjabin (1964), Schell (1970), Schmidt (1970) and Hofstad (1978).

Blood protozoa. Blood smears were stained with Wright-Giemsa stain (Fisher Sci. Co.) according to the procedure of Schalm (1975). Smears were then examined at 1000X using oil immersion. Moderately populated areas of single-cell thickness were examined. Each slide was examined about 15 minutes. Commercially prepared study slides and the plates and text of Lucas and Jamroz (1961) were used as aids in identification.

Final identification of all parasites was made with the concurrence of parasitologists at the University of Tennessee Veterinary Hospital.

Organ Weights and Measurements

The loop of the duodenum containing the pancreas was place on a moistened paper towel. With the aid of 8-15X magnification, the pancreas was excised. The organ was then weighed. The adrenal glands were similarly removed and the combined adrenal weight was recorded. The testes were individually measured (length and width at the greatest point) and weighed. The four largest ovarian follicles of breeding females were separately measured and weighed as was the oviduct. The general appearance and color of all reproductive structures was noted. All organs were returned to the body cavity.

Fat Analysis

After all dissection was completed, birds were sectioned and frozen for at least 24 hours. They were then ground, dried and extracted for 18 hours in a Soxhelet ether extraction apparatus following the procedures of McRae (1978). Body fat was calculated as a percent of oven-dry weight.

Food Habit Analysis

Crop contents were separated under a dissecting microscope while they were still moist. Animal material was immediately placed into specimen jars of alcohol-glycerine. Seeds were dried at 70° C in a forced air oven and then stored in specimen jars until examination (Landers and Johnson, 1976). Leafy matter was air dried and stored in specimen jars containing phenol crystals added as a preservative. Seeds were identified using Martin and Barkley (1961) and Landers and Johnson (1976) and by comparing with the seed collection at the University of Tennessee Forestry, Wildlife, and Fisheries Department. Animal matter was keyed to the lowest possible taxon using Chu (1949), Borrow, et al. (1971) and Bland and Jacques (1978). The deteriorated state and the small quantity of leafy material prevented its further classification. Volume and relative volume of each food item were determined (Korschgen 1948).

IV. DATA ANALYSIS

Data were entered using the DECsystem-10 and then submitted to the IBM main frame computer for computation. The Statistical Analysis System (SAS) was used for data analysis. Means, standard deviations and correlation coefficients of all variables were examined. T-tests and Analysis of Variance procedures were used to discern important differences among observations.

Correlation was deemed the most useful and appropriate statistical technique for studying relationships between parameters. The inherent variation of the measured components in an ecological field study of this type is an underlying assumption of the correlation analysis and makes it the most applicable test of association in this situation (Sokal and Rohlf 1969: 495). Factor analysis, another statistical test of association, was also used to examine interrelationships between parameters.

CHAPTER III

RESULTS

During late July and August, 1981, 26 quail were captured (Table 1). Body weight, body fat weight, gastrointestinal helminth number, blood protozoa, adrenal weight, pancreas weight, and food in the crop were determined for each bird. Testes and follicle weights and measurements were also taken. Plasma biochemical values were assessed for 22 birds.

Relationships among variables were considered significant if probability of chance occurrence was less than or equal to .05. However, because of the study's small sample size, other possibly important relationships that did not yield a statistically significant probability level were mentioned in the text.

I. BODY WEIGHT

The mean body weight for all birds was 158.0 g (Table2). Juvenile birds were notably lighter than adults (140.9 g); however, there were too few juvenile birds for statistical comparison. Mean body weight of adult females (180.3 g, n=5) was significantly heavier than that of adult males (154.7, n=18) ($P \leq .001$). Also, adult males of August were significantly heavier than those of July ($P \leq .05$).

Mean oven-dry weight of all birds was 47.6 g (Table 2). Juvenile birds had the lowest oven-dry weights in the study (mean=38.6 g). Among adults dry weight was not significantly different between sexes, however, dry weights significantly increased from July to August in adult males ($P \leq .01$).

TABLE 1

NUMBER OF BIRDS EXAMINED BY SEX, AGE AND MONTH OF COLLECTION

		July	August	Total
Male	Juvenile	0	3	3
	Adult	8	10	18
Female	Juvenile	0	0	0
	Adult	4	1	5
	Total	12	14	26

TABLE 2

BODY WEIGHT, DRY WEIGHT AND PERCENT BODY FAT[a] BY SEX AND AGE

	(n)	Adult Males	(n)	Adult Females	(n)	Adults	(n)	Juveniles[b]	(n)	Total
Body Weight (g)	(18)	154.7[c]	(5)	180.3[c]	(23)	160.3	(3)	140.9	(26)	158.0
Dry Weight (g)	(18)	47.8	(5)	52.5	(23)	48.8	(3)	38.6	(26)	47.6
Percent Body Fat (g)	(17)	12.9	(5)	15.5	(22)	13.5	(3)	8.4	(25)	12.9
Oven Dry Weight Minus Fat Weight (g)	(17)	41.7	(5)	44.3	(22)	42.3	(3)	35.4	(25)	41.4

[a]Percent body fat is percent fat of oven-dry weight.

[b]These are birds "of the summer" and not considered somatically mature.

[c]Denotes a significant difference ($P \leq .05$) between other means of the similar designation (juveniles not included.

II. BODY FAT

The mean body fat percentage for all adult birds was 13.5; mean for females was 15.5 and for males, 12.9 (Table 2). Mean fat percent for adult birds was not significantly different by sex or month. Mean fat percent of adult males trapped in July was 9.7 (n=10) and was 15.2 (n=7) for males trapped in August. Mean fat percentage of juveniles was 8.4 (n=3).

III. PLASMA BIOCHEMICAL VALUES

Plasma biochemical values were determined for 22 quail. The number of plasma values recorded per observation (range 7-22) was determined by purity of the sample, the volume of the sample or the fact that some of the values were out of the range of the SMAC's analytical ability.

Biochemical values for the juvenile age class had only 2 observations per parameter and, therefore, statistical tests for difference by age were not conclusive. Inspection of the data revealed juvenile values (all males) were largely within the range of adult male values (see Appendices). However, triglyceride, total protein, albumin and globulin values for juveniles tended to be at the bottom of the adult male range (Table 3).

Some of the variation in plasma parameters appeared to be sex related (Table 4). Plasma levels of triglyceride, albumin and iron were significantly higher in females, while males showed a significantly higher glucose value ($P \leq .01$ for both sexes). Both cholesterol and albumin levels increased significantly from July to August in adult male birds.

TABLE 3

AGE RELATED PLASMA BIOCHEMICAL
VALUES OF MALE BOBWHITE

	Adults			Juvenile	
	Mean	(n)	Range	#17	#18
Triglyceride mg/dl	73.4	(15)	20.0-138.0	21.0	17.0
Total Protein g/dl	3.5	(12)	2.7-4.5	2.9	2.9
Albumin g/dl	1.5	(14)	1.2-2.0	1.3	1.3
Globulin g/dl	2.0	(12)	1.5-2.5	1.6	1.6

TABLE 4

PLASMA BIOCHEMICAL VALUES DIFFERING SIGNIFICANTLY BY SEX AMONG ADULTS[a]

	Females	(n)	Males	(n)
Glucose mg/dl	155.6±76.3	(5)	325.7±78.7	(15)
Triglyceride g/dl	293.5±289.2[b]	(2)	73.4±47.0	(15)
Albumin g/dl	2.2±.8	(5)	1.5±.2	(14)
Iron g/dl	170.8±46.5	(5)	86.1±36.6	(15)

[a]Level of significance was $P \leq .01$.

[b]This value is perhaps unrepresentative because one observation was 5½ times greater than the other (89 and 498).

IV. PARASITE LOAD

Gastrointestinal Helminths

Gastrotintestinal helminths were present in every quail examined. Five species of nematodes, 1 species of cestode and 2 species of trematodes were recovered (Table 5).

Heterakis bonasae were present in the ceca of all the birds examined ($n=26$, range of 3 to 553, $\bar{X}=126$). Adult females had a significantly higher number of H. bonasae ($\bar{X}=345$) than did adult males ($\bar{X}=80$) ($P \leq .02$). Juvenile birds carried much lower infections ($\bar{X}=10$).

Tetrameres pattersoni were recovered from 50% of the birds. Female T. pattersoni were found encysted in the proventricular wall of 31% of the birds. When female Tetrameres were recovered the male worms were always present (in one female bird 29 male worms were found and only 1 female was present); however, male Tetrameres were found in some proventriculi when no females were present. Female Tetrameres infected 3 of the 5 female quail, with the highest number of female worms (26) coming from one of the females. Of the 3 juvenile birds caught, only 1 was infected with Tetrameres (4 female and 3 male worms).

Three other species of nematodes were recovered in low numbers from the proventriculus, the gizzard and the gizzard lining (Table 5). Dispharnyx nasuta was present in 1 juvenile bird (5 worms), Cheiliospirura spinosa infected 2 birds ($\bar{X}=2.0$ worms) and Cyrnea colini was recovered from 7 birds ($\bar{X}=2.0$ worms).

Cestodes, present in 3 female birds (60% infection), were identified as Rhabdometra odiosa. As these worms were found fragmented, it was impossible to enumerate individuals or measure their volume accurately.

TABLE 5

INCIDENCE, MEAN NUMBER AND LOCATION OF HELMINTHS
RECORDED FROM BOBWHITE QUAIL

	Frequency/Mean [a]				
	Adults				
	Males (18)	Females (5)	Juveniles (3)	Total	Location
Heterakis bonasae	100%/80 [b]	100%/345 [b]	100%/10	100%/125	Cecum, colon, post. int.
Tetrameres pattersoni [c]	22%/10	60%/10	33%/4	31%/9	Proventriculus
Cyrnea colini	28%/2	40%/2	- [d]	23%/2	Gizzard Lining
Cheileispirura spinosa	11%/2	-	-	8%/2	Gizzard
Dispharnyx nasuta	-	-	33%/5	4%/5	Proventriculus
Rhabdometra odiosa	-	60%/ [e]	-	12%/ [e]	Post. & ant. int.
Echinoparyphium sp.	-	20%/4	-	4%/4	Post. int.
Leucochloridium sp.	-	20%/2	-	4%/2	Post. int.

[a] Mean is calculated from infected birds only.

[b] Similarly lettered means are significantly different ($P \leq .05$).

[c] Females encysted in the proventricular wall only.

[d] Denotes no parasites were recovered.

[e] Number of cestodes could not be determined because of their fragmented condition.

Two species of trematodes were recovered from 2 adult female birds. Four individuals of _Echinoparyphium_ sp. were present in the posterior intestine of a July-caught female and 2 specimens of _Leucochloridium_ sp. were recovered from the posterior intestine of another July female. Incidence of infection by trematodes was 8% of all birds and 40% of adult females.

Blood Protozoa

Stained blood smears from all birds were examined. A careful examination of stained blood smears revealed no blood cell inclusion bodies indicative of malarial-like protozoan infections.

V. ORGAN WEIGHTS AND MEASUREMENTS

Adrenals and Pancreas

The adrenals were removed from 25 birds. Adrenal weights were adjusted for body size and were reported as a percentage of body weight (Table 6).

The mean adrenal value for all birds was .0198. This value included 2 adult male birds which had adrenal weights far greater than any other birds (6.6 and 18 times as great, see Appendices). When these high values were excluded, the total mean adrenal value was .0105 and, for adult males was .0100. Female mean adrenal value was a comparable .0119, as was the juvenile of .0107. Adrenal values were not significantly different between sexes or months.

Pancreas weights were taken from 24 birds and were expressed as a percentage of body weight (Table 6). The mean pancreas value for all birds was .1192 (coefficient of variation=.60). Adult male and female mean values were .1128 and .1643 respectively and were not significantly different. Juvenile pancreas comprised .0959% of body weight.

TABLE 6

MEAN ADRENAL AND PANCREAS VALUES[a]
BY SEX AND AGE

							Adults			
	(n)	Total	(n)	Adult	(n)	Juvenile	(n)	Male	(n)	Female
Adrenals	(25)	.0105 .0198[b]	(22)	.0140 .2080[b]	(3)	.0107	(17)	.0100 .0237	(5)	.0119
Pancreas	(24)	.1192	(21)	.1226	(3)	.0959	(17)	.1128	(4)	.1643

[a]Adrenal and pancrease values are organ weights expressed as a percentage of body weight.

[b]This mean calculated using 2 "extreme" values for adult male birds #5 and #22.

Reproductive Organs

Weights and dimensions of the 4 largest follicles were determined for each hen (n=5) (Table 7). Follicle weights were expressed as a percentage of total body weight. As would be expected, follicle percentage correlated well with follicle volume. However, only the 3 smallest follicles showed a significant relationship (F_1: r=.84, $P \leq .08$; F_{2-4}: r .97, $P \leq .05$). Mean percent value for each of the 4 most developed follicles was 1.2, .60, .20 and .07 respectively.

Oviduct length of the 5 females averaged 23.5 cm. Size and weight of the developing eggs increased with their corresponding stage of advancement in the oviduct. One subadult bird had an egg partially developed and extruding from the infundibulum.

The testes of each cock were weighed and measured (n=21) (Appendix, Table 10). Mean weight for the left and right testes for adults was .584 g and .421 g, respectively. The mean left and right testes weight for juveniles was .006 g and .005 g. The left testis was heavier and larger than the right testis in both adults and juveniles. Only the left testis was used for further comparisons. Among adult males, the mean left testis percent of body weight was .384. Left testis percent of body weight for juveniles was .004. Because juvenile birds were sexually immature, they were not included in the correlation of testis values with the other physiologic parameters. Left testis percent of adult males was significantly lower in August ($P \leq .01$).

VI. FOOD HABITS

All birds were examined for the amount and type of food in their crops (Table 8). Fifty-eight percent (15 of 26) of the crops contained food. Plant

TABLE 7

WEIGHT AND SIZE OF THE FOUR LARGEST OVARIAN FOLLICLES, OVIDUCT LENGTH, EGG SIZE AND EGG POSITION BY BIRD NUMBER

Bird Number	Age[e]	Follicle Weight[a,b] F_1	F_2	F_3	F_4	Follicle Size[b,c] F_1	F_2	F_3	F_4	Oviduct Length[d]	Egg Size[c]	Egg Position
1	SA	1.30	.75	.33	.13	16X17	12X15	11X11	8X9	23.5	20X27	Uterus
2	A	.96	.57	.15	.06	14X17	10X13	7X9	5X6	23.5	17X26	Magnum
8	SA	1.17	.48	.11	.02	15X16	11X12	7X8	4X4	20.0	15X15	Infundibulum
11	A	1.77	1.00	.38	.11	15X22	13X18	9X13	6X8	23.5	22X28	Vagina
15	A	.91	.37	.01	.01	15X18	11X11	4X5	4X4	27.0	22X28	Uterus

[a] Follicle weight is expressed as a percentage of total body weight.

[b] F_1 denotes the largest follicle and F_4 the smallest.

[c] Measurements are in millimeters.

[d] Measurements are in centimeters.

[e] SA=subadult; these are birds in their 1st breeding season as evidenced by buff-tipped primary coverts.
A=adult; these birds in their 2nd or subsequent breeding season.

TABLE 8

RELATIVE PERCENT VOLUME OF FOOD ITEMS RECOVERED FROM QUAIL IN JULY AND AUGUST

Common Name	Scientific Name	Percent of Total Volume		
		July(7)[a]	August(8)[a]	Total
Plant Foods				
Sassafras	Sassafras albidum	29.0	26.5	27.3
Wheat	Triticum aestivum	11.6	19.6	16.3
Corn	Zea mays	-[b]	19.6	11.6
Field paspalum	Paspalum laeve	-	4.9	2.9
Veth	Vicia sp.	5.8	tr.[c]	2.3
Panicum	Panicum sp.	tr.	tr.	tr.
Trefoil clover	Trifolium sp.	1.5	-	tr.
	Pisum sativum	1.5	-	tr.
Partridge pea	Chamaecrista fasciculata	1.5	-	tr.
Chickweed	Cerastium sp.	tr.	tr.	tr.
Ragweed	Ambrosia artemisifolia	tr.	-	tr.
Wood sorrel	Oxalix sp.	tr.	-	tr.
Unidentified leafy matter & grit		tr.	1.0	
subtotal		53.6	72.5	64.5
Animal Foods				
Grasshopper	Orthoptera	13.1	15.7	14.6
Beetles	Coleoptera	7.3	2.0	4.1
Truebugs	Hemiptera	tr.	4.0	2.9
Unid. Insecta		4.4	2.9	3.5
Treehopper	Membracidae	8.7	-	3.5

TABLE 8 (Cont'd)

Common Name	Scientific Name	Percent of Total Volume		
		July(7)[a]	August(8)[a]	Total
Snail	Gastropoda	4.4	tr.[c]	2.3
Caterpillar	Lepidoptera larvae	2.9	1.0	1.8
Spider	Aransae	tr.	1.0	Ant
Ant	Formicidae	tr.	-[b]	tr.
Biting lice	Mallophaga	tr.	-	tr.
Leaf hopper	Cicadelidiae	tr.	-	tr.
Spotted Cucumber beetle	Diabrotica undecimpunctata	tr.	-	tr.
Eggshell		tr.	27.4	35.5
subtotal		46.4	27.4	35.5

[a] Number of crops containing food.

[b] Dash denotes food item not present.

[c] Less than 1 percent of the volume.

matter was more prevalent in the diet in both months. The most abundant plant items were seeds of Sassafras albidum (27.3%), Triticum aestivum (16.3%) and Zea mays (11.6%).

In both months, quail had also consumed a significant volume of animal matter. Animal matter comprised 46.4% of the July diet but declined to 27.4% in August. Grasshoppers (Orthoptera) were the most abundant animal food item both months. More different kinds of food items (both animal and plant) were eaten in July than in August (crops containing food were about equal for each month).

VII. INTERRELATIONSHIPS

Though not necessarily suggesting a direct cause and effect relationship, several significant correlations indicated a degree of association between parameters. Body weights correlated significantly with oven-dry weights ($r=.88$, $P \leq .001$), but correlated weaker to fat percent ($r=.61$, $P \leq .001$). Body weight correlated well to numbers of H. bonasae ($r=.70$, $P \leq .001$, $n=26$) but not with any of the other measured physiologic parameters.

Dry weight showed a strong relationship to fat percent ($r=.83$, $P \leq .001$). Factor analysis repeatedly associated body weight, dry weight and percent fat with the same factor. A significant relationship existed between fat percent and plasma cholesterol that was strongest among adult males ($r=.75$, $P \leq .001$, $n=14$).

Left testes weights expressed as percentages of body weights showed a significant negative correlation to dry weight ($-.64$, $P \leq .01$, $n=18$), fat percent ($r=-.66$, $P \leq .01$, $n=17$), cholesterol ($r=-.56$, $P \leq .01$, $n=15$) and albumin ($r=-.61$, $P \leq .05$, $n=14$).

A statistical technique that will often further clarify the interrelationships of several variables is factor analysis. Factor analysis aims to express covariation of variables through a lesser number of hypothetical factors and, in this way, "group" variables about the factors (Sokal and Rohlf, 1969: 542). Analysis of my data produced a factor pattern that indicated a complex association of variables where all factors explained similar portions of the total variance (Table 9). Factors 2 and 3 were mainly comprised of the component variables of total protein and total body weight respectively. These variables would be expected to factor together because of their component relationship. Other factor variables did not show such a clear relationship. The obscured factor pattern that emerged was likely the result of the varied physiologic phenomena of summer males and females being expressed through a small sample size.

TABLE 9

ROTATED FACTOR PATTERN[a] OF SELECT STANDARIZED VARIABLES

Variable	Regression Weights[b] Factor 1	Factor 2	Factor 3	Factor 4	Final Communality Estimates[d]
Carbon Dioxide	-.89	.06	.09	.02	.80
Glucose	-.82	.05	-.11	.28	.76
Iron	.81	.34	-.02	.24	.84
H. bon.	.81	.07	.33	.00	.77
LDH [c]	-.52	-.19	-.02	.43	.48
Albumin [c]	.64	.61	.24	-.06	.84
Tot. Protein	.44	.82	.18	-.03	.90
Globulin	.07	.82	.07	-.01	.68
Adrenal [c]	.20	-.81	.23	.00	.75
Dry Weight	.20	.01	.97	.04	.98
Fat %	-.06	.06	.91	-.01	.84
Body Weight [c]	.50	-.10	.78	.15	.89
Cholesterol [c]	-.28	.50	.58	-.14	.69
T. patt.	-.10	.09	.07	.88	.80
Triglyceride [c]	.41	.12	-.01	.82	.86
Chloride [c]	-.20	.36	-.16	-.72	.71
Uric Acid	.20	.05	.06	-.63	.44
Potassium [c]	.38	.38	.10	-.49	.54
Portion [e]	.33	.23	.22	.22	

[a] Factor method was principal axis; rotation was by VARIMAX criterion.

[b] Regression weights are the correlation coefficient between each variable and each factor.

[c] These variables are considered "complex" in that they are not specifically associated with one factor.

[d] Communality estimates are estimates of the amount of variance in each variable shared by at least one other variable. Therefore, the smaller communality values indicate the more "uniqueness" in the variable.

[e] This is the percentage of total variance explained by each factor.

CHAPTER IV

DISCUSSION AND CONCLUSION

I. BODY WEIGHT AND BODY FAT

Body weight and percent body fat were moderately correlated ($r=.61$, $P \leq .001$). Other studies of bobwhites on Ames Plantation during winter (Dabney, 1974) and spring (McRae, 1978) detected a similarity of trends between the two parameters, but their values were not significant. Robel (1972) reported a high correlation ($P \leq .01$) between body weight and body fat levels of quail in fall and winter in Kansas. Anderson (1972) suggested that pheasant body weight alone was as reliable an indicator of physical condition (i.e. an estimate of visceral and strip fat, and sternal and leg muscle) as a condition index that took structural size into account. Breitenbach et al. (1963) found that pheasant fat reserves were highly correlated with body weight. Close examination of my data indicated that large individual variations in body fat levels were often hidden in total body weights of relatively less variation. The result was that some birds showed a slight difference in total weight but had a large difference in percent body fat. It was the non-proportional variation in the heavier non-fat components that made total body weight only a moderate indicator of fat level. King and Farner (1966) concluded that because of the variation in the non-fat portion of body weight of the white crowned sparrow, Zonotrichia leucophys, body weight was not a reliable indication of variation in fat reserves in that species. Though the small sample size and inherent experimental error undoubtedly added to the variation of my data, percent fat seemed to be highly variable from bird to bird (even within sex). Though body weights usually reflected changes in fat levels, the magnitude of change of each parameter was often dissimilar. Because of this, body weight was not considered a reliable index to individual body fat.

Dry weight correlated better with fat percent in this study ($r=.83$, $P \leq .01$) than wet weight did, indicating that elimination of the water portion of body weight provided a stronger correlation. Comparison of wet and dry weights of all birds (Table 2, Page 11) revealed that water comprised over 50% of the total bird weight. This larger water component seemed to represent a sizeable source of variation that effectively clouded the fat-dry weight relationship. The relationship between body protein and fat was pointed out by Hanson (1962). During food deficiency, glycogen reserves are first depleted and then fat is metabolized "in the flame of protein metabolism" to enable its metabolic products to enter the citric acid cycle. Anderson (1972) also demonstrated the simultaneous degradation of protein and fat reserves in starving pheasants. In such a nutritional crisis, one would expect a positive relationship between protein and fat. However, dry weight and percent body fat also strongly correlated as bobwhite were adding weight over the winter months (Dabney, 1974; McRae, 1978), indicating that protein and fat change similarly during positive energy balance as well as during negative energy balance when body components are metabolically degraded for energy production. Since oven-dry weight proved to be a more sensitive index to fat level in this study and others, it promises to be a more useful index of general bird condition. Obviously however, sacrifice of birds, added processing time and added laboratory expense would accrue when using this index compared to using body weight alone.

Because of different behavioral activities of adult males and laying hens during the breeding period, unequal physiologic demands are placed on each sex.

In this study, there was a marked difference between sexes in both mean body weight and percent body fat (Table 2, Page 11). Additionally, juvenile birds (1st summer) were in a stage of rapid juvenile growth and would be expected to reflect substantially different body weights and percent body fat values than those of the adult birds. Juvenile weights and percent fat were noticeably lower than those of adults but too few juveniles were sampled for statistical comparison. Because of these behavioral and developmental differences between sexes and between ages, adult male, adult female and juvenile birds were discussed separately.

Adult Males

The mean body weight of adult males (154.7 g) was similar to the April-May weights reported by McRae (1978) (153.4 g). McRae characterized April-May males as juveniles or adults, but juveniles were birds born the preceding year and had attained full adult size. Adult male weights increased significantly, however, from July to August in contrast to the decline in weights from April to May found by McRae. Other longer terms studies (Perkins, 1952; Roseberry and Klimstra, 1971) have shown that weights of adult male bobwhites continue a spring/summer decline until about June and then increase through the late summer and fall. This trend is a likely occurrence among adult male birds on Ames Plantation as evidenced by decreasing early and then increasing late summer body weight.

The percent body fat of adult male birds also increased from July to August. The August mean value of 15.1% represented a 57% increase over that of July (mean=9.7%). Additionally, the combined mean for adult males (12.9%) was a 44.3% increase over the April-May value reported by McRae (1978).

Adult males in July and August are either paired with a breeding female, are "singles" or are possibly incubating in the absence of the female. Roseberry and Klimstra (1984) implied that the weight dynamics of the breeding male are a reflection of the stresses of courtship, calling, territory establishment and copulation. These authors showed that male body weight had an inverse relationship to incidence of nest initiation; body weights were lowest during the month of peak nesting. Dimmick (1968) showed nest initiation on Ames Plantation peaked in June which would imply that male breeding stress would peak then and would decrease thereafter. Increasing body weight and percent fat in July and August could be an indication of decreasing breeding-associated stress during these months.

Another factor that would influence the energy demanded of the male bird in summer is the extent of their movements. Urban (1972) showed that the difference in range of mated and unmated cocks was significant. Unmated cocks ranged significantly farther. The added movement of unmated birds may require more energy and could possibly be reflected in lowered body weight. A third consideration is that the incubating male might be under greater physiologic stress caused by reduced feeding opportunities associated with lengthy periods on the nest. Incubation duties assumed by the male in the absence of the female might place a greater stress on the bird that could be reflected in lower body weight or fat.

However, the increased body weight and fat levels found in this study during July and August indicated that male bobwhite were in a positive energy balance (Robel, 1969) and not experiencing energy depletion. This increase in male July-August weight and fat was probably the result of decreased breeding-associated stress coupled with an increase in the quality of summer foods.

Adult Females

Both body weight and percent body fat of adult females in this study (180.3 g and 15.5% respectively, n=5) were higher than the values reported by McRae (1978) from Ames Plantation during April/May (172.8 g and 12.7% respectively, n=5). In McRae's study, as well as in the present study, 4 of 5 laying females were caught in the first month of the sampled period (ie. in April and in July) so the mean values reported in these studies largely reflect values of hens in April and July. Roseberry and Klimstra (1971) found a similar increase in July hen body weights over those of April but these months were reported as part of a summer trend that showed an initial body weight peak in May, a decline to June, a smaller increase to July and then a continued decreased through August to September. Later work by Roseberry and Klimstra (1984) brought out the close positive relationship between the summer female weight trend and nesting incidence.

Adequate fat levels are important to the laying hen as an energy source because of the increased energy demand of egg formation. Case (1972) calculated that the production energy of egg laying in the bobwhite hen at 25° C was nearly equal to energy required for existence at the same temperature. He concluded that the elevated metabolism of egg laying did not impose a physiologic strain on the female. But, it is an additional "reserve" of energy that enables the hen to meet stresses in addition to egg laying. Kabat et al. (1956) concluded that diminshed fat reserves and higher physiologic demands of breeding afforded post-breeding pheasant hens the least protection from the applied stresses of caging and starvation. Though the physiologic demands of egg laying might not constitute a strain on a healthy hen under "normal" conditions, these demands might prove excessive to a hen in diminished condition or in a situation where stress in addition to that of laying is significant.

Two long term bobwhite studies (Roseberry and Klimstra, 1971; Dimmick, 1974) have suggested that fall population levels are largely dependent on the condition of birds as they enter breeding. Dimmick (1974) found that the size of the fall population (December) best correlated with the total number of nests (r=.81), suggesting that it was the ability of the bobwhite to renest that most affected the total nesting effort and hence the population's productivity. For several initially healthy individuals perhaps continued stress of a long nesting season may result in declining condition (McRae and Dimmick, 1982). Hens caught in this study were laying in latter July and August and probably represented late layers or re-nesters since peak nesting on Ames was reported to occur during June (Dimmick, 1968). The increased percentage body fat found in July and August hens in this study suggested that stress was not significant and, in fact, a positive energy balance existed resulting in an increased body weight over that of spring.

Juveniles

Three juvenile males caught in this study were aged at 3 months based on the status of their wing molt (Rosene, 1969). Developing birds of this age would not be expected to have reached full adult weights (Stoddard, 1931; Robinson, 1947; Hamilton, 1951; Roseberry and Klimstra, 1971; Leopold, 1977). Mean body weight, oven-dry weight and percent body fat was lower for juveniles than for male or female adults in this study.

Hamilton (1951) reported that in Missouri bobwhites, juvenile body weights increased linearly for the first 100 days when they attained the average weight of 1st year adults. Roseberry and Klimstra (1971) reported a rapid weight gain in juveniles to about 74 days and then a slower increase to 200 days when body weight stabilized. Using Roseberry and Klimstra's data (pg. 118), a 3 month bird had attained approximately 88% of the body weight of 6-7 month olds. The mean juvenile weight in this study was 90% of the mean weight of adults in August (the month in which all juveniles were trapped).

Stoddard (1931: 78) concluded that the food supply during the juvenile period of development was a significant factor in determining quail size. Birds from well-cultivated country were noticeably heavier than those from calcareous flatwoods. Nestler et al. (1942) concluded that higher protein level in the diet significantly affected rate of growth up to 10 weeks of age, noting that juvenile bobwhite matured best on a 28% protein diet.

The rapid increase in body weight of precocial juvenile quail is accompanied by continual feather growth from natal down to adult plumage. Rapid feather growth, so vital to survival during this developmental period, is undoubtedly a drain on the maturing bird's energy reserves and requires an adequate source of high grade protein for its normal advancement (Spearman, 1971: 618). This protein requirement is being met by juvenile birds on Ames Plantation through the insect diet of the summer months (Eubanks, 1972). The lowered fat level found in juvenile birds in this study was probably a reflection of the demands of rapid maturation and increased metabolism during continual feather moult.

II. PLASMA BIOCHEMICAL ANALYSIS

Lipids

Circulating plasma lipids can be separated into several lipid groups whose concentrations vary with changes in lipid metabolism. The relative concentrations of these lipid components provides an indication of the lipid energy source being most utilized. Energy storage and purveyance through lipids is extremely important during the breeding period when continuous high energy demands must be met. The evaluation of plasma lipids in this study indicated the relative contribution of lipid sources to energy metabolism during the later breeding period.

Triglycerides and cholesterol were the plasma lipids directly measured in this study. Free fatty acid (FFA) level was indirectly determined by measuring the plasma albumin content since FFA is primarily transported in the blood coupled with albumin (albumin-FFA complex) (Steinberg, 1963). Triglycerides and cholesterol indicated dietary intake or synthesis from non-lipid precursors (lipogenesis) while FFA level indicated the degree of fat depot utilization (Annison, 1971).

Significant changes in plasma lipid components occur as bobwhite enter the breeding period. McRae (1978) documented dramatic increases in triglycerides, cholesterol and albumin as the laying bobwhite met additional energy requirements through increased dietary intake, lipogenesis and lipolysis of fat reserves. Also, McRae found that breeding males continued to utilize fat reserves through May as evidenced by declining fat depots and increased plasma albumin level. Triglyceride levels declined in males suggesting diminished lipogenesis, dietary intake, or both.

In this study, lipid values were considered separately by sex. All females were in laying condition, so different rates of lipid metabolism would be expected between sexes. Analysis of variance revealed significantly higher levels of plasma triglyceride and albumin ($P \leq .01$ for both) in hens when both month's data for adult birds were pooled (n=2 for female triglyceride values). Cholesterol levels were not significantly different between males and females. Metabolic information determined by plasma lipid analysis was compared to information ascertained at earlier breeding by McRae (1978).

Males. The data indicated that the degradation of fat depots and low dietary intake and/or level of lipogenesis shown in April/May bobwhite males (McRae, 1978) had stopped. Fat levels in July/August males had increased to 12.9 percent and plasma albumins had decreased (1.5 ± .4 g/dl) indicating increased fat storage and decreased depot utilization. Additionally, levels of triglyceride and cholesterol were greater than April/May levels, suggesting that dietary intake of fatty acids and/or the rate of lipogenesis had increased.

The increased level of plasma lipids was most likely associated with the changing hormone levels of the late summer cock. Balnave (1969) found that testosterone treatment decreased total blood lipids when compared to non-treated control birds. Perhaps the decrease in androgen level in July/August males, indicated by decreasing testes size (Anthony, 1970; Ottinger, 1983), was associated with the increase in plasma triglyceride and cholesterol seen in this study. Cholesterol is a precursor to testosterone formation and perhaps the significant increase in adult male plasma cholesterol in August ($P \leq .01$, July= 124, August=167) at least partially resulted from lower testosterone production. Prolactin could also have contributed to lowered androgen levels and increased lipogenesis at this time. Prolactin increases in birds of both sexes during breeding, reaching peak levels around incubation (Sturkie, 1976). It has an "anti-gonadal" action in quail seemingly by its suppression of the output of FSH (Alexander and Wolfson, 1970). When administered to pigeons and chicks

(Hazlewood, 1976: 227), prolactin markedly increased hepatic lipogenesis while not affecting lipolysis of abdominal fat pads. Perhaps increased prolactin levels contributed to the increased fat levels in July/August males. An increased estrogen level in July/August males would have increased depot fat and plasma lipid levels. Lofts and Murton (1968) pointed out strong circumstantial evidence that male birds produced estrogen during gonad regression. Hillard et al. (1956) and Abraham et al. (1960) observed large amounts of low density lipoprotein (63% triglyceride, 4% cholesterol) in the plasma of estrogenized cocks. Increased levels of estrogen cause increased fat levels in both males and females (Griminger, 1976.)

Females. Triglyceride and cholesterol levels are greatly elevated in the laying hen in response to the large demands of the developing egg yolk for low density and very low density lipoproteins. The increased demand for these lipid fractions is largely met through an increased intake of dietary fatty acids or through increased lipogenesis Additional energy demands of the hen and the developing follicle are met through the degradation of depot fat and the subsequent release of FFA into the blood.

McRae (1978) found that plasma triglyceride, cholesterol and FFA dramatically increased in laying bobwhite hens in the April/May period. In this study, levels of plasma lipids in laying hens were lower than the earlier breeding levels found by McRae. Mean triglyceride dropped considerably to 293.5 ± 289.5 mg/dl; cholesterol was 130.6 ± 47.5 mg/dl and albumin was lower by almost half at 2.1 ± .7 g/dl.

Harris (1970) stated that decreasing plasma FFA in breeding blue-winged teal hens reflected a depletion of fat depots after continual decline over the breeding period. Harris also showed a strong positive relationship between body condition and metabolic reserves as evidenced by relative body weight. In his study, body weight dropped as breeding progressed and body condition fell. Korschgen (1977) found that FFA levels in nutritionally stressed breeding eider hens increased as fat stores were utilized and body weight declined. FFA never did decline indicating that fat stores were not totally used up. In the present study, the relatively lower plasma FFA level than earlier breeding (McRae, 1978) (as indexed by plasma albumin) indicated a lower level of utilization of fat depots. This could not have been the result of depot depletion since body fat reserves in these late summer hens had increased. Rather, the lower mean albumin level in this study reflected a reduced level of depot degradation and was in concurrence with the finding of increased body fat.

Lower plasma triglyceride and cholesterol values from those of spring (McRae, 1978) would seem to indicate either lowered production of these lipids (from dietary intake and/or lipogenesis) or increased plasma clearance relative to production (most likely from breeding demand or increased fat storage). The demand for triglyceride and cholesterol-rich lipoproteins by the developing follicles in late breeding hens was probably comparable to the elevated demand in earlier breeding hens. The fact that summer breeding quail hens consume an increased quantity and variety of foods (Eubanks, 1972) would indicate that an insufficient lipid contribution by the diet was probably not a major contributing factor. Lower plasma triglyceride and cholesterol levels likely were due to reduced lipogenesis or increased fat deposition.

Estrogen stimulates lipogenesis at the onset of lay (Annison, 1971) and an estrogen decrease for whatever reason would probably cause a decrease in lipogenesis. Van Tienhoven (1961) suggested that an inhibitory feedback resulting from high levels of estrogen over a long time lowered release of gonadotrophins. This lowered level of gonadotrophin would, in turn, reduce gonad output of estrogen which would have a diminished effect on lipogenesis. A complexity of interacting hormones probably affect avian lipid metabolism at this time of the summer, both directly and through feedback systems (El Halawani et al., 1984; Stokkan et al., 1985). Heald and Rookledge (1964) strongly suggested that the decreased plasma levels of FFA and total lipids in the starved laying hen was due to failure of the pituitary hormones to maintain the ovary. However, dietary restrictions above that of starving (82, 75 and 62% of ad libitum) lowered hepatic lipogenic enzyme activity (and presumably lipogenesis) but still allowed weight gain and successful egg production in laying hens (Pearce and Brown, 1971).

Glucose

The mean level of plasma glucose in late breeders was lower in both sexes than that found in quail from earlier breeding (McRae, 1978). This lowered level (281.7 ± 102.3 mg/dl, n=2) indicated that the decrease from the winter glucose peak reported by McRae continued through the summer months.

Plasma glucose was significantly lower in adult females ($\bar{X}$=155.6 ± 76.3, n=5) than in adult males (325.7 ± 78.7, n=15) ($P \leq .001$). A similar though less pronounced difference between sexes was noted in quail at earlier breeding (McRae, 1978: 22). Sturkie (1965) reported higher glucose levels in whole blood of female chickens than in males. Gee (1981) reported a significantly higher glucose level in captive masked bobwhite females than that of males. Of 7 avian species studied (Gee, 1981), all had significant sex related glucose differences, however one sex was not consistently higher or lower.

A lower glucose level would be expected in cases of lowered dietary intake or nutritional quality (Langlow et al., 1970; Hazelwood, 1976). However, other physiologic parameters measured in this study indicated that neither insufficient diet nor poor nutrition were implicated. Body weight and body fat were higher and uric acid and FFA levels (indicators of protein catabolism and gluconeogenesis) were lower than earlier levels. Harris (1970) found that plasma glucose increased linearly along with FFA and non protein nitrogen (essentially uric acid) with the declining condition of breeding blue-winged teal. However, Pearce (1983) showed that restricting diets of domestic fowl altered its lipid metabolism (increase in lipogenesis) but had little effect on pathways of glucose dissimilation.

Another physiologic response of quail experiencing stress would be an increased output of glucocorticoids by the adrenal cortex (Siegel, 1980). The principal glucocorticoid in birds is corticosterone which has a marked hyperglycemic effect on avian metabolism (Ringer, 1976; Heald, et al. 1965). If stress-increased corticosterone affected the birds in this study, their glucose levels must have been much lower before the steroid response. Other physiologic evidence indicated this was not the case. Also, if trapping and handling caused an adrenal response of increased corticosterone (Whatley et al., 1977), then glucose values presented here are higher than those of a non-stressed bird.

The glucose level in the blood is largely the result of hepatic and renal uptake and release, tissue removal and hormonal influences. The intestinal uptake of glucose has only a temporary effect on blood levels (Coles, 1968). Mean plasma glucose level of birds in this study with full crops was not significantly different from those birds with empty crops. Tissue demand for glucose in the laying hen is certainly increased, but laying demand was not the entire reason for decreased glucose because male glucose level was also lower. Both sexes were infected with several internal parasites (see other section) which may have had a subclinical pathogenic effect on the birds. Christie and Halliday (1978) showed that the pathogen E. coli injected into the airsacs of broilers was responsible for a decrease in serum glucose along with an increase in total protein (increase in globulin, decrease in albumin). Similar biochemical results were seen in this study except that body weight increased instead of decreasing.

Protein

Plasma protein of bobwhite adults was higher in July-August than in April-May (McRae, 1978; using SMAC results not refractometer). In both sexes, albumin decreased over summer while globulin had substantially increased. This contrasted with an increase of albumin and decrease of globulin at the onset of breeding (McRae, 1978). The greatest change in mean total protein from April/May was in the males but females showed the greatest changes in the albumin and globulin fractions. Protein values in juvenile birds (n=2) were in the lower level of the adult range (see Appendix).

Plasma protein serves several different functions in the avian body (Griminger, 1976b). Adequate levels of plasma proteins are needed to exert a colloidial osmotic pressure to aid in maintenance of blood volume and pH. Of particular relevance to this study are the extravascular tasks of plasma proteins. Albumins are believed to act as an amino acid reserve and a protein source at times of subnormal intake. Albumins also carry many nutrients including minerals (iron-transferron, copper-ceruloplasmin, calcium) and lipoproteins. Immunoproteins are globulin fractions (part of B and essentially all of the Yglobulins) that are synthesized in response to a variety of antigentic stimuli.

Mean albumin level of females (2.1 ± .7) was significantly higher than that of males (1.5 ± .5) ($P \leq .001$). This is probably a reflection of the greater protein requirements of the laying female. However, the albumin in females in this study was lower than that observed at earlier breeding (4.0 ± 1.8, McRae, 1978). The male level was also down, though less so (earlier breeding level of 1.8 ± .5). These levels were probably influenced by the gradually changing concentration of anabolic androgens and estrogens over the breeding period (Schalm et al., 1975). Plasma albumins are synthesized in the liver from amino acids derived from food intake or from the catabolism of tissues. Their existence in the plasma is short lived and daily replacement is essential. Tissue catabolism in hens did not appear to have been significant since April/May mean dry weight was similar to that in July/August (53.6g vs. 52.5g). Perhaps an insufficient amino acid uptake contributed to the lower albumin level. Lowered albumin levels are seen in malnutrition, malabsorption, starvation, GI pathology (including parasitic gastroenteritis), decreased liver synthesis and in protein demanding conditions if the diet is insufficient (Cohn and Kaplan, 1960; Kelly, 1984). The lower female albumin level was probably a combination of lower liver synthesis and high protein demand.

The most noticeable change in the relative level of protein fractions from that of earlier breeding was the increase of the globulin component, especially in the female. Female globulin (2.1 ± .7, n=4) was 5 times higher than that reported by McRae (.4 ± .3 g/dl, n=2). The most common cause of increased globulin is through an increase in immunoglobulin level in response to infection (Woerpel and Rosskupf, 1984). Though birds in July-August had more cecal worms than birds in

April-May, many disease conditions produce similar changes in plasma proteins (Galvin, 1978, in Woerpel and Rosskupf, 1984). Galvin (1978) found that changes in various components of plasma proteins suggest trends in the bird but are not specifically diagnostic in themselves. Seigel (1980) noted that increased corticosteroids associated with increased stress were catabolic in lymphocytes and consonant with lymphoid cell destruction and reduced antibody production. If the high globulin level in this study was largely due to increased circulating antibodies, it probably indicated that significant catabolic agents such as corticosteroids were not present. Plasma proteins in the globulin fraction combine with triglycerides and cholesterol to form low-density and very low-density lipoproteins prominent in breeding females. However, the increased globulin fraction in this study was probably not in response to increased blood lipid demand since triglyceride and cholesterol decreased from earlier breeding values. Increased globulin levels most likely indicated an increased antibody level in response to higher numbers of gastrointestinal parasites.

Uric Acid

Plasma uric acid was measured in this study to evaluate the degree of protein catabolism in quail during late summer. The majority of waste nitrogen (from protein catabolism) is present in the plasma in the form of uric acid. An increase in protein breakdown would be reflected in raised plasma uric acid levels. As carbohydrate reserves are depleted, energy requirements are met through degradation of protein and fat depots in a "glucose sparing" shift in metabolism (Hazelwood, 1976). Adrenal involvement is suspect in such a metabolic shift. Corticosterone output from adrenals has a marked gluconeogenic effect on metabolism and increases the amount of uric acid excreted (Dela Cruz et al., 1981). Birds react to a number of non-specific stressors through heightened adrenal output (Siegal, 1980).

Studies on waterfowl have documented an increase in plasma uric acid in response to stresses associated with breeding (Harris, 1970, blue-winged teal) and weather (Bennett and Bolen, 1978, green-winged teal). However, Korschgen (1977) did not see a change in plasma uric acid of female eiders along with declining weights during incubation but noted that levels of uric acid appeared to be considerably depressed. McRae (1978) noted that bobwhite of late winter and early spring had significantly higher plasma uric acid levels than those quail sampled earlier in the winter or later in the spring. McRae felt that the increased level of uric acid was a result of nutritional and energy stress experienced by the birds during the later winter/early spring period.

The mean uric acid level in this study (8.4 ± 3.4) was lower than that reported from quail in April and May (McRae, 1978: 21). However, while the female level had decreased over summer, the male level had increased. Perhaps this is explained by the different physiology of males and females at this time. Male birds are rapidly increasing their percent body fat (Roseberry and Klimstra, 1971: 109; data from this thesis) possibly by utilizing gluconeogenic pathways that result in increased waste nitrogen and higher uric acid levels. Also, decreasing testes weights in the late summer males indicate lower levels of circulating nitrogen-conserving androgens (Hanson, 1962; Anthony, 1970; Ottinger, 1983). Females, on the other hand, are also increasing fat levels but are making large protein contributions to the developing yolk and egg albumen, which would lower the level of end-product nitrogen (Bell et al., 1959). Sturkie (1965) reported lower non-protein-nitrogen (essentially uric acid) in female than male chickens that were both starved and fed.

The two juvenile birds' uric acid determinations were in the lower range of adult values (juvenile mean = 5.7 ± .7, n=2). Woodward et al. (1983) reported a significantly lower plasma uric acid level in 1 year old partridges (Alectoris chukar) than that of 7 year olds. No information was found on the effect of ageing on uric acid specifically, however, Brandt et al. (1951) found that plasma proteins generally increased from 4 weeks to adulthood in chickens. Perhaps increased protein specific demands of the still growing young birds had a nitrogen-conserving effect on protein metabolism that resulted in lower end-product nitrogen in the form of uric acid.

The most abnormal uric acid level in this study was 14.8 mg/dl in adult male number 6. Besides the high uric acid, this bird had the lowest percent body fat and low oven-dry weight. All other plasma parameters appeared to be within the normal range as indicated by this survey. McRae (1978) felt that interference with protein digestion caused by several female proventricular nematodes, T. pattersoni, accounted for depleted lipid reserves, protein depletion and increased uric acid levels. In this study, bird number 6 did not have any T. pattersoni in its proventriculus and a lower than average number of other parasite species. Other birds with high numbers of T. pattersoni (20 and 13) did not have corresponding high uric acid levels. There did not appear to be a significant relationship between T. pattersoni and uric acid among birds I examined.

Because plasma uric acid is a primary end product of protein degradation, its concentration can be a useful indicator to relative levels of gluconeogenic metabolism. However, its usefulness relies on the availability of comparison baseline values as well as other simultaneously taken plasma biochemical values. The plasma uric acid levels I observed did not seem to indicate that an increased amount of protein catabolism was occurring. This further indicated that energy needs were being met through dietary intake and "regular" glycolytic pathways. However, both male and female birds could be experiencing increased requirements for protein that could be utilizing some of the end-product nitrogen that would otherwise show up as uric acid.

III. PARASITE LOAD

Nematodes

The cecal worm, Heterakis bonasae, was recovered from every bird in this study and has been found in almost every quail examined on Ames Plantation (Blakeney, 1970; McRae, 1978). Also, this parasite has been reported in wild bobwhite from several other localities (Kellogg and Prestwood, 1968). Blakeney (1970) found that the intensity of H. bonasae infections on Ames varied little between seasons, and attributed this to the direct life cycle of the parasite. But, Davidson, et al. (1980) reported that numbers of H. bonasae in Florida bobwhite increased from May to September and then declined to the following March. The mean number of H. bonasae in adult birds in this study (138) was higher than the mean reported by McRae for April/May bobwhite (94) which could indicate a summer rise in abundance similar to that observed by Davidson et al. (1980). Most of this increase seemed to be contributed by a significantly higher number of worms in female birds ($P \leq .05$). Esch (1975: 345) reported that an increase of adrenocorticoids associated with stress reduced host resistance to parasitism, possibly explaining the increased infection in breeding females in late summer. However, infection intensities were most likely increased as a result of the cumulative effect of warm weather on the build up of parasite eggs in the Ames environment. Adequate environmental conditions would enable a greater number of H. bonasae eggs to mature to infective stage and be available for quail ingestion. Davidson et al. (1980) reported that H. bonasae infection in juveniles increased until January when levels approached that found in adults. Juvenile birds were only trapped in one month of this study so monthly comparisons were not made. However, Blakeney (1970) found that cecal worm burdens of juvenile bobwhites on Ames were 4 times greater in the October-December quarter than in the July-September quarter indicating that intensity of infection increased with length of exposure.

Large numbers of H. bonasae have been reported from bobwhite with little associated pathology, (Cram, 1931; Blakeney and Dimmick, 1971; Davidson et al., 1982). I observed normal cecal appearance in 2 birds that harbored 416 and 553 worms. H. bonasae has been considered as a possible reservoir for the spread of blackhead disease, however, Davidson et al. (1978) reported that the parasite's ability to transmit the blackhead organism, Histomonas meleagris, was not very good. Because the bobwhite has been reported to be more resistant to the symptoms of blackhead, it should be considered as a potential carrier of the disease, but probably not via H. bonasae.

Tetrameres pattersoni were found in the proventriculi of 50% of the birds in this study; female T. pattersoni were present in 31% of the infected birds. Both sexes of this nematode were not always present in the same bird. Ruff (1984) noted that the male apparently enters the proventricular glands only long enough to mate with the female. Female worms were large, globular and found encysted in the proventricular wall. Males were smaller, white,filiform worms that were found in the mucosa.

Pathological conditions associated with blood sucking female Tetrameres range from swelling of the proventricular wall to mucosal swelling, inflammation and secretory gland dysfunction (Cram, 1931; Kellogg and Doster, 1972; Wehr, 1971). McRae (1978) suggested that large numbers of Tetrameres led to impaired proteolytic function of the proventriculus and to a state of protein deficiency. McRae noted lowered body weight, depleted fat levels and increased uric acid in an individual that harbored 18 female T. pattersoni. In this study, 2 birds harbored 20 and 26 female T. pattersoni in their proventriculi but no extremes in physiologic parameter values were associated with these birds. However, a thick yellow mucous present in the proventriculus was probably a result of infections. It was not determined whether the infections or the increased mucous impaired the function of the proventriculus. Because of the abundance of the intermediate host of T. pattersoni during the summer months, there is a potential for serious infection with this parasite during this time.

Cyrnea colini was recovered from beneath the gizzard lining of 7 birds, however, 5 of the birds had 2 or fewer worms. Cram (1931) reported that C. colini was common in mature wild bobwhite and frequent in juveniles from all sections of the southeastern states. Though parasite incidence was high in Cram's survey, number of parasites per bird was low (2-5) and she associated no pathology with their presence. In this study, the one adult male that harbored 6 C. colini (plus 20 T. pattersoni) had above average body weight, dry weight and fat percent. This bird appeared to be in good condition in spite of the presence of these worms.

The higher number of C. colini found in this study (27%) compared to that reported in McRae's winter/spring bobwhite study (2.6%) (1978) was probably a consequence of the parasite's life cycle. The arthropod intermediate host (probably a cockroach) necessary for transmission is more prevalent during the summer months and comprises a larger portion of the bobwhite diet at that time (Eubanks, 1972). Davidson et al. (1980) reported a peak of immature *C. colini* during the summer months in bobwhite in Florida and attributed it to the seasonal abundance of the arthropod intermediate host. The absence of *C. colini* infection in juveniles was probably due to lack of sufficient exposure of the birds to infected intermediate hosts. Cram (1931) reported it took 41 days for mature worms to develop in the host after its ingestion of the intermediate host. The potential for heavy infections of this heteroxenous parasite exists in juvenile bobwhite during the summer because of the abundance of arthropod intermediate hosts available to a large juvenile summer population. Davidson et al. (1980) reported a sharp increase of *C. colini* in summer juvenile quail that continued with time to eventually approach a prevalence of 100%.

Cheilospirura spinosa was found in the gizzard of a male bird each month (2 and 1 worms each). This parasite has been frequently recovered from bobwhite in other studies on Ames but usually in low numbers per bird (Cram, 1931; Blakeney, 1970; Dabney, 1974). *C. spinosa* also has been reported as a common parasite in quail from Tall Timbers Research Station, Leon County, Florida; again, usually in low numbers (Davidson et al., 1980; Kellogg and Prestwood, 1968).

No pathological symptons due to *C. spinosa* were noted in the infected birds. Ruff (1984) noted that heavy infections can cause marked proliferative changes in the gizzard wall and tortuous paths between the lining and muscular wall. In lighter infections, Blakeney and Dimmick (1971) noted some erosion of muscle adjacent to the gizzard lining. The light infections found in this study and reported in others indicated that this parasite was not a serious problem to quail on Ames. However, heavier infections do occasionally occur on Ames (Dabney, 1974) and the parasite could be a problem in those instances.

C. spinosa requires a grasshopper for an intermediate host to complete its life cycle (Cram, 1931). It would be expected to increase in quail as grasshoppers increase in summer months. Davidson et al. (1980) showed that this was the case in bobwhite in Florida where prevalence per bird peaked in August and then returned to a stable level for the rest of the year. Blakeney (1970) reported a 4-fold increase in C. spinosa prevalence in the July to December half of the year and attributed it to the life cycle of the parasite. The heteroxenous life cycle of C. spinosa subjects summer quail to potentially significant infections. However, this study indicated a low infection prevalence and intensity among quail in July and August. C. spinosa was an infrequent parasite of little pathologic significance for summer bobwhite.

Seven specimens of the proventricular worm, Dispharnyx nasuta, were recovered from the proventriculus of an August caught juvenile bird. This bird had the lowest body weight, dry weight and percent fat of all juveniles. After being transported inside for blood collection, this bird died during handling. No biochemical data were available from this individual, however, the proventriculus contained a thick yellow mucous and worms were buried in the mucosa.

Wehr (1971) noted that young partridges and pheasant chicks infected with D. nasuta became droopy and usually died as the result of the infection. Heavy infections caused maceration and thickening of the proventricular wall to entirely block the opening and prevent the passage of food. Hwang et al. (1961) reported that in severe infections of this parasite in pigeons there was evidence of secondary bacterial invasion in addition to proventricular inflammation, hypersecretion of mucous and congestion. He reported thousands of pigeon deaths in the southern U.S. caused by D. nasuta. D. nasuta is an important parasite pathogen in ruffed grouse, Bonasa umbellus, (Allen, 1924; Goble and Klutz, 1945; Madsen, 1952). Bump (1935) regarded it as the most important parasite in wild game birds in New York.

D. nasuta infections have been reported in significantly higher abundance in juveniles of bobwhite (Davidson et al., 1980) and ruffed grouse (Goble and Klutz, 1945). Madsen (1941) observed that D. nasuta was encountered in greater numbers in young partridges and only in pheasant chicks. Its prevalence in juveniles is attributed to the abundance of the intermediate host (sow bug, Porzellio scaber and pillbug, Armadillidum vulgare, Cram, 1931) at a time when increasing numbers of young birds enter the summer population. Cram (1931) reported that it took 1 month for this worm to mature after ingestion of the intermediate host. The lowered ability of the young bird's body defenses to throw off a parasitic infection (Wehr and Herman, 1954) further enhances this parasite's pathogenicity. D. nasuta should be considered an important pathogen in young-of-the-year birds in late summer and fall.

Cestodes

The only species of cestode found in this study, Rhabdometra odiosa, occurred in 3 females. Rhabdometra has been reported in almost every parasite study on Ames Plantation (Cram, 1931; Blakeney, 1970; Dabney, 1974) and also from studies in several other localities (Kellogg and Prestwood, 1969 from Blakeney 1970; Kellogg and Caplin, 1971).

This parasite uses various beetles as its intermediate hosts and one may expect that its transmission would increase as numbers of beetles increased in the bobwhite diet during the summer months. However, Blakeney found the incidence of cestode infection in both adult and juvenile quail remained about constant throughout the year. Davidson et al. (1980) found that incidence of Raillietina cesticullus and Raillietina colinia (cestodes which also use beetles as intermediate hosts) showed erratic fluctuations in prevalence and intensity without any indication of peaks in transmission or seasonal trends in level of infection. These cestodes would probably cause problems only when they were present in sufficient numbers to congest the intestine to the point where movement of its contents was impaired. The small numbers of individuals found in this study were not believed to cause any problem for the quail.

Trematodes

The two trematode species found in this study, Leucochloridium sp. and Echinoparyphium sp. are the first reported trematodes of these genera from bobwhite quail in Tennessee. Each was found in the lower small intestine of a laying hen. Other reports of trematodes from bobwhite in the southeast have been rare (Davidson et al., 1982). Davidson et al. (1982) reported both Leucochloridium and Echinoparyphim in their survey of ruffed grouse parasites from several (mostly eastern) localities in the United States.Hon et al. (1975) reported finding trematodes in 33% of wild turkeys examined in Florida. However, most fluke burdens were small and the majority were single species infections. The most common trematode these investigators found was Echinoparyphium recurvatum, a species listed as a common fluke of waterfowl (McDonald, 1969).

The life cycles of Leucochloridium and Echinoparyphium involve development in a snail intermediate host. Eggs are shed from the contaminated definitive host, and if conditions are favorable, hatch as miracidium that infect a snail intermediate host. Further development in the snail produces cercariae that either encyst and develop into metacercariae in the same snail host or in other mollusks or tadpoles. A remarkable feature of the life cycle of Leucochloridum is the multi-colored broodsack that develops and pulsates in the tentacle of the snail intermediate host. This broodsac which contains the infective metacercariae can be seen from some distance away (Byrd, 1940) and would surely enhance its selection by bobwhites. Lewis (1974) reported a 6-10% infection of Leucochloridium sporocysts in Succinia ovalis, a snail species that characteristically inhabits deciduous woodlands. Byrd (1940) found an intermediate stage of Leucochloridium in a snail specimen, Succinea retusa, at Reelfoot Lake, Tennessee. Kingston (1984) reported 3 snail species as intermediate hosts for E. recurvatum: Symnaea palustris, Planorbis planorbis and Physa acuta. The snails recovered from the crops of birds in this study were too digested to be categorized below class Gastropoda, however, Eubanks (1972) reported that several families of snails (including Succineidae) were present in the summer diet of the bobwhite on Ames Plantation. The present study indicated that the intermediate stage of the fluke was in the Ames environment and was most likely being harbored in snails. The flukes probably have always been an accidental parasite of the bobwhite on Ames, but have not been reported previously.

Gut dwelling flukes attach to the intestinal wall of their host by means of oral and ventral suckers. Feeding is suctorial and associated with the attachment of the oral sucker (Halton, 1967). Feeding may involve the enzymatic breakdown of host epithelium and ingestion of this along with associated mucoid secretions (Noble and Noble, 1976). Generally, trematodes reported from birds seem to cause only light to moderate pathogenic changes. Pathogenic conditions only seem to occur when large numbers of trematodes are present (Kingston, 1984). No intestinal wall abnormalities were observed in the infected birds in this study and the few trematodes found were considered pathogenically insignificant to the birds.

It is perhaps of more interest that flukes were found only in laying hens. These hens could have become infected because of different feeding habits from the other birds or because of different body responses once infection took place. Eubanks (1972) found that female birds consumed both more food and more animal food than males during the summer months. One of the infected females had the most encysted T. pattersoni and the other the most H. bonasae suggesting they may have been under some stress. Increased output of adrenocorticoids in response to stress is known to lower host resistance to parasitic infections (Esch, 1975). It was likely that feeding habits or body response, or both, played a role in the acquisition of trematodes in the female birds in this study.

IV. ORGANS

Adrenals

Adrenal weights were examined in this study as an index to stress in July and August quail. Kirkpatrick (1980) reported that an increase in adrenal weights was probably the most often used indicator of prolonged general stress response in animals. In birds, increase in adrenal weight is largely the result of hypertrophy of adrenal cortical tissue (Siegal, 1980). Anderson (1972) reported that breeding pheasant hens had adrenal percents of .01044, an increase over winter and prebreeding. Noting the higher adrenal weights of cocks during prebreeding, Anderson stated that cocks were subjected to considerable stress during prebreeding but this was short lived. Hens, on the other hand, were under less stress but it persisted throughout the summer months.

Mean weights of adrenals in July and August were lower than in winter (Dabney, 1974) which seemed to indicate that quail at late breeding were less stressed than bobwhite during winter. Dabney and Dimmick (1977) reasoned that increasing adrenal weights coupled with declining fat reserves during winter indicated a stress response of the bird to winter conditions. The lowered adrenal weights and increased fat reserves found in this study indicated that the latter breeding period was probably not a stressful period for quail. However, because the small size of the bobwhite adrenals made extraction difficult, differences in extraction technique could account for a portion of the difference in adrenal weights between these 2 studies.

Two male birds in this study had adrenal values 6.6 and 18 times greater than the mean of all other birds (Appendix, Table 10). One of these birds could have been experiencing significant physiologic stress due to an unusually high 28 percent body fat level. This high fat content may have hindered thermoregulation during the hot summer months, perhaps stressing the bird enough to cause the adrenal increase. Other body parameters of these birds did not reflect similar deviations.

Adrenal values were higher for females than males, but not significantly so. Adjusted adrenal weight in laying female bobwhite (this study) was lower than that found in late winter prebreeding females (Dabney, 1974). Therefore, the adrenal "peak" occuring during laying in hen pheasants (Breitenbach and Meyer, 1959) does not appear to occur in laying bobwhites. This was also an indication that laying bobwhites were less stressed than birds during late winter.

Pancreas

The avian pancreas contributes significantly to the metabolic process by its production of gastric secretions to aid digestion and its synthesis of hormones influencing carbohydrate, lipid and protein metabolism (Assenmacher, 1973; Hazelwood, 1976).

The mean percent body weight comprised of pancreas for the 21 adult quail in this study was .1226. Dabney (1974) reported a much higher pancreas value of .3962 for late winter (March) quail on Ames Plantation. A portion of this difference was likely due to increased mesenteric fat included in the pancreas extraction (Dabney, 1974: 49). Additionally, Chernick et al. (1948 in Dabney, 1974) revealed that an antitrypsin present in uncooked soybeans caused a significant increase in pancreas size in young chickens. Soybeans were not found in the crops of the birds in this study but were available to the birds in Dabney's study and this difference in diet could have affected pancreas size. Dabney reported substantially larger pancreas size from birds where soybeans were available compared to birds from an area where soybeans were not grown.

Pancreas values were higher for females than males. Anderson (1972) observed a similar difference during most of the year among pheasants. Hanson (1962) also found this relationship in Canada geese. Breitenbach and Meyer (1959) reported that hen pheasants' pancreas weights peaked at the end of laying and then rapidly declined as food intake decreased during incubation. Female bobwhite eat a larger quantity and a greater variety of food than males during the summer months on Ames (Eubanks, 1972). This difference in diet could cause an added demand on pancreas function that could result in an increased weight.

Follicles and Oviduct

The 5 females (all adults) were in laying conditions. The ovaries of these birds contained several developed follicles and their oviducts were enlarged. The birds were laying at a time past the peak laying period for bobwhite on Ames (Dimmick, 1968), and follicles and oviducts seemed to be of normal breeding size.

Leopold (1977) found that the follicle diameter of wild California quail peaked at 20 mm before ovulation. Wilson et al. (1973) found that mature ova of housed bobwhite were 18-19 mm in diameter. The largest follicle found in this study was 15 X 22 mm (oval in shape) and was found in the female with the most developed egg in her oviduct. Because this female was close to laying and because there is little follicle development in the last day before ovulation (Lewis, 1963) this follicle likely represented maximum follicle size.

Wilson et al. (1973) determined that the stage of final rapid development of the bobwhite follicle was about 10 days. During this time the follicle is filled with high lipid yellow-yolk. The difference in sizes of the hierarchically arranged follicles represented about 1 days growth since bobwhite usually lay 1 egg per day (Stoddard, 1931).

The mean oviduct length (from the infundibulum to the cloaca) was 23.5 cm. Lewin (1963) stated that the oviduct was capable of increasing in weight 700 times during the rapid growth of the breeding season. Ricklefs (1976) found that the oviduct size did not correlate to body weight in the starling but positively correlated to albumen content in the laid egg. Since he found that egg sizes varied because of their relative amounts of albumen, he speculated that larger oviducts secreted more albumen and therefore produced larger eggs. Rzasa (1981) felt that the oviduct might play a physiologic role in the regulation of laying because of estrogen stimulated prostaglandin production in the uterus. Lake and Gilbert (1964) showed that mechanical blockage of the oviduct (such as an egg) would inhibit ovulation indicating synchronous and interrelated physiologic processes taking place in the ovary and oviduct.

Several factors can influence what size the female reproductive structures will be at a certain time during the breeding season. Lewin (1963) and Leopold (1977) correlated spring weather conditions to initiation and duration of reproductive condition. Obviously, starvation would have a seriously inhibiting effect on development of reproductive structures (Morris and Nalbandov, 1961). Limited food intake, though perhaps not affecting gonad size, also could influence the output of reproduction (Kendeigh, 1941; Barrett and Baily, 1972; King, 1972). It is also probable that increased, prolonged stress could affect size and function of reproductive structures. Flickinger (1966) noted that the increase in adrenals and circulating corticoids and the decrease of gonads brought about by administration of ACTH was similar to conditions in his earlier work where birds were under significant social stress due to crowding. Flickinger suggested that increased endogenous levels of adrenal corticoids may interfere with reproductive responses to gonadotrophins or gonadal steroids, or ACTH may have a direct effect on the gonads themselves.

Testes

The testes of the adult cocks trapped in this study were all in an enlarged state characteristic of the breeding period. Mean testes weight of adult cocks of August was significantly lower than in July ($P \leq .01$). Lewin (1963) found that only when the left testis of California quail was over 8.0 mm in length did it produce sperm in sufficient numbers for successful reproduction. Lewin felt that he could delineate the viable part of the male breeding season by assessing testis size. The July and August testes lengths of this study were much greater than those in Lewis' California quail and mean length was greater than the minimal spermatogenic size of 8.0 mm. This indicated that the breeding readiness of bobwhite males at Ames lasted longer than that of California quail. Immelman (1971 in Leopold, 1977) noted that development of the testes was most importantly governed by the proximate effect of photoperiod and the ultimate effects of weather, temperature and body condition. Detrimental spring weather and quality of food was believed to contribute to the lower peak size and earlier regression of testes in wild California quail (Leopold, 1977). Shortened breeding due to early regression of the cock's testes would lower total nest production which appears to be so vital to fall population level on Ames (Dimmick, 1974).

There was a significant negative correlation between testes percent and oven-dry weight and fat percent in this study ($r=-.64$, $P\leq.01$, $n=18$). Anderson (1972) suggested a correlation between testes weight and level of breeding activities in male pheasants. Larger testes in bobwhite in July could indicate an increased production of androgens which have been correlated with expressions of courtship and agressive behavior (Temple, 1974). The increased energy demands of such behaviors could cause a drop in body energy reserves that would show up as lowered oven-dry weight and fat percent. Perhaps this explains the lower fat percent and dry weight of July males. Certainly, more information is needed to clarify this relationship in bobwhite quail.

Several other relationships were found. A significant negative correlation occurred between testes values and plasma cholesterol ($r=-.56$, $P\leq.01$, $n=15$). The interstitial Leydig cells are the most probable sites of androgen production

(Sturkie, 1976: 341) and cholesterol is an important precursor to this production. Jones (1970) found a depletion of interstitial cell cholesterol in California quail in the spring and an increase as testes regressed. Increased plasma cholesterol in late summer male bobwhite might have been partially due to lower androgen production from regressed testes. There was a significant negative correlation between testes values and plasma albumins. Albumins are believed to act as a protein reserve (among other functions) (Griminger, 1976) and therefore would be expected to increase in the presence of increased anabolic androgens in breeding males. The negative correlation was curious and unexplained.

CHAPTER V

SUMMARY

During July and August, 1981, 26 bobwhite quail were trapped on Ames Plantation, Tennessee. After blood samples were collected, each bird was sacrificed. Later, determinations were made for body weight, body fat, gastrointestinal parasites, food habits, and blood plasma biochemical values. Adrenal, pancreas, testes, follicle and oviduct measurements were also taken.

The mean body weight for all birds was 158.0 g. Adult females were significantly heavier that adult males (180.3 g _vs_ 154.7 g, $P \leq .05$). Mean body weight of juveniles was 140.9 g. Adult male body weight increased significantly from July to August ($P \leq .05$). This increase was believed to be associated with changing hormone levels and reduced breeding activity. Body weight and body fat correlated weakly, but significantly ($r=.61$, $P \leq .001$) among all birds. Because the non-fat component of body weight tended to "mask" fat levels, body weight was not a reliable indicator of body fat level. Body dry weight correlated much better with percent body fat ($r=.83$, $P \leq .01$) but its applicability as a fat index was limited because its use necessitated the bird's sacrifice and lengthy laboratory analysis.

Percent body fat for all adult birds was 13.5. The adult male level of 12.9 was not significantly different from the female level of 15.5. The juvenile level was 8.4. Adult males were fatter in August (15.2%) than in July (9.7%). Because adult male body fat increased substantially from July to August, and because adult females were fatter than at earlier breeding, the population appeared to be in a positive energy state, with fat deposits increasing.

Changing hormone levels brought about by environmental and behavioral cues were most likely the cause of this metabolic state.

The degree of lipid metabolism was determined by measuring blood plasma levels of triglyceride, cholesterol and free fatty acid (FFA). FFA was determined by measuring the plasma level of albumin. Triglyceride and cholesterol indicated the dietary fat intake or lipogenesis while albumin indicated the degree of fat depot degradation. Albumin levels in both sexes were lower than in birds examined earlier in the breeding season. This biochemical blood characteristic accompanied an increase in body fat. The significantly lower male albumin level in August further indicated a decline in lipolysis and was accompanied by a marked increase in body fat from July to August. Adult male triglyceride level (73.4 ± 47.0, $n=15$) was higher than reports from earlier breeding and was not significantly different by month. This increase in triglyceride along with a rise in cholesterol indicated increased lipogenesis and/or dietary fat intake. Conversely, female triglyceride appeared to have decreased from earlier breeding (293.5 ± 289.5, $n=2$). This decrease most likely was caused by lowered lipogenesis and/or increased fat storage.

Plasma glucose was significantly lower in adult females (155.6 ± 76.3, $n=5$) than in adult males (325.7 ± 78.7, $n=15$) ($P \leq .001$), and the glucose level of all birds (281.7 ± 102.3, $n=22$) was lower than that reported at earlier breeding. Decreased glucose in females may have resulted from the increased metabolic demands of laying. The increase in globulin fraction and decreased plasma glucose may have indicated a biochemical reaction to a significant increase in gastrointestinal parasites.

Total plasma proteins in this study were higher than reported from bobwhites in April/May. Though the albumin fraction was lower, the globulin fraction had increased substantially. Increasing globulin levels in birds are often seen as an immune response to some sort of pathogenic invasion. The increased number of parasites in late summer may have generated such an immunologic response.

Plasma uric acid increased in males (9.0 ± 3.4) and decreased in females (7.6 ± 3.8) over summer. Decreasing influence of anabolic androgens and/or increased gluconeogenic metabolism in males and the large protein requirement for the developing ova in females may have instigated these changes.

Five nematodes, 1 cestode and 2 trematodes were identified in the gastrointestinal tracts. Heterakis bonasae, a common bobwhite cecal worm, was recovered from every bird, averaging 138 worms per adult bird. Females harbored a significantly higher number of these worms than did males. Tetrameres pattersoni were found in the proventriculi of 50% of the birds in this study; female T. pattersoni were present in 31% of the infected birds. Female T. pattersoni were lodged in the proventricular ducts; 2 birds with 20 and 26 worms had a thick yellow mucous indicating an aggravated body response. Cyrnea colini and Cheiliospirura spinosa were recovered from the gizzards of a few birds. These worms were present in low numbers and were not associated with any detectable pathology. Dispharnyx nasuta caused noticeable damage to the one juvenile bird infected. This parasite, along with others requiring an intermediate host, was considered potentially dangerous during the summer months when conditions were conducive to high rates of infection. The cestode Rhabdometra odiosa was found in 3 females.

Two genera of trematodes, Leucochloridium and Echinoparyphim, were recovered from the intestines of 2 hens. Only a few individuals were recovered and no pathology was associated with their presence.

Adrenal glands were examined as an index to a general stress condition. Mean adrenal percent of body weight was .0105 and was not significantly different between sexes. Adrenal values in summer were lower than in winter, suggesting that late breeding season bobwhites were not experiencing significant stress. Mean pancreas percent was .1126, with no significant difference between sexes.

The 4 largest follicles and the oviduct from each of the 5 laying females were weighed and measured. Maximum pre-ovulation size of the hierarchal follicle development was 15 X 22 mm. Follicle percent of body weight correlated well to follicle volume, but only significantly in the 3 smallest follicles. Oviduct length averaged 23.5 cm.

The testes of each cock were weighed and measured. The left testis was heavier and larger in both adults and juveniles. Juvenile testes were significantly smaller than adults. Mean testis percent of body weight declined significantly in August adults and showed a significant negative correlation ($r=-.66$, $P\leq .01$) to increasing fat percent.

The July bobwhite diet contained about equal volumes of animal and plant matter as indicated by crop content analysis. Animal matter in the August diet dropped to 27.5% as did the variety of food items present. Seeds of *Sassafras albidum* and grasshoppers were the most abundant plant and animal foods respectively.

Interrelationships of variables were complex and therefore correlations were often unclear. Factor analysis indicated this complexity through its high parameter loadings across more than one factor. Each factor of the analysis explained a similar portion of the total variance which indicated that several complex biologic phenomenon were affecting the birds.

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APPENDIX

TABLE 10

BIOLOGICAL INFORMATION, ADRENAL WEIGHT, PANCREAS WEIGHT, TESTES WEIGHT AND TESTES SIZE BY MONTH AND BIRD NUMBER

Month	Bird No.	Age	Sex	Body Wt.	O.D. Wt.	% Fat	Adrenal Wt.	Pancreas Wt.	Testes Weight Left	Testes Weight Right	Testes Size wXl	Testes Size wXl
July	1	A	F	187.8	54.0	15.6	.0160	.1810				
July	2	A	F	164.5	46.2	17.1	.0122	-				
July	3	A	M	145.0	42.5	9.3	.0124	.1538	.7966	.3793	13X17	10X12
July	4	A	M	147.0	40.0	-	-	-	.3884	.2752	10X15	10X12
July	5	A	M	159.7	50.6	12.6	.1878	.1259	.5066	.3569	11X17	10X13
July	6	A	M	150.4	42.0	3.7	.0133	.1297	.6017	.4023	12X17	11X14
July	7	A	M	144.5	43.6	10.8	.0104	.1475	.4846	.4569	10X16	10X14
July	8	A	F	176.3	50.7	12.0	.0057	.0970				
July	9	A	M	146.7	44.3	8.3	.0092	.0491	.5051	.3865	11X17	11X13
July	10	A	M	134.2	42.4	8.7	.0075	.1043	.3204	.2392	9X13	8X10
July	11	A	F	202.0	61.0	19.3	.0099	.2955				
July	12	A	M	150.5	46.0	14.9	.0102	.2724	.4590	.3673	10X15	10X13
x̄				159.1	46.9	12.0	.0398	.1581	.5078	.3580	11X16	10X13
August	13	A	M	163.0	48.5	11.0	.0123	.1162	.2877	.2049	9X13	9X11
August	14	A	M	144.1	44.0	12.7	.0097	.0030	.4976	.3872	10X16	10X13
August	15	A	F	171.0	50.4	13.3	.0158	.0836				
August	16	A	M	164.5	51.9	14.9	.0091	.2000	.2614	.2073	9X13	8X9
August	17	J	M	144.5	41.3	7.2	.0097	.0473	.0065	.0042	2X4	2X3
August	18	J	M	144.7	40.2	11.4	.0107	.1797	.0035	.0035	2X4	2X4
August	19	J	M	133.4	34.4	6.6	.0016	.0607	.0032	.0019	2X4	2X3
August	20	A	M	173.3	57.7	19.8	.0087	.0635	.1454	.1143	9X11	8X10
August	21	A	M	147.9	46.0	11.4	.0074	.0710	.3121	.2394	10X15	9X12
August	22	A	M	170.2	61.0	28.5	.0646	.0447	.0921	.0813	7X9	7X9
August	23	A	M	146.5	46.5	15.7	.0126	.0194	.2298	.1113	8X13	6X10
August	24	A	M	163.0	46.8	5.7	.0123	.1614	.4644	.3926	10X16	11X14
August	25	A	M	181.0	59.8	22.1	.0083	.1122	.3011	.2359	10X14	10X12
August	26	A	M	153.3	46.2	10.2	.0065	.0287	.2551	.1324	9X14	9X14
x̄				157.2	48.2	13.6	.0142	.0915	.2200	.1628	7X11	7X10

TABLE 11

NUMBER OF PARASITES, PLASMA LIPID AND PROTEIN VALUES
BY MONTH AND BIRD NUMBER

		Nematodes					Lipids		Protein		
Month	Bird No.	*H.* bon.	♀*T.* patt.	♂*T.* patt.	Other	Gluc.	Trigly.	Chol.	T.P.	Alb.	Glob.
July	1	416	1	29	2 *C.c*;*R.o*	133	89	85	2.2	1.0	-
July	2	199	-	-	*R. od.*	207	-	83	4.5	2.7	1.6
July	3	34	-	-		395	122	129	-	1.3	-
July	4	142	-	-		340	49	86	3.4	1.5	1.9
July	5	52	-	-		-	-	-	-	-	-
July	6	18	-	1	1 *C.c*;2*C.s*	343	62	118	3.5	1.2	2.3
July	7	80	3	3	1 *C. co.*	403	135	109	3.0	1.8	2.0
July	8	171	26	2	2 *Leucoch.*	260	498	128	3.8	1.8	2.0
July	9	35	5	2	1 *C. co.*	-	-	-	-	-	-
July	10	68	-	1		277	43	137	-	-	-
July	11	553	-	-	4 *Ech*,*R.od*	102	-	172	4.6	2.7	1.9
July	12	51	20	1	6 *C. co.*	443	20	165	-	1.1	-
$\bar{x}$		152	5	3		290	87	121	3.6	1.6	1.9
August	13	94	-	1		287	127	134	4.1	1.6	2.5
August	14	50	-	-		-	-	-	-	-	-
August	15	387	2	-	1 *C. co.*	76	-	185	5.5	2.8	2.7
August	16	110	-	-		249	16	161	3.0	1.4	1.6
August	17	17	-	-		245	21	166	2.9	1.3	1.6
August	18	9	-	-		290	17	163	2.9	1.3	1.6
August	19	3	4	3	5 *D. nas.*	-	-	-	-	-	-
August	20	37	-	-		225	21	248	4.5	2.0	2.5
August	21	133	-	2		274	100	155	4.2	1.9	2.3
August	22	53	-	-	1 *C. co.*	351	58	190	3.4	1.5	1.9
August	23	168	-	-		326	44	156	3.5	1.5	2.0
August	24	98	-	1	1 *C. spin.*	246	134	152	2.7	1.2	1.5
August	25	58	13	6		484	138	191	3.3	1.4	1.9
August	26	162	-	-		242	32	132	3.3	1.5	1.8
$\bar{x}$		99	1	1		275	64	169	3.6	1.6	2.0

TABLE 12

PLASMA NON-PROTEIN NITROGEN, MINERALS AND ELECTROLYTES
BY MONTH AND BIRD NUMBER

	Bird	NPN			Minerals			Electrolytes		
Month	No.	U. Ac.	BUN	Creat.	Ca	Phos.	Iron	Na	K	Ca
July	1	8.7	1.0	-	12.2	6.2	90	130	1.6	96
July	2	5.5	-	0.4	-	-	181	-	4.1	114
July	3	9.0	-	-	-	7.8	160	155	6.4	-
July	4	9.4	2.0	0.3	9.3	4.6	74	-	2.2	122
July	5	-	-	-	-	-	-	-	-	-
July	6	14.8	1.0	-	8.1	4.7	36	157	2.4	-
July	7	3.9	1.0	-	10.9	4.0	115	156	2.2	110
July	8	3.8	1.0	-	-	6.1	190	123	2.6	95
July	9	-	-	-	-	-	-	-	-	-
July	10	4.7	-	-	-	-	63	-	-	-
July	11	12.5	-	0.3	-	-	184	156	8.9	114
July	12	6.0	-	-	9.4	3.8	39	-	3.3	-
$\bar{x}$		7.8	1.0	0.3	10.0	5.3	113	146	3.7	109
August	13	6.6	0.0	0.3	10.6	9.6	138	154	6.6	104
August	14	-	-	-	-	-	-	-	-	-
August	15	-	-	0.3	4.4	-	209	155	-	113
August	16	13.2	-	0.0	10.2	-	104	-	8.9	113
August	17	5.2	-	0.3	9.7	7.1	86	156	3.6	105
August	18	6.2	-	0.4	0.4	5.6	68	159	3.1	116
August	19	-	-	-	-	-	-	-	-	-
August	20	9.3	2.0	0.5	14.2	7.4	88	-	4.1	113
August	21	14.2	-	0.4	12.8	-	119	-	5.6	119
August	22	7.8	1.0	0.4	10.6	4.0	68	-	4.1	114
August	23	7.1	-	0.4	11.7	-	68	-	8.1	117
August	24	12.6	0.0	0.5	9.0	3.3	102	-	3.6	122
August	25	7.1	-	0.5	9.4	2.7	43	156	1.9	110
August	26	9.5	-	0.4	11.2	-	74	-	4.7	116
$\bar{x}$		9.0	1.0	0.4	9.5	5.7	97	156	4.9	114

TABLE 13

PLASMA BILIRUBIN AND ENZYMES
BY MONTH AND BIRD NUMBER

Month	Bird No.	Bili.	Enzymes Alk. Ph.	LDH	SGOT
July	1	0.1	-	365	-
July	2	0.1	-	438	-
July	3	0.1	332	352	-
July	4	0.1	3	481	-
July	5	-	-	-	-
July	6	0.1	-	-	-
July	7	0.0	421	383	-
July	8	0.0	11	107	189
July	9	-	-	-	-
July	10	0.1	173	348	-
July	11	0.1	-	231	339
July	12	0.1	-	-	-
$\bar{x}$		0.1	188	338	264
August	13	0.1	619	528	427
August	14	-	-	-	-
August	15	0.1	-	380	401
August	16	0.1	-	-	-
August	17	0.1	-	575	184
August	18	0.1	-	-	378
August	19	-	-	-	-
August	20	0.1	-	349	-
August	21	0.1	324	298	360
August	22	0.1	652	528	-
August	23	0.1	280	286	-
August	24	0.1	697	-	-
August	25	0.1	660	390	-
August	26	0.1	-	404	-
$\bar{x}$		0.1	539	415	350

PART II. WING FAT AS AN INDICATOR OF TOTAL BODY FAT

CHAPTER I

INTRODUCTION

An adequate level of body fat is essential to the well being of all avian species. Fat depots are the main source of reserve energy on which species rely for survival. Moreover, assessing fat levels in a population provides a method for evaluating the relationship of that species to environmental conditions.

Body fat levels of bobwhite quail (*Colinus virginianus*) are useful indicators of this bird's ability to cope with changing environmental stresses. Robel (1972) detailed the "starvation protection" afforded bobwhite quail possessing high body fat levels. Dabney and Dimmick (1977) considered total body fat to be the best single indicator of condition for bobwhite quail.

Many studies of fat levels of birds have called for special population sampling and the utilization of the entire bird in the fat extraction process (Blem 1976). This type of study takes a significant investment in time, manpower and equipment and is often impractical. A simpler, less expensive procedure to evaluate body fat levels is needed.

Norman and Kirkpatrick (1981) found that wing fat levels of fall and winter killed ruffed grouse (*Bonasa umbellus*) were significantly correlated with total body fat levels. They pointed out that grouse wing samples collected from hunters would be a convenient source of information on population condition. Bobwhite quail wings are collected annually by some wildlife agencies, and if wing fat were significantly correlated with body fat, these wings would be useful as a convenient "yardstick" to measure condition.

The objectives of this study were to evaluate the usefulness of bobwhite quail wings as indicators of total body fat and, secondly, to identify the significance of feathers in the fat comparisons.

CHAPTER II

METHODS AND MATERIALS

I. COLLECTION OF BIRDS

The quail used in this study were shot on Tall Timbers Research Station, Tallahassee, Florida during the winter of 1981. All birds were frozen until their use in this study.

II. EXTRACTION OF BODY FAT

Each carcass was thawed for 4 to 6 hours. The left wing was removed at the humerus/radius-ulna junction and its feathers were clipped. Feathers were removed from the carcass, which was then cut into 8-10 pieces. The wing, the wing feathers, the sectioned body and the body feathers were frozen for 24 hours. Fat was extracted and measured for each of these sections of bird following the procedure mentioned earlier in this thesis (Fat Analysis, pg.7). Fat content was expressed as percentage of oven dry weight.

III. STATISTICAL METHODS

The Statistical Analysis System (SAS) programming package was used for data analysis. Coefficients of correlation and regression and paired T-tests were used to delineate the relationships of oven dry and fat weights between total body, wing and feathers. Means and standard deviations were determined for all variables.

CHAPTER III

RESULTS

The 26 birds used in this study consisted of 5 adult males, 3 adult females, 8 juvenile males and 10 juvenile females. Differences between parameter values were considered significant if the probability of chance occurence was less than or equal to .05 and highly significant if less than or equal to .01.

I. BODY, WING AND FEATHER WEIGHTS

The mean wet weight of all quail was 154.1 g. Weight differed significantly only between juvenile males (159.5 g) and females (148.7 g)($P \leq 01$) (Table 14). Total wet weight was not significantly correlated with total body fat weight; however, total dry weights correlated significantly with total body fat weights when computed with and without feathers ($r=.81$ and $r=.82$ respectively, $P \leq .001$ for both) (Table 15). Total dry weight was significantly higher in juvenile males than juvenile females ($P \leq .05$).

Dry weight and fat weight of the feathered wings were poorly correlated ($r=.59$, $P \leq .005$) as were dry weight and fat weight of the unfeathered wings ($r=.41$, $P \leq .05$). However, feathered wing dry weights correlated well with feathered wing fat weights among adult birds ($r=.87$, $P \leq .01$, $n=7$) (Table 15).

The dry weights of the total feathers and the wing feathers were not significantly correlated. Dry weights of the body and the body feathers showed little relationship ($r=.49$, $P=.01$), but dry weights of the wing and the wing feathers showed a strong relationship ($r=.89$, $P \leq .001$). This may be partially explained by the fact that the wing feathers comprised 35% of the wing dry weight while the total feathers only contributed 10% to the total body dry weight.

TABLE 14

BODY WEIGHTS, OVEN-DRY WEIGHTS, PERCENT FAT[a] AND FAT-FREE DRY WEIGHTS OF QUAIL BY BODY COMPONENT AND SEX

		Total Body			Total	Total	Wing
	Sex	Juvenile	Adult	Total	Wing	Feathers	Feathers
Body Weight (g)	Male	159.5	157.5	157.4	--[c]	--	--
	Female	148.7	167.2	150.8	--	--	--
	$\bar{X}$			154.1	--	--	--
Oven-dry Weight (g)	Male	54.0	52.4	53.4	2.0	5.8	.7
	Female	49.9	52.6	50.5	1.8	5.1	.6
	$\bar{X}$			52.0	1.9	5.5	.7
Percent Fat	Male	12.5	12.9	12.7	15.8	2.7	7.1
	Female	12.4	11.9	12.3	17.0	3.5	9.4
	$\bar{X}$			12.5	16.4	3.1	8.3
Fat Free Dry Weight (g) (C.V.)[b]				45.4 (4.7)	1.6 (9.2)	5.3 (10.8)	.6 (16.6)

[a] Ether-extractable body fat expressed as a percentage of oven-dry weight.

[b] Coefficient of variation=standard deviation÷mean X 100.

[c] Two dashes denote no information.

TABLE 15

CORRELATION MATRIX[a,b] OF FAT WEIGHTS (g) AND OVEN-DRY WEIGHTS (g) OF BODY COMPONENTS

	Tot. Carcass Fat Wt.	Str. Carcass Fat Wt.	Tot. Wng. Fat Wt.	Str. Wng. Fat Wt.	Tot. Carcass Dry Wt.	Str. Carcass Dry Wt.	Tot. Wng. Dry Wt.	Str. Wng. Dry Wt.
Total Carcass Fat Weight	1.0**	.99**	.24b	.39*	.81**	.82**	.23b	.40*
Stripped Carcass Fat Weight	.99**	1.0**	.20b	.37	.81**	.82**	.21b	.40*
Total Wing Fat Weight	.24b	.20b	1.0**b	.77**b	.26b	.26b	.59**b	.52*b
Stripped Wing Fat Weight	.39*	.37	.77**b	1.0**	.40*	.38*	.44*b	.41*
Total Carcass Dry Weight	.81**	.81**	.26b	.40*	1.0**	.99**	.51*b	.57**
Stripped Carcass Dry Weight	.82**	.82**	.26b	.38*	.99**	1.0**	.46*b	.59**
Total Wing Dry Weight	.23b	.21b	.59**b	.44*b	.51*b	.46*b	1.0**	.83**b
Stripped Wing Dry Weight	.40*	.40	.52*b	.41*	.57**	.59**	.83**b	1.0**b

[a] ** denotes $P \leq 0.01$; * denotes $P \leq 0.05$.

[b] n=21; other correlations n=26.

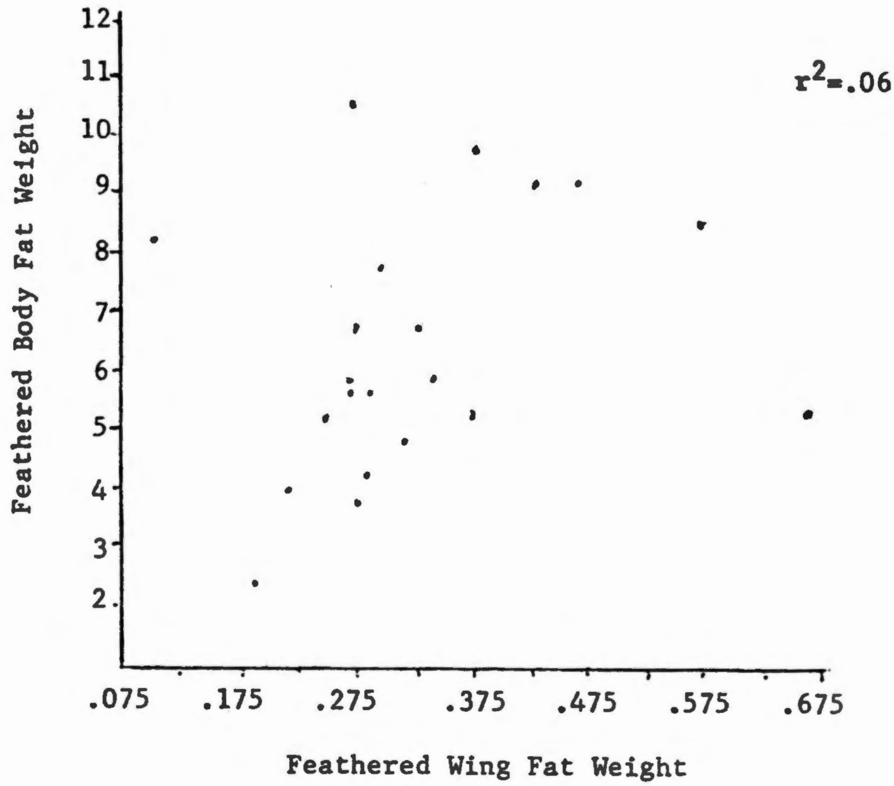
Fat-free dry weights of the total body showed half the variation of wing fat-free weights (Table 14).

II. BODY AND WING FAT

Fat weights and percentages were not significantly affected by age or sex. From the pooled data, wing fat and body fat weights in feathered or stripped birds (or any combination of feathered and stripped) were poorly correlated (Table 15) and showed weak linear relationships when plotted (Figure 1). In addition, mean wing fat percentage was significantly higher than mean total body fat percentage in the feathered ($P \leq .004$) and in the stripped analyses ($P \leq .001$). However, juvenile males did show good body fat to wing fat correlations in the feathered comparison and when the body was unfeathered and the wing feathered ($r=.87$, $P \leq .05$ for both). The unfeathered fat comparison in juvenile males did not show significant correlation. These 3 correlations were calculated on a sample of 6 birds. Adult females showed an almost perfect correlation between wing and body fat, but also had a low sample size ($n=3$).

In the feathered analyses, juvenile females averaged the highest wing fat percentage of dry wing weight (17.4) and adult males showed the highest body fat percentage of dry body weight (12.9). In the unfeathered determinations, adult males had the highest relative body and wing fat percentages (14.1 and 4.7 respectively).

Fat weights of the wing and of the total body varied considerably about their means. In the feathered wing, fat weight showed a coefficient of variation of 39% while the unfeathered wing fat varied less (26%). Fat varied less in the unfeathered wing than the feathered wing in all sex and age groups. This relationship was most evident in juvenile females where the fat in the feathered



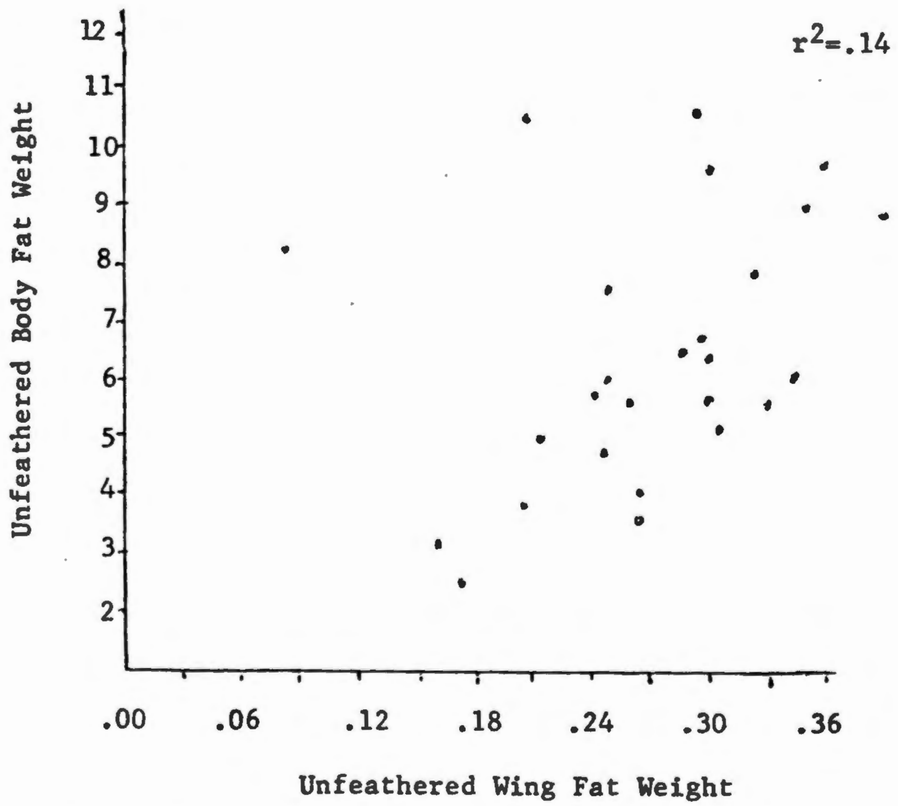
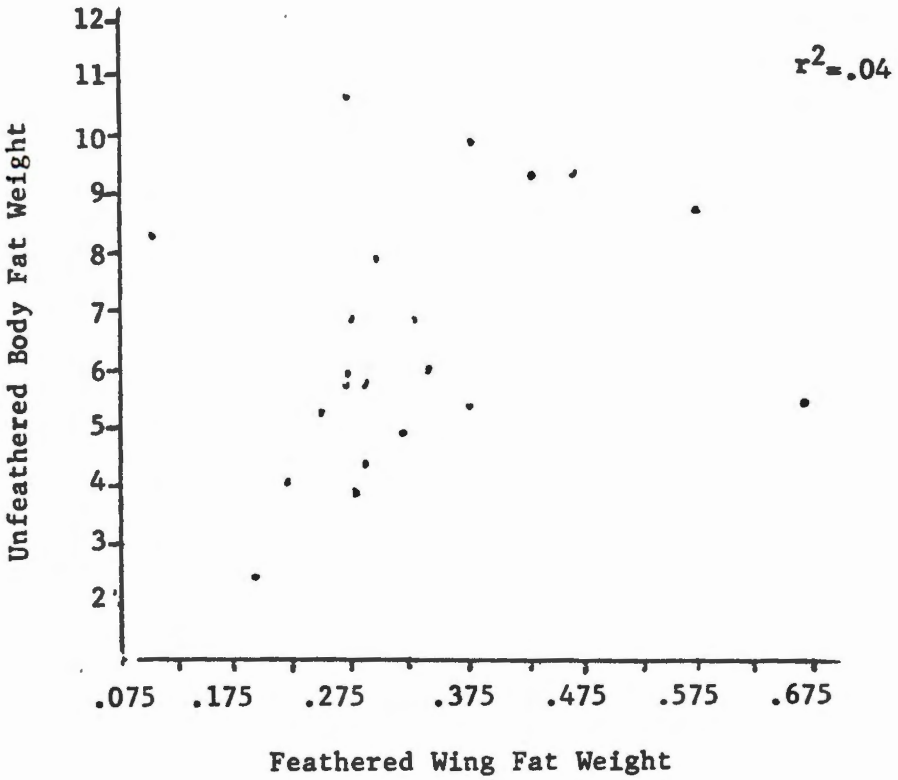


Figure 1. Plotted weights (g) of wing fat versus body fat of feathered and unfeathered combinations showing regression coefficients.



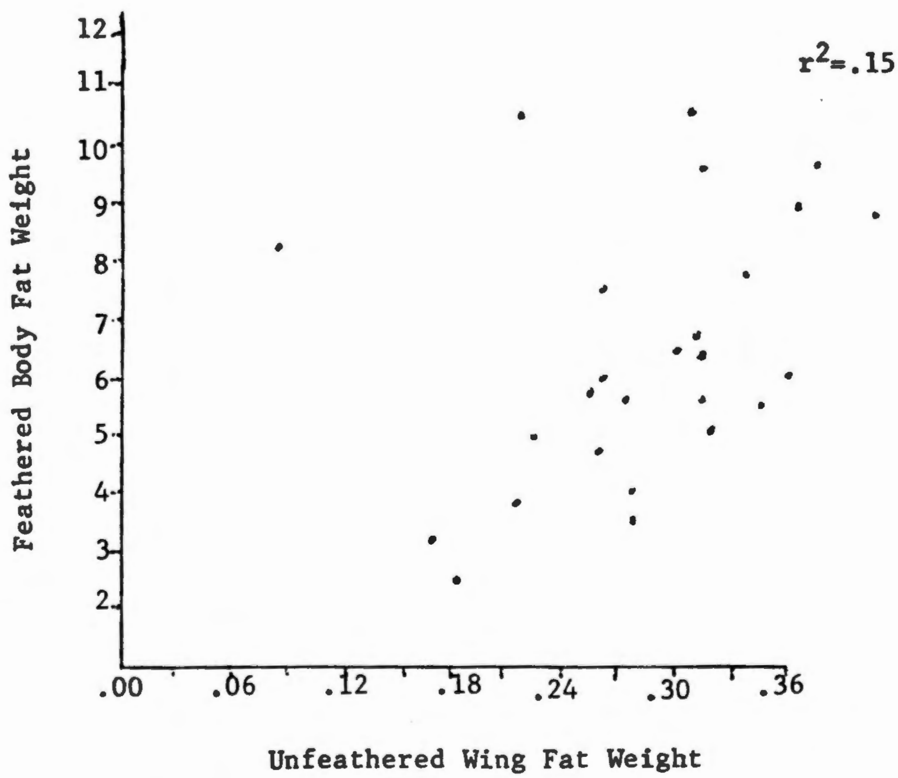


Figure 1. (Continued)

wing varied 53% versus 33% in the unfeathered wing. Variation in body fat (from feathered and unfeathered carcasses) was similar to that of the wing (c.v.=35%). However, body fat showed similar variation in all sex and age groups.

III. FEATHER FAT

Feathered fat percentages were significantly higher than unfeathered percentages in the total body and in the wing ($P \leq .001$ for both). However, including feathers in the wing-to-body fat comparison weakened the correlation (Table 15) and the coefficient of determination (Figure 1).

Wing feathers contained more than double the fat in total body feathers (8.3% and 3.1% respectively) (Table 14). The percentage of dry wing weight comprised of feather fat (2.9%) was over 9 times the percentage of the total dry weight that was feather fat (.3%). Feather fat levels of both components varied considerably (coefficients of variation were 141% and 63% respectively) and correlated highly ($r=.87$, $P \leq .001$). An average of 32.5 ± 19.3 percent of the total feather fat came from feathers of one wing.

CHAPTER IV

DISCUSSION

I. FAT COMPARISONS

Wing fat proved to be a poor index to total body fat. When data were pooled, percent wing fat and percent body fat were significantly different and poorly correlated. The strong correlations between wing and body fat seen in the juvenile males and the adult females are perhaps interesting but of limited management value since bobwhite wings are of questionable value in sex differentiation (Rosene, 1969: 45). The low sample sizes on which these correlations were determined (n=6 for juvenile males and n=3 for adult females) invites the speculation that these correlations may be spurious.

Norman and Kirkpatrick (1981) showed a high correlation (r=.86) between wing and body fat percentages in 10 winter killed ruffed grouse (Bonasa umbellus). These authors included the more muscular upper section of the wing in their fat analysis which caused an overall lower wing fat percentage. Including the upper wing in the comparisons of this study might have yielded a better correlation to body fat since wing fat percentages were consistently higher than body fat percentages. However, hunter donated wings are often obtained with various lengths of the upper wing missing, necessitating a lower wing detachment (such as the humerus/radius-ulna joint as this study uses) to standardize the wing samples.

Other studies comparing specific fat depots to total body fat have shown that abdominal fat was the single best index of body fat. Bailey (1979), Iverson and Vohs (1982) and Whishart (1979) found that in several species of waterfowl, abdominal fat significantly correlated to total body lipids and could easily be taken by the hunter. Becker (1979) found significant regression (r^2=.82) between abdominal fat and body fat in 200 chickens (Gallus domesticus). Abdominal fat also correlated highly (r=.95) to body fat in young guinea fowl (Numida meleagris) (Blum and Luclerq, 1980). The abdomen is a major site of fat deposit in quail but excising this fat is a more difficult and exacting procedure due to the quail's smaller size. It would be particularly difficult to obtain consistent samples from hunter contributors. From a management standpoint, these difficulties make the abdominal fat depot an impractical index to body fat for wild quail populations.

The ordered accumulation of fat in specific depots has long been noted in the bird body (McCabe, 1943). Subcutaneous fat layers appeared in the first stages of fat deposition and increased with subsequent fattening in the white-crowned sparrow (Zonotrichia leucophrys) (Blem, 1976). In this study, the fact that the wing had a consistently higher percentage of fat is only partly understood. The wing feathers and the wing carcass (minus feathers) had a significantly higher amount of fat per unit dry tissue than did the body. However, one would expect that since the wing is composed of "white meat" (lower in fat; higher in glycogen (Hazelwood, 1976) and does not have large fat depots similar to the body, that the wing fat percentage would be less. The far greater "bulk" of the body (non-fat tissue) compared to the wing evidently negates the greater amounts of fat deposits in the body. Norman and Kirkpatrick (1981) excluded the head, legs and feathers in their analyses of ruffed grouse body fat and found a good correlation between wing and total body fat.

II. FEATHER FAT

The percentage fat extracted from the total body feathers was substantially higher than that reported from the chicken (Steltenhiem, 1972). Accordingly, there was a significant difference in the amount of fat present in feathered and unfeathered birds in this study. But including feathers in the fat analyses did not yield a significant correlation between body and wing fat (Table 15, page 85). Therefore, presence or absence of feathers was not a determining factor in obtaining significant body-to-wing fat correlations.

The considerable variation in total feather fat (c.v.=63%) was caused by the significant and varied contribution of wing feather fat. The left wing's feathers contributed 32.5% of the fat in the total feathers and had a coefficient of variation of 141%. This large variation in fat percentage undoubtedly accounted for the fat variation in the total body feathers since 65% of the total feather fat would have been contributed by the two wings (presuming that the right wing feather fat was similar to the left). This disproportionate contribution of wing feather fat to total feather fat was not mirrored in the fat contribution of the wing carcass to the total carcass. Wing feather fat variation could be partially due to conspecific differences in "dusting" intervals. Borchelt and Duncan (1974) showed that dusting lowers the level of oily secretions present on the feather surface of the bird. Ether-extractable lipids from avian feathers consist of an endogenous fraction formed as a by-product of keratinization and an external oil covering of preen gland origin (Bollinger and Varga, 1960). Dusting behavior in the wild bobwhite is an important and relatively frequent function (Rosene, 1969; Stoddard, 1931) but even a lengthy absence of dustbathing would not be likely to cause all of the wing feather fat variability found in this study. Exclusion of both wings' feathers would result in a lower and probably more consistent feather fat level.

III. BODY WEIGHTS

Body weight correlated poorly to body fat in this study and is regarded as a poor index to physiologic condition by other authors (McRae, 1978; Owen and Cook, 1977; Whishart, 1979). Body weights vary considerably among bobwhites (Rosene, 1969) due to the varying levels of water, fat, digestive tract contents and body size. Clark (1979) noted that variation in body weights among individuals and closely related species handicaps it as a standard of body size. However, body weight has been used as a basis of subspeciation (Ripley, 1960). Linear measurements are more practical body size indicators in closely related taxa. A significant relation between body weight and body fat was found when an allowance was made for variation in structural size in several migratory species (Bailey, 1979; Iverson and Vohs, 1982). Rogers and Odum (1964) demonstrated that body weight and wing length could be used to predict body fat in 4 species of wood warblers.

Wing length or other structural measurements were not taken in this study; however, allowance for body size variability could be significant in achieving good correlations between body components in bobwhite quail. Using a structural index from the wing factored with wing fat or weight may produce a good index to total body fat.

In this study, there was a significant correlation between total oven-dry weight and body fat weight. McRae (1978) and Dabney (1974) found similarly high correlations in their comparisons of body fat and dry weight in bobwhite. This positive relationship is better understood when the small variation in non-fat dry weight is noted (Table 14, page84). The consistency of non-fat dry weight has been noted in some migratory birds (Connell et al., 1960; Johnston, 1973; Rogers and Odum, 1964) but it has also been shown to vary significantly in other migratory birds and willow ptarmigan (Berthold, 1975; West and Meng, 1968). Whishart (1979) pointed out that non-fat dry weight is composed of a protein fraction that is utilized as an energy source in times of starvation.

Wing fat and wing dry weight correlated moderately ($r=.59$, $P\leq.005$). This moderate correlation was probably due to the high variability in weight of the non-fat dry portion of the wing.

CHAPTER V

SUMMARY AND CONCLUSIONS

Comparisons were made between fat levels of the wing and body of 26 bobwhite quail (Colinus virginianus) obtained from Tall Timbers Research Station, Tallahassee, Florida. Fat was extracted from the total body, the total feathers, the left wing and the left wing feathers. The importance of the feathers to the fat comparisons was ascertained.

The mean total body fat percent (percentage of oven dry weight) for all birds was 12.5%. The mean fat percent from the wing was a significantly higher 16.4%. Furthermore, fat weights from the total body and the wing correlated poorly when data were pooled. The significant wing fat to body fat correlations seen in juvenile males and adult females were of questionable validity because of the small sample sizes (n=6 and n=3 respectively) and of questionable applicability because of the difficulty in sexing bobwhites by the wings alone.

Including feathers in the comparison of body and wing fat only weakened an already poor correlation. But, fat contributed by the feathers was significant to total fat in both the body and the wing. The majority of total feather fat appeared to be contained in the wings' feathers since the average contribution from the left wing alone was 32.5%.

The mean total wet weight of all quail was 154.1 g and was not significantly related to total body fat. However, total dry weight correlated significantly with total body fat in feathered and unfeathered analyses. Only a moderate correlation was found between the wing dry weight and wing fat.

Because of the independence shown between the fat of the total body and the wing, the wing proved to be a poor index to total body fat. The presence of feathers in the fat comparisons was important in the fact that it lowered the correlation strengths.

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LITERATURE CITED

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APPENDIX

TABLE 16

AGE, SEX, BODY WEIGHT, OVEN-DRY WEIGHT AND PERCENTAGE FAT OF BODY COMPONENTS BY BIRD NUMBER

Bird No.	Age	Sex	Body[a] Wt.	Tot. O.D. Wt.	%[b] Fat	Wng. O.D. Wt.	% Wng. Fat	Feath. O.D. Wt.	% Feath. Fat	Wng. Feath. O.D. Wt.	% Wng. Feath. Fat
1	J	F	155.0	48.7	19.6	1.1[c]	31.4[c]	6.3	6.0	--[d]	--
2	J	M	155.0	47.3	11.7	1.1[c]	29.9[c]	5.3	5.0	--	--
3	A	M	145.0	43.5	14.6	1.2[c]	23.7[c]	6.0	1.5	--	--
4	J	F	148.0	39.8	8.0	1.0[c]	15.1[c]	5.3	2.1	--	--
5	J	M	171.5	53.4	20.0	1.2[c]	23.0[c]	6.3	3.3	--	--
6	J	F	154.0	46.3	10.9	1.3	23.3	5.6	8.7	.9	40.0
7	J	M	167.0	48.6	12.1	1.2	23.5	6.4	2.4	.5	5.6
8	A	M	164.5	51.8	20.2	1.4	16.1	6.1	1.2	.7	4.5
9	J	M	155.0	46.5	14.0	1.2	22.3	5.9	2.8	.7	6.9
10	J	F	157.5	47.3	17.2	1.2	6.3	5.0	1.1	.5	2.8
11	J	F	147.5	43.5	11.5	1.2	17.3	4.9	3.6	.6	6.0
12	J	M	163.0	49.8	15.2	1.3	19.1	5.0	5.0	.6	7.8
13	A	M	156.0	49.2	16.2	1.4	22.0	5.0	5.6	.8	27.6
14	J	F	149.0	44.0	14.7	1.2	21.7	4.8	1.9	.6	2.4
15	J	M	149.0	41.2	5.7	1.1	15.4	5.8	.6	.8	2.4
16	J	F	140.5	43.0	9.5	1.2	20.5	4.9	2.0	.6	4.0
17	J	F	135.5	42.8	11.3	1.2	21.2	4.6	5.3	.4	12.2
18	A	F	154.0	44.9	8.9	1.2	16.5	5.1	1.8	.7	2.9
19	A	F	161.0	47.0	12.3	1.2	18.8	5.4	1.3	.6	5.0
20	A	M	149.0	44.2	8.2	1.3	20.2	4.9	3.1	.7	2.6

TABLE 16 (Cont'd)

Bird No.	Age	Sex	Body[a] Wt.	Tot. O.D. Wt.	%[b] Fat	Wng. O.D. Wt.	% Wng. Fat	Feath. O.D. Wt.	% Feath. Fat	Wng. Feath. O.D. Wt.	% Wng. Feath. Fat
21	J	F	146.3	47.0	18.7	1.2	28.7	4.7	4.9	.5	17.0
22	A	F	158.5	49.7	17.7	1.5	27.6	5.5	4.2	.7	7.4
23	A	M	155.0	44.8	11.5	1.3	25.2	6.6	2.4	.8	2.4
24	J	F	155.5	46.2	12.8	1.1	22.6	4.4	2.9	.6	3.4
25	J	M	162.5	50.3	11.3	1.3	19.2	5.5	1.4	.7	3.7
26	J	M	153.0	48.5	19.9	1.2	23.7	6.3	1.7	.7	7.4
$\bar{x}$			154.2	46.5	13.6	1.2	21.3	5.5	3.1	.7	8.3

[a] Total body weight and oven-dry in grams.

[b] Ether extractable body fat expressed as a percentage of oven-dry weight.

[c] These wing values were computed with the feathers and were not used to calculate the mean or coefficient of variation. Other wing values computed without the feathers.

[d] Two dashes denotes no information.

VITA

Herbert Eugene Trammell, Jr., son of Mr. and Mrs. H.E. Trammell, was born in Oak Ridge, Tennessee in 1954. He attended Oak Ridge public schools and graduated from Oak Ridge High School in 1972. In the fall of 1972, he entered the University of Tennessee, Knoxville and graduated from there in August of 1977 with a B.A. in Biology. He was accepted into the graduate program in the Department of Forestry, Wildlife and Fisheries at the University of Tennessee in January, 1980. He received the Master of Science Degree in Wildlife and Fisheries Science in June, 1986. He is married to Denise Bradley of Bristol, Tennessee.