GROWTH AND REPRODUCTION OF BOBWHITE QUAIL RAISED IN CONFINEMENT

Thesis for the Degree of Ph. D.

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Taha Hassan Hussein Mahmoud

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This is to certify that the

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RAISED IN CONFINEMENT

presented by

Taha Hassan Hussein Mahmoud

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Poultry Science

Theo H. Coleman
Major professor

Date July 8, 1966

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ABSTRACT

GROWTH AND REPRODUCTION OF BOBWHITE QUAIL
RAISED IN CONFINEMENT

by Taha Hassan Hussein Mahmoud

Several experiments were undertaken with the objective of accumulating information concerning the effect of certain management practices on the growth and reproduction of Bobwhite quail. For comparative purposes, Coturnix quail were used in certain experiments. Observations were also made on certain physical properties of Bobwhite and Coturnix eggs.

A significant correlation was found between body weight and egg weight and between egg weight and the weight of Bobwhite chicks at hatching time. There was a significant correlation between the weight of Bobwhite chicks at hatching time and their weight at 16 weeks of age for both sexes.

No significant reduction in growth occurred when Bobwhites were raised at 0.24, 0.12 and 0.06 sq. ft. of floor space per bird. Significant differences in egg production, fertility, hatchability, age at sexual maturity and livability of Bobwhite quail, when housed at these three different floor space allowances, were found. Significant differences were found in growth, livability and egg production of which received different allowances of drinking water.

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Fertility and hatchability of Bobwhite quail eggs varied considerably. The lowest hatchability for the eggs of an individual quail was 48.0 percent and the highest was 100 percent. Best results in fertility of Bobwhite eggs (both mass and pen matings tested) and Coturnix eggs (only mass matings tested) were obtained when the male to female ratio was 1:1 in pen matings and 6:6 in mass matings. However, higher fertility was obtained from eggs produced by Bobwhite pen-matings (1:1) than from mass-matings (6:6).

Where Bobwhite were paired in individual cages, considerable variation in age of females at sexual maturity was noted.

Bobwhite eggs averaged about 10 grams in weight. Giant eggs, weighing almost 17 grams, as well as dwarf eggs, weighing as little as three grams, were observed. Immediately following sexual maturity, Bobwhite quail laid eggs of increasing size until somewhere between the fifth and seventh week of production.

The size of eggs produced by a mature Bobwhite in relation to their position in the cycle did not follow as definite a pattern as had been reported in the chicken.

No significant differences could be demonstrated between egg weight loss of Bobwhite quail eggs and Coturnix eggs stored at the same temperatures.

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On the average, albumen contributed 47 percent and yolk 32 percent to the total weight of Coturnix eggs and 41 percent and 40 percent, respectively, to the total weight of Bobwhite eggs. The shells of Coturnix eggs were significantly thicker than those of Bobwhite eggs; whereas, shell membranes of Bobwhite eggs were significantly thicker than those of Coturnix eggs.

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GROWTH AND REPRODUCTION OF BOBWHITE QUAIL RAISED IN CONFINEMENT

By

Taha Hassan Hussein Mahmoud

A THESIS

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INTRODUCTION

Bobwhite quail management is essentially a process of defining and solving problems concerning raising Bobwhites whether in wild life or in captivity. The observation function, as one of the six managerial functions (problem definition, observation, analysis, decision making, action and responsibility bearing) as defined by Johnson and Hover (1952), has to do with the gathering and accumulation of information concerning Bobwhite quail in this case. This function is necessary and important because good information is a prerequisite for good decisions.

Such information might be useful, whether Bobwhite quail were raised as profitable birds or were used as a pilot animal.

In nature, Bobwhites are considered as an ally for farmers who rank them first among the game birds. For aesthetic reasons, Bobwhites have a stronghold on the American's affections (Stoddard, 1931).

In captivity, their possible use as a pilot animal for poultry research has stimulated the accumulation of data on nutrition and management, incubation and brooding and behavior and physical characteristics of this avian species. There is a need for exact detailed, and dependable information concerning the influence of certain management practices on growth and reproduction of Bobwhites raised in captivity.

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Many attempts have been made to restore and increase the Bobwhite population through the practice of artificial propagation and release. Almost twenty years ago, it was decided that this was an inefficient practice (Greenberg, 1949).

When raising Bobwhite quail in captivity was practiced (Le Compte, 1931; Petty, 1934; Bass, 1937; Greenberg, 1949; and many others), quail breeders realized that the quail was deprived of many things that mother nature had provided during the wild stage. If, for instance, there is a good choice of food materials available, the bird in the wild stage will balance its diet successfully. On the other hand, when Bobwhites are raised in captivity, they must depend entirely upon man to furnish them with sufficient quantities of necessary nutrients. Lack of information in the field of quail management led some Bobwhite breeders to believe that Bobwhite quail are hard to raise in captivity, mortality frequently amounting to from 40 to 60 percent of the hatched young (Nestler *et al*., 1942). With this high mortality, Bobwhite quail rearing is thought to be both inefficient and costly.

A better understanding of Bobwhite quail management might contribute to an increase in efficiency and, therefore, maximize the profit when raising Bobwhite quail in captivity is practiced.

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understanding of the factors which influence growth rate and reproduction of Bobwhite quail is needed. Therefore, an attempt was made to compile information on factors which affect growth rate on one hand, such as egg weight and adult body weight, egg weight and the weight of one-day-old chick, and other factors such as water restriction and overcrowding. In addition, age at sexual maturity, fertility and hatchability, and egg characteristics were studied. For comparative studies, Coturnix quail were used in some of these experiments.

All the information concerning the proper raising of Bobwhite quail in captivity could not be accumulated in one thesis. It is hoped that the information this thesis contains will contribute to a better understanding of the problem of raising the Bobwhite quail in captivity.

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REVIEW OF LITERATURE

It is evident that there are many managerial practices that affect the growth and reproduction of Bobwhite quail raised in captivity.

I. Certain Factors Which Affect The Growth of Bobwhites

Lack of information about the factors that influence the growth of Bobwhite quail led to a review of the literature concerning some of the experiments conducted on other birds, especially the chicken and the turkey. Some of the factors that might influence the growth of the Bobwhite and those which were of special interest for this study are:

A. The influence of egg weight on the weight of the chick at hatching time.

No documented reports could be located concerning the interrelationship between the dam weight and the egg weight on one hand, or the interrelationship between egg weight and the chick weight at hatching time on the other hand with respect to Bobwhite quail.

In some studies on chickens, results showed that there is a high correlation (0.4) between hen weight and the weight of the eggs she produces (Asmundson, 1921; Atwood, 1923; Jull, 1924; and many others). After both body weight and egg weight reach their maximum, it seems that this correlation between these two variables persists (Atwood and Clark, 1930).

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On the other hand, several investigators, including Jull and Quinn (1925) and Hays and Sanborn (1929) have shown that in the chicken at hatching time chicks weigh from 61 to 68 percent of the weight of the eggs from which they hatched, part of the range of variation being due to the relative humidity during incubation. The average body weight of Bobwhites at hatching time was reported by Romanoff (1960) to be 6.43 grams. Assuming that the average weight of the eggs incubated was ten grams, the chicks would weight about 64 percent of the weight of the eggs from which they hatched. Although no documented reports could be located concerning the correlation between egg weight and chick weight of Bobwhites at hatching time, a high positive correlation (0.68 - 0.95) between these two variables was reported in the chicken (Upp, 1928; Graham, 1932; Galpin, 1938; and many others).

B. Chick size and growth rate

While certain studies on the chicken indicated that rate of growth was independent of chick size at hatching time, other workers observed that during the first few weeks, chicks small at hatching time grew somewhat slower than large chicks hatched from the same dam (Halbersleben and Mussehl, 1922; Hays and Sanborn, 1929; and Wiley, 1950). These workers also found a relationship between weight of the chick when hatched and weight at four weeks, but at 21 weeks no such relationship was evident.

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The interrelationship between chick weight at hatching time and its growth for Bobwhite quail seems to be unknown. Very little information concerning body weights of quail is available.

Female Bobwhite quail grow faster than males and they are heavier when they reach full body maturity (Stoddard, 1931; Nestler *et al.*, 1942; Nestler, 1943, 1949; Baldini, 1951; and Baldini *et al.*, 1953). There are race differences with respect to fully mature body weight of Bobwhites (Stoddard, 1931; Aldrich, 1946; and Ripely, 1960).

Similar to the fowl, Bobwhite quail make a greater gain in live weight per unit of feed consumed during the early growth stages than during the later growth stages. In other words, as a Bobwhite quail increases in weight, the gain in weight which it makes per pound of feed consumed decreases (Baldini, 1951; and Heuser, 1955).

C. Influence of floor space

Overcrowding and too close confinement are the most frequent errors in poultry management conducive to the development of vicious habits such as cannibalism, besides their ill effect on growth of the birds. Very little information has been published concerning the amount of floor space required by Bobwhite quail for optimum growth and production.

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McNamara (1933) stated that he allowed 0.52 to 0.58 square foot per bird and obtained favorable results to four weeks of age. He reported mortality to four weeks as being between 16 and 20 percent.

Bobwhite quail may be kept in battery brooders for as long as ten weeks with an average of 30 square inches of floor space per bird, without danger of cannibalism (Greenberg, 1949). Bobwhite quail did very well when there were 33 birds in 999 square inch compartments, each bird having 30.2 square inches of floor space at ten weeks of age (Baldini *et al.*, 1950).

Theoretically, it might be expected that Bobwhite quail would react in somewhat the same manner as Coturnix quail, chickens or turkeys in studies of this type.

It has been recommended that Coturnix quail raised in outdoor cages be allowed 2.0 to 2.6 square feet of space per bird (Wilson *et al.*, 1961). They also reported that in a relatively crowded pen (20.5 square inches per quail) sexual maturity was delayed about one week when birds in this crowded pen were compared with birds in pens under optimum management conditions. Optimum management conditions were not defined in this paper. Ernst (1963) reported that body weight means were not significantly different when Coturnix quail were raised in concentrations of four, eight, twelve, sixteen and twenty birds per square foot. Egg production nd fertili

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and fertility were higher at a concentration of four birds per square foot than in the more dense groups. Intense crowding resulted in more checked and dirty eggs. Quail in the more crowded groups were also poorly feathered and dirty.

Thus, little experimentation has been done with floor space allotments for either Coturnix quail or Bobwhites. Some work has been done with chickens and turkeys. No documented reports could be located concerning the optimum space allotment for chicken pullets. For best results in brooding, it was suggested by Rice and Botsford (1956), Winter and Funk (1960) and many others that the chicks should have from 7 to 12 square inches of floor space per chick under the hover and one-half to three-fourths square foot of floor space and that this should be increased by one-half square foot per chicken each four weeks until the pullets are ready for the laying house. There, they should have one to three square feet of floor space per bird. Broilers require three-fourths to 1.0 square foot of floor space to market age.

The fact that the growth rate of chicken broilers is depressed by increasing the population density beyond certain limits has been repeatedly demonstrated (Hartung, 1955; Brooks et al., 1957; Siegel and Coles, 1958; and Moreng et al., 1961). Many researchers have demonstrated that egg pr

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that egg production of chickens can be depressed by increasing the population density in the house or pen (Kimber, 1941; Hoffmann and Tomhave, 1945; Siegel, 1959; Nordskog, 1959; Godfrey and Butler, 1959; and Fox and Clayton, 1960).

Crowding turkey breeder hens resulted in lower fertility in naturally mated turkeys (Wolford, 1959).

The incidence of cannibalism among Bobwhite quail has been reported by many investigators. Although cannibalism was reported as a serious problem in Bobwhite management by some investigators (Stoddard, 1931; Nestler, 1940; Nestler et al., 1945), it was reported by others (Baldini et al., 1950) that Bobwhite quail can be reared in battery brooders in close confinement without evidence of cannibalism, provided the diet is adequate.

D. The effect of restricted water consumption

The essentiality of water for all living cells is well known. This, besides many other functions of water, makes it evident why the animal body is able to exist much longer without food than it can without water. Since the water supply is no better than the poorest water available, all sources other than those known to be clean and safe from contamination should be removed. Birds should have a continuous supply of water for they drink only a small amount at one time. Especially with dry-mash feeding it is necessary to have water available (Kellerup et al., 1965; and others). On the other hand, behavioral adaptations to water

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restriction have been reported. The physiological adaptations have been intensively studied in desert rodents, particularly the kangaroo rat (genus Dipodomys). This animal can remain in water balance on a diet of dry pearled barley with no drinking water at all atmospheric humidities above 10 percent relative humidity at 25° C. (Mitchell, 1962). A similar case was reported by Davison (1949). He stated that "Bobwhites do not need water to drink. They get moisture from their foods. Neither dew nor surface water is essential . . ., but all through the summer heat they can live without drinking. Water is not one of the problems of quail management. Many people have wasted kindly efforts building watering troughs for Bobwhites, hauling water to keep them filled, and have even drilled wells to furnish the birds this unnecessary element for their welfare . . . . Actually, quail require no water at all, not even dew. I learned that under the dryest conditions under which Bobwhites ever lived . . . our ranch in western Oklahoma during the history-making summer drouths of 1933, 1934 and 1935, went weeks with no drop of water, dew or rain. Temperatures went above 100 degrees day after day, reaching 110, 111 and 112 in several mid-afternoons. In 1934, the longest period of no dew or rain whatsoever was 62 days in June, July and August. Little quail far from water survived in excellent health."

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Reports by several investigators showed that a continuous water supply for the chicken and the turkey is essential if best results are to be obtained.

Kare and Biely (1948) placed New Hampshire chicks on diets containing 0.9 to 4.0 percent salt and deprived them of water four to six hours per day. The water restricted chicks compensated by drinking more water when water was before them which resulted in approximately the same water:feed ratios as the controls with water *ad libitum*. Restricting the water intake to three one-half hour periods per day resulted in depressed growth and feed consumption of one-week old New Hampshire chicks (Ross, 1960). Bierer *et al*. (1965) indicated that the average survival time of one-week-old chicks was in the neighborhood of one week, whether deprived of feed, water, or both feed and water. Chicks developed symptoms and lesions like those seen in avian nephrosis, when receiving feed without water. Two of one group of 10 chicks developed lesions of a visceral gout. Romanoff and Romanoff (1949) reported that a 10 percent loss of body weight through dehydration and excretion resulted in serious physical disorders.

Adult laying hens receiving feed without water died in the first week. The birds developed symptoms of Blue Comb disease in two or three days with a sudden drop in egg production on the third and fourth days (Bierer *et al*., 1965).

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Loss in body weight and a drop in egg production was also reported by many investigators (Wilson and Edwards, 1955; Sunde, 1962; and others) when birds were allowed restricted amounts of drinking water.

On the other hand, the turkey is no exception. Hammond (1944) showed that lack of water during the first week of a turkey poult's life was more deleterious than lack of feed. The effect of depriving poults of feed and water for 24, 48 or 72 hours after hatching was progressively detrimental to growth and livability as shown by Chilson and Patrick (1946).

Marsden (1964) observed 18 and 28 percent mortality in 15 and 22-day-old poults after a change in the method of supplying the water.

II. Certain Factors Which Influence Reproduction Of Bobwhite Quail

Little is known about those factors which may influence the reproduction of Bobwhite quail. Some observations have been made on this aspect. Unfortunately, these observations were based on systems of rules and methods that were expressions of the experience of those who were interested in wild life management, in general, and those who had been most successful in rearing Bobwhite quail, in particular. Information in this field is too sparse to help very much to place the reproduction of Bobwhite quail on a scientific basis.

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Generally speaking, reported egg production of Bobwhite quail is fairly low. According to Hutt (1947), Coleman (1930) was able to increase egg production of Bobwhite quail through domestication. He found the mean production of 107 birds to be 72 eggs, with individual records up to 125. Assuming that this figure was on a 365 day basis, this will average about 19 percent production. On the other hand, Nestler et al. (1944) reported that one quail fed 23 percent protein in her diet produced 122 eggs, averaging an egg every 33 hours for the breeding season of 168 days (72.7% production). Baldini et al. (1952) reported that a total of 344 eggs were obtained over a period of 79 days from a total of 12 birds. The production was from 3 to 40 eggs per bird over this period, for those birds mated in pairs. In a multiple mating pen, the average production was 42 eggs per bird. Nestler (1943) reported egg production per hen per day to be 0.348 and 0.361 when the salt levels in their diets were 0.5 percent and 2.0 percent, respectively. Nestler et al. (1944) reported that the best egg production was obtained from birds on a diet containing 23 percent of protein, with an average of 58 eggs per hen for the season of 168 days. Baldini et al. (1954) reported that three hens laid 511 eggs (from November 24, 1950 to July 5, 1951) for an average of 170 eggs. From July 12 to November 2, 1951, the hen lai

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one hen laid 67 eggs in intermittent production before she died on the later date. Baldini stated, "Assuming only average production over the span of 344 days, this hen would have a total production of 240 eggs."

The influence of light on egg production of Bobwhites has been studied by some investigators (Funk et al., 1941; Baldini et al., 1952; Kirkpatrick, 1955, 1964; and Robinson, 1963). Funk et al. (1941) stated that an increase of egg production in the Bobwhite was accompanied by an increase in the size of the cycle. The average cycle size for birds under all-night light was larger than for the control (daylight only). An average egg production of more than 60 percent was obtained during a five-month period during which birds received 24-hour light (Funk et al., 1941).

The reproductive efficiency of the Bobwhite quail, like that of the domestic fowl, is determined by the number of eggs laid, the percentage of these eggs that are fertile, and the percentage of fertile eggs that hatch into chicks.

It is evident that egg quality is also of great imprtance in determining hatchability. The intact avian egg possesses various external qualities by which it may be identified. Among these attributes are its size and shape, and the color and texture of its shell. There is considerable variation in these characteristics among the eggs of all birds, both wild and domesticated. External differences not only ser

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not only serve to distinguish the eggs of various species but also are observable in eggs laid by individuals of the same species, or even by the same bird.

The external characteristics of the egg varies because the reproductive functions of the bird are influenced by numerous hereditary, physiological and environmental factors. The operation of these factors, particularly as modified by domestication, is a subject of interest to many workers.

A. Fertility and hatchability

Generally speaking, the problem of obtaining a high percentage of fertile eggs is of economic importance to poultry raisers and hatchermen. Information concerning the nature of fertilization and the various factors affecting it should, therefore, be of particular interest to the hatchery industry. The wide variation between individual Bobwhite quail with respect to fertility and hatchability requires more studies in order to confirm or disprove the observations made by some workers. Funk *et al.* (1941) observed that there was a marked variation in fertility of Bobwhite eggs. Infertility ranged from about 3.5 percent to 100 percent. No other documented reports concerning the variation between fertility of eggs produced by individual Bobwhite quail were found.

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Since the ratio of males to females in the breeding flock undoubtedly influence the percentage of fertile eggs produced, one would expect to find considerable experimental data on this point. However, there is not a great deal of material on this subject whether with respect to the chicken or the Bobwhite quail. Byerly and Godfrey (1937) found that fertility decreased in linear fashion as the number of female chickens per male increased from about 95 percent when the ratio was 4:1 to about 35 percent when the ratio was 166:1. These studies indicated that the maximum total of eggs fertilized by a single male would be obtained by mating that male to about 120 laying females. Hays and Sanborn (1939) found that a range of 1 to 14 in the number of chicken females mated to each male had no significant influence upon the percentage of fertile eggs produced. Since this is a problem of considerable importance to the hatchery industry, critical experiments designed to measure the relation of the sex ratio in breeder flocks to fertility of eggs as influenced by age, rate of production, breed and season of the year should be encouraged.

Preferential mating, or the tendency for the male to mate more often with certain females in the flock than with others, has been observed by Hayes and Sanborn (1939) and many others.

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Very little information concerning the male to female ratio of the Bobwhite quail is available. Bobwhite quail are monogamous (Stoddard, 1931; Mitchell, 1936; and Greenberg, 1949). Observations made in the field showed that quail usually pair off and remain mated throughout the season and may also remain mated or mate in the following season (Stoddard, 1931). On the other hand, in captivity--especially when artificial lighting is used--Bobwhite quail can be made polygamous (Stoddard, 1931; Funk *et al.*, 1941; and Baldini *et al.*, 1952). Fertility was as high in eggs produced by females mated in the ratio of 4 males to 12 females as it was in eggs from individual pair mating (Funk *et al.*, 1941). Strange as it may seem, higher fertility was obtained from the mating having two females and one male than in pair matings (Funk *et al.*, 1941).

The hatchability of Bobwhite quail eggs varies considerably (Funk *et al.*, 1941; Baldini *et al.*, 1952; and others). Funk *et al.* (1941) reported that hatchability of Bobwhite quail eggs ranged from a low of 41.3 percent to a high of 94.7 percent.

B. Age at sexual maturity

This is usually measured in females by the age at which the first egg is laid. There are many factors that influence the age at sexual maturity. If female Bobwhite quail reach the age of sexual maturity earlier than the male, this should rea

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should create a problem in fertility of first eggs laid. Although certain data could be accumulated concerning the age at which Bobwhite quail reach sexual maturity, no documented reports could be located concerning the differences in age of male and female Bobwhite quail at sexual maturity.

Caged Bobwhite quail 4 to 6 months of age are capable of reproduction (Kirkpatrick, 1955, 1964; Robison, 1963). Introduction of artificial lighting caused a great increase in weights of reproductive tissue of Bobwhites (Baldini *et al.*, 1952). It was concluded also that Bobwhites could be stimulated by continuous light to reproduce during other than the normal season. Under these conditions, Bobwhites may attain sexual maturity as early as 139 days of age (Baldini *et al.*, 1952).

C. Egg size

Various environmental factors due to domestication of chickens have profoundly influenced this bird's nesting and feeding habits, body size and structure and physiological processes. In turn, the size of the egg has been affected (Romanoff and Romanoff, 1941). Semi-domesticated Bobwhites are probably much closer to their wild ancestors than are chickens to theirs. Consequently, at the present time, research information resulting from studies involving these semi-domesticated Bobwhites would be more applicable to their wild ancestors than information from research with chickens w

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chickens would be to the junglefowl. Stoddard (1931) compared the weight of Bobwhite eggs produced in captivity (largely by birds in their first year of production) at Beachton, Georgia, 1926-1928. The average weight of eggs produced by these birds did not exceed 9.29 grams. The highest weight was 10.23 grams. Funk et al. (1941) and Romanoff and Romanoff (1949) reported the average egg weight of the Bobwhite quail in their experiments to be 9.13 grams and 9.20 grams, respectively.

Because of its great bulk of nutrients, the bird's egg is a very large reproductive cell, both absolutely and in relation to the size of the parent (Romanoff and Romanoff, 1949). The relationship between age of the Bobwhite females and the weight of the eggs they produce is not very clear. Neither has the relationship between female body weight and egg size been well established with respect to this species. Stoddard (1931) found that Bobwhites in the Southeastern United States laid smaller eggs in their first breeding season than in their second.

The weight of eggs laid by a chicken changes throughout the laying cycle (Bennion and Warren, 1933; and many others). There is a general tendency for the first egg of the cycle to be the heaviest, and for the succeeding eggs to decrease gradually in size; however, the weight of the successive eggs may not decrease with perfect regularity, and often the last egg is somewhat heavier than the egg immediately

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preceding it. In short cycles, the decline in weight is, of course, more rapid than in long cycles. The longer the cycle, the smaller is the average decrease in the weight of each egg within the cycle, but greater is the total decrease from the first egg to the last (Bennion and Warren, 1933). Often, however, the tendency for the pullet's eggs to grow larger during the initial stages of laying may somewhat offset the trend toward diminishing weight within the cycle (Bennion and Warren, 1933). To explain this phenomenon, egg weight, largely determined by the bird's physiological efficiency, probably diminishes throughout the cycle because the bird is unable to build up enough material to form a series of full-sized eggs. It is also possible that, as the cycle advances, the strain on the hen's reproductive organs is sufficient to lower her capacity for converting available material into eggs (Curtis, 1914; and Romanoff and Romanoff, 1949).

Funk et al. (1941) indicated that the weight of a Bobwhite egg was influenced by the position of the egg in the clutch. It was found that the first egg laid in a clutch was usually the largest egg laid in the particular clutch. When the average weights of a representative number of eggs in the cycle were compared, the first egg was slightly larger than the eggs laid on succeeding days (Funk et al., 1941). It was also indicated that Bobwhites n captivit

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in captivity laid eggs of increasing size until approximately the fifth week of production, after which time the egg weight was fairly uniform. Hot weather apparently did not have a depressing effect on egg weight in quail (Funk et al., 1941).

The numerous variations in the contour of individual eggs obviously cannot be expressed in mathematical terms. However, the shape of the egg can be approximately indicated by the ratio between length and breadth. At present, the shape index is commonly employed. This value is obtained by dividing the transverse diameter of the egg by the length and multiplying the result by 100. The shape index for Bobwhite eggs was calculated from Funk et al. (1941) and Romanoff and Romanoff (1949). It was found to be approximately 77 percent (average reported egg length ranged from 3.0 to 3.1 cm.).

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GENERAL EXPERIMENTAL PROCEDURES

Bobwhite quail used in all experiments were from stock which has been maintained by the Department of Poultry Science, Michigan State University, for at least four years.

All stock descended from 28 birds which were hatched from eggs secured from a commercial quail breeding farm in Arkansas. The Coturnix quail used for comparative purposes in some experiments were likewise from stock which has been maintained by the Poultry Science Department for a period of at least six years. No further information concerning either of the stocks of quail is available.

In these experiments, lack of facilities and equipment designed for the purpose of keeping and raising Bobwhite quail made it essential in many instances to utilize equipment designed for chickens. Therefore, some inconvenience was noted because of the utilization of such equipment. Growing and/or adult quail were housed in either Petersime chick starting battery compartments, 100 x 75 x 24 cm., or wire cages. The wire cages were of two sizes, both of which had a sloping floor and one of which ranged from 30 to 25 cm. in height and was 30 x 30 cm. in length and width, respectively. The other size of cage ranged from 16 to 20 cm. in height from front to back and was 23 cm. in length and 15 cm. in width. Jar-type gravity-feed waterers designed for baby chicks were utilized for the first three weeks unless otherwise noted. Although a wire net type cover was sometimes used in the exposed part of the waterer to prevent baby quail

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baby quail from drowning, a marked loss in birds was noted, especially in the first week, because of the above mentioned reason. Because of the small size of baby quail, scotch tape was used where applicable to prevent them from getting out of the batteries and helped somewhat to overcome this problem. The equipment utilized might have affected the results obtained from some of these experiments, especially where data pertaining to mortality were collected during the first week of age.

Incubation: In those experiments involving the incubation of eggs, eggs that were to be incubated were usually candled to detect checks and the sound eggs were set in Jamesway 252 forced-draft-type incubators. Eggs were set in the standard Jamesway egg trays. Cone-type egg flats were cut into strips and were placed in the egg trays to hold the smaller eggs. During the first 21 days of incubation the incubator was operated at a temperature of 99.0 to 99.5° F. dry bulb and 86 to 87° F. wet bulb. On the 21st day of incubation the eggs were transferred to a hatcher. The hatcher temperature was 98.5 to 99.0° F. dry bulb and 88.0 to 92.0° F. wet bulb. On the 24th day of incubation the quail chicks were removed. Chicks were either weighed and wing banded with small wing bands or were placed in Petersime batteries to be weighed and banded at two weeks of age. Eggs which failed to hatch were candled and sometimes

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sometimes broken out to determine fertility. Where eggs had not been candled prior to incubation, dry eggs were excluded from the data. Hatchability was calculated as a percent of fertile eggs. Chicken boxes were utilized in transporting the chicks from the incubation room to the brooder house. All the side holes of the boxes were closed by scotch tape. Top holes were open to assure a supply of fresh air.

Growing Quail: In all experiments involving the starting and growing of Bobwhite quail chicks, the chicks were placed in Petersime starting batteries. They were reared on paper for three weeks. This was done to prevent the feet of the chicks from being trapped as the size of mesh of the wire making up the floors of these batteries was not designed for baby quail. At the end of three weeks the paper was removed and the quail were held in the batteries up to as much as 18 weeks of age. In many experiments, birds were wing banded and individually weighed at two weeks of age and were randomly divided into experimental groups. An attempt was made to provide equal heat in the battery for the different groups. All groups received continuous (24 hour) lighting, providing not less than ten-foot candles of light at the level of the feed and to all parts of the pen except inside the curtain where the heating elements were located. A quail breeder ration (Table 1 - Appendix) was fed throughout all experiments unless otherwis

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otherwise noted. This ration had been utilized for quail by the Michigan State University Poultry Science Department for at least two years and had proven to be adequate for growth and reproduction in both Bobwhite and Coturnix quail. Birds were weighed each 14 days. Mortality was recorded daily. Not until the quail were 15 to 16 weeks of age were they easily sexed. Throat and head markings were distinct at this age. Therefore, all birds had to be wing banded at the beginning of each experiment. In other words, banding the birds was the only method to trace the weights of the birds of both sexes from the beginning to the end of the experiment. Since sex could not be easily determined before 15 to 16 weeks of age, mortality with respect to sex prior to this age is not reported as no attempt was made to distinguish sex of dead birds anatomically.

Breeder Quail: In some experiments breeder Bobwhite quail were placed in Petersime starting batteries. Similar conditions, except that of heat, were provided for the breeder quail as had been provided for growing quail. Three groups of birds housed in individual cages were also used in these experiments. The incidence of cracks or checks was much higher in eggs produced by breeder birds housed in the Petersime brooders than in eggs produced by birds in cages. This was at least partially due to the fact that the brooders had flat-deck wire floors, whereas the wire cages had sloping roll-away bottoms which allowed the eggs to roll

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roll outside the cage as soon as laid. Eggs were gathered daily. For some experimental purposes, eggs were weighed to the nearest 0.001 gram each day. Some of the eggs were incubated in Jamesway incubators as mentioned before.

Statistical Procedures: Certain data from the experiments were subjected to statistical analysis. Help was gained from the utilization of the Computer Center at Michigan State University. The most common analysis used was the analysis of covariance and analysis of variance. Certain data were converted into new data as shown by Snedecor (1950). The "t" test and chi-square were also used in certain data.

The least squares routine[1] was used to estimate relationships between a dependent variable and a set of independent variables. Simple (Pearson product moment) correlation was calculated as:

$$r_{ij} = \frac{\sum_{t=1}^{N} (X_{it}-\overline{X}_i)\,(X_{jt}-\overline{X}_j)}{\sqrt{\sum_{t=1}^{N} (X_{it}-X_i)^2}\;\sqrt{\sum_{t=1}^{N} (X_{jt}-X_j)^2}}$$

where N is the number of observations in the problem.

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[1]Stat. Series Description No. 7. Michigan State University Computer Center.

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The analysis of contingency[1] tables performs any combination of the following operations on designated tables: row and/or column means and standard deviations; percentages of each cell on the associated row, column and/or table totals; theoretical frequencies; cell contributions to table chi-square and degrees of freedom; contingency coefficient and product-moment correlation coefficient.[2] The analysis of covariance program was designed to compute analysis of covariance information for one analysis of variance variable with multiple covariates and unequal treatment group sizes. The analysis of variance program[3] was used to calculate a one-way analysis of variance table in which unequal frequencies (number of replications) may occur in each category.

The "t" test was calculated from the information given in previous programs.

Individual as well as group differences for such characteristics as weight of the birds, weights of the eggs, etc., were analyzed statistically for significance at the 95 and 99 percent levels of probability.

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[1]Technical report No. 18. Michigan State University Computer Center.

[2]Technical report No. 37. Michigan State University Computer Center.

[3]Stat. Series Description No. 13. Michigan State University Computer Center.

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Egg production data were available 7 days per week with respect to both birds raised in pens and in individual cages. Three replicates was the least number for experiments concerning egg production. The rate of production for a treatment was usually calculated as "egg per hen per day" basis. However, the actual number of eggs--not the percentage of egg production--was often used for statistical analysis.

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EXPERIMENT I

THE INTERRELATIONSHIP BETWEEN DAM WEIGHTS, EGG WEIGHTS AND ONE-DAY-OLD CHICK WEIGHTS FOR BOBWHITE QUAIL

It is well known that eggs laid by birds of the same species may differ considerably in weight and that even the eggs laid by an individual bird are not all of the same weight. There are many factors which influence the size of the egg. That dam weight is one of the factors has been reported in many species. No documented reports could be located concerning the relationship between Bobwhite body weight and the weight of the eggs they produce. From an experimental standpoint, such information should be of value if Bobwhites are to be used as pilot animals. From a practical standpoint, egg weight would also be of importance to the quail breeder provided that there is a relationship between egg weight and the size of quail chick hatched from the egg.

Objectives:

1. To determine the relationship, if any, between the weight of the female Bobwhite quail and the weight of the eggs they produce.
2. To determine the relationship, if any, between the weight of the eggs produced by Bobwhite quail and the weights of one-day-old chicks hatched from those eggs.

EXPERIMENTAL PROCEDURE

Ninety-two (92) female Bobwhite quail were used in this experiment. They were housed in individual wire cages. Birds were classified into three different groups on the basis of age. The first group of birds (55 females) was in the first year of production. The second group (18 females) was in the second year of production and the third group (19 females) was in the third year of production. The number of observations (978) and not the number of birds was used in calculating the simple correlation coefficients between body weight and egg weight (r was calculated as shown in the general experimental procedure).

Birds were weighed to the nearest gram once each four weeks. Eggs were gathered and weighed each day for a period of approximately eight months. They were weighed to the nearest 0.001 gram. They were incubated in Jamesway 252 incubators with settings made at weekly intervals. Each egg was individually segregated before hatching. Chicks were weighed to the nearest 0.1 gram and wing banded with small wing bands, at one day of age. Individual records were made to include the dam weight, egg weight and chick weight. In the case where some chicks failed to hatch, only information concerning egg weight and the dam weight was included. Simple correlation coefficients between egg weight and body weight of the quail chick at hatching time were computed.

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In addition to the individually pedigreed eggs, more than 500 eggs produced by mass mated quail, were weighed to the nearest 0.001 gram. These eggs were identified individually and were also individually segregated before hatching. Chicks hatched from these eggs were wing banded and weighed to the nearest 0.1 gram at one day of age. These data, besides the previous data, were included in the determination of the correlation between egg weight and chick weight.

RESULTS AND DISCUSSION

1. The Correlation Between The Body Weight of Female Bobwhite Quail and Egg Weight:

Tables 1, 2, 3 and 4 show the simple correlation between the body weight of female Bobwhite quail and their egg weight. The overall correlation for the 978 observations in this experiment was 0.36. The correlation (0.81) between body weight of female Bobwhite quail in their first year of production and the egg weight was very high (significant at the 0.01 level). A significant correlation between these two factors also existed with birds that were in their second year (0.51) and third year (0.18) of production ($\alpha = 0.01$).

The correlation between body weight and egg weight of the chicken was reported to be in the neighborhood of 0.4 (Atwood and Clark, 1930; and others). After both egg weight and body weight became maximum, the correlation between the chicken body weight and egg weight seemed to become almost constant (Atwood and Clark, 1930). In the Bobwhite quail that were in their first year of production in this experiment, there was much variation in both body weight and egg weight; however, the correlation between the two was very high. Despite the fact that body weight of both the birds in their second year and those in their third year of production was quite variable, eggs produced by the

TABLE 1.-Simple correlation between egg weight, body weight of laying[1] Bobwhite quail and the weight of chicks at hatching time

	Av. body wt.		Av. egg wt.		Av. one-day-old chick wt.	
	gram	s.d.	gram	s.d.	gram	s.d.
	228.6	12.6	10.3	1.0	6.5	1.2

	Body wt.	Egg wt.	One-day-old chick wt.
Body wt.	1.00	0.36**	0.31**
Egg wt.		1.00	0.84**
One-day-old chick wt.			1.00

$$\text{Av. chick:egg ratio} = \frac{6.4506}{10.2933} = 0.63$$

[1] Birds of different ages (includes all birds in experiment).
** Significant at the 0.01 level.

TABLE 2.-Simple correlation between egg weight, body weight of Bobwhite quail in their first year of lay and the weight of chicks at hatching time.

	Av. body wt.		Av. egg wt.		Av. one-day-old chick wt.	
	gram	s.d.	gram	s.d.	gram	s.d.
	237.0	14.6	10.8	1.0	6.8	1.0

	Body wt.	Egg wt.	One-day-old chick wt.
Body wt.	1.00	0.81	0.77**
Egg wt.		1.00	0.81**
One-day-old chick wt.			1.00

Av. chick:egg ratio $= \frac{6.8321}{10.8249} = 0.63$

** Significant at the 0.01 level.

TABLE 3.-Simple correlation between egg weight, body weight of Bobwhite quail in their second year of lay and the weight of chicks at hatching time.

Simple Correlation	Av. body wt.		Av. egg wt.		Av. one-day-old chick wt.	
	gram	s.d.	gram	s.d.	gram	s.d.
	228.1	11.1	10.5	1.0	6.6	1.1
	Body wt.		Egg wt.		One-day-old chick wt.	
Body wt.	1.00		0.51		0.39**	
Egg wt.			1.00		0.81**	
One-day-old chick wt.					1.00	

Av. chick:egg ratio $= \frac{6.5885}{10.4547} = 0.63$

** Significant at the 0.01 level.

TABLE 4.-Simple correlation between egg weight, body weight of Bobwhite quail in their third year of lay and the weight of chicks at hatching time.

Simple Correlation	Av. body wt.		Av. egg wt.		Av. one-day-old chick wt.	
	gram	s.d.	gram	s.d.	gram	s.d.
	228.7	13.9	10.0	0.1	6.24	1.2
	Body wt.		Egg wt.		One-day-old chick wt.	
Body wt.	1.00		0.18**		0.20**	
Egg wt.			1.00		0.86**	
One-day-old chick wt.					1.00	

$$\text{Av. chick:egg ratio} = \frac{6.2452}{10.0437} = 0.62$$

** Significant at the 0.01 level.

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oldest birds did not vary considerably in size. This could explain the reason for obtaining different correlations when birds were classified with respect to their ages.

2. The Correlation Between Egg Weight And One-day-old Bobwhite Chick Weight:

There was a high correlation between egg weight and one-day-old chick weight regardless of the age of the dam ($\alpha = 0.01$). The overall correlation for all observations was 0.84. For eggs laid by Bobwhite in their first year of production it was 0.81 and 0.86, respectively. Chick weight as a percentage of egg weight averaged 62.7 and ranged from a high of 66.2 to a low of 51.1 when eggs were grouped by weight ranges. Relatively speaking, the smaller the chick weight as a percentage of egg weight (Fig. 1). This was possibly due to the fact that the smaller chicks may have hatched out first and thus dehydrated more by the time they were weighed.

At hatching time, the weight of the Bobwhite chick, like that of the chicken, probably depends more upon the weight of the egg than upon anything else. That this is true in the chicken was reported by Upp (1928), Galpin (1938) and others. Bobwhite chicks, in this experiment, weighed, on the average, 62.7 percent of the weight of the eggs from which they hatched. These results fall within the range of that of the chicken reported by Hays and Sanborn (1929) and many others.

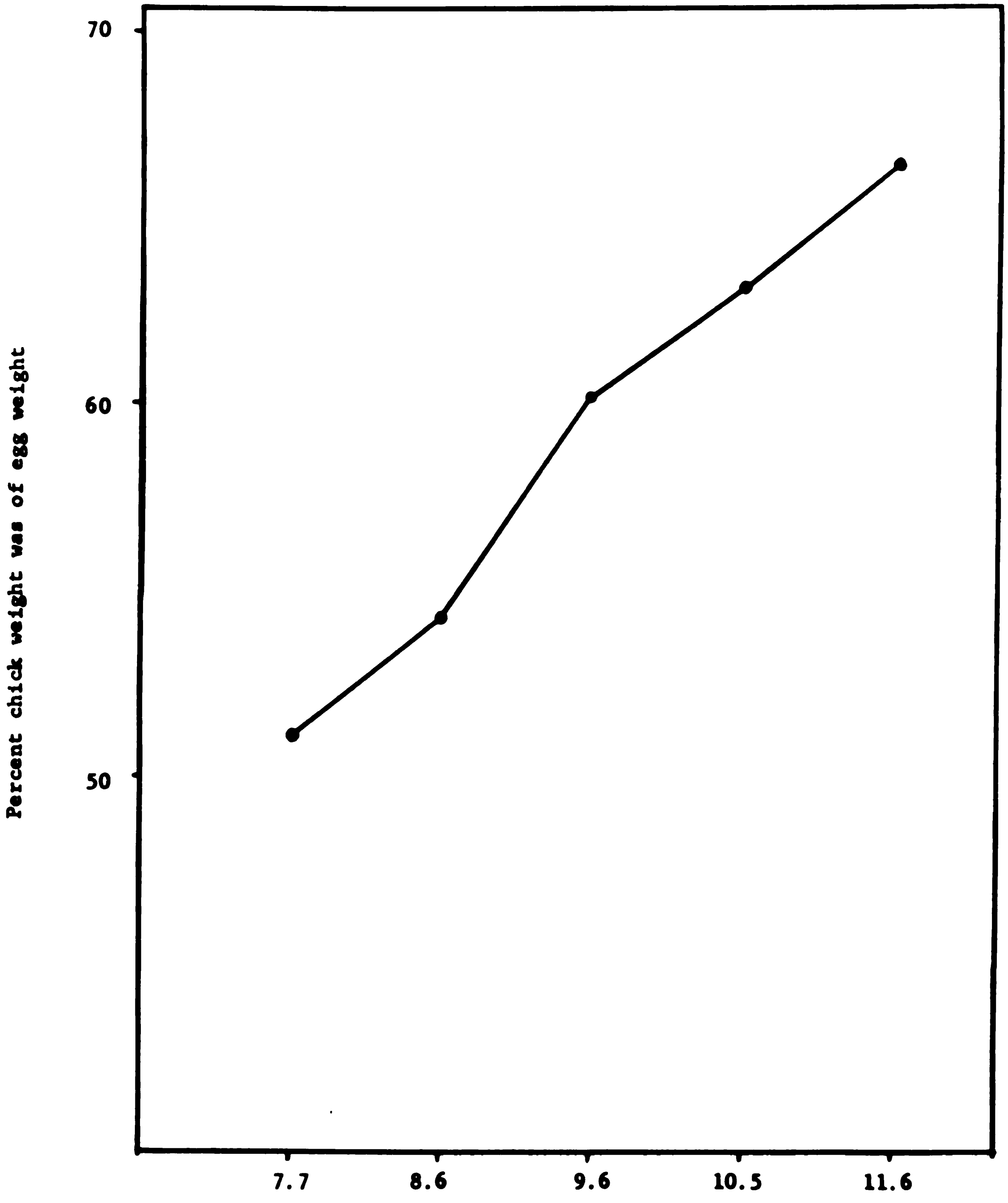

Fig. 1. The interrelationship between egg weight and percentage chick weight was of egg weight for Bobwhite quail

SUMMARY AND CONCLUSIONS

1. An attempt was made to determine the correlation between the weight of the female Bobwhite quail and the weight of the eggs they produce on one hand and the correlation between the weight of the eggs and the weight of one-day-old chicks hatched from these eggs on the other hand. For a period of approximately eight months, all eggs produced by 92 individually mated Bobwhite female quail were weighed to the nearest 0.001 gram on the same day they were produced. The 92 females were weighed to the nearest gram once each four weeks.

2. Eggs from the 92 females were incubated with settings made at weekly intervals. In addition, more than 500 eggs from mass-mated quail were also weighed to the nearest 0.001 gram and were incubated in the same intervals. Chicks hatched from all eggs were wing banded and weighed to the nearest 0.1 gram at one day of age.

3. There was a significant ($\alpha = 0.01$) correlation between body weight and egg weight on one hand (0.36), and between egg weight and the weight of Bobwhite chick at hatching time (0.84) on the other hand. Although the correlation between the first two variables was greatly influenced by the age of the birds, the correlation between the second two variables was almost constant.

4. Average chick weight as a percentage of egg weight ranged from a high of 66.2 percent to a low of 51.1 percent. Relatively speaking, the smaller the Bobwhite egg, the smaller the chick weight as a percentage of egg weight.

5. The influence of body weight of female Bobwhite quail on egg weight and the influence of the latter on chick weight at hatching time should be of considerable importance from the standpoint of selecting for bigger egg size and for bigger chick size at hatching time.

EXPERIMENT II

THE RELATIONSHIP BETWEEN BODY WEIGHT AT HATCHING TIME AND SUBSEQUENT GROWTH OF BOBWHITE QUAIL

From a practical standpoint, quail breeders could make extensive use of body weight as an index of the characteristics desired, when birds are selected for various purposes. Extensive data on rate of growth as measured by body weight could also be of value to quail breeders as a standard to guide their operations. Bobwhite body weight could be used as a possible criterion of sexual maturity, potential egg size, vigor and other essentials. Theoretically speaking, in light of the data obtained with chickens, it could be hypothesized that the weight of a Bobwhite chick at hatching time has a lot to do with its subsequent growth. No documented data could be located concerning the interrelationship between chick weight of Bobwhites at hatching time and their subsequent growth. Therefore, this study was undertaken in an attempt to determine the relationship, if any, between the weight of one-day-old Bobwhite chicks and their weights up to 18 weeks of age. The experimental period of 18 weeks of age was determined in light of what was found in the literature, together with personal experience, about the age at which Bobwhite quail reach sexual maturity. It should be kept in mind that greater uniformity and consistency would possibly be attained in studies of this type if stock in which prior selection for growth rate had been practiced were

available. This was not true for the stock used in this experiment. Also, influence on body weight of varying environmental conditions should not be overlooked.

Objectives:

1. To study the growth rate of the Bobwhites.
2. To determine the relationship, if any, between the weight of a quail chick at hatching time and its subsequent weight up to 18 weeks of age.

EXPERIMENTAL PROCEDURE

One-day-old Bobwhite chicks from Experiment I were raised to 18 weeks of age in Petersime chick batteries. Birds were weighed at two week intervals to the nearest 1.0 gram. They were sexed at 16 weeks of age. All possible information concerning the weight of the birds which did not survive until the end of the experimental period was utilized; i.e., if a bird died at three weeks of age, information concerning its weight at two weeks of age was included in the data and so on. Individual records for each chick were established. An attempt was made to predict the sex of the birds in this experiment at four weeks of age by means of the melanin concentration of the toes. This was only partially successful (about 75 percent accuracy). This attempt at sexing was based on the observation that the concentration of the melanin pigment in the toes and claws of the adult males is higher than that of the adult females.

RESULTS AND DISCUSSION

Tables 5 and 6 show the correlation between body weight of quail in this experiment at hatching time and their growth up to 18 weeks of age. There was a relationship between body weight at hatching time and body weight at two weeks of age ($\alpha = 0.01$). This relationship did not hold at four weeks of age but was again apparent by 16 weeks of age and was true with respect to both sexes (Tables 7, 8, 9 and 10). A high correlation was also noted between body weight at ten weeks of age and the weight of the bird up to 18 weeks of age ($\alpha = 0.01$). Figure 2 shows the average body weight of Bobwhite quail in this experiment.

The size of the Bobwhite chick at hatching had a lot to do with its subsequent growth in this experiment. Hays and Sanborn (1929) stated that despite the fact that they found a relationship between weight when hatched and the weight of the chicken at four weeks, no such relationship was evident at 21 weeks of age. Schnetzler (1936), on the other hand, found a significant correlation between chicken weight at 8 and 12 weeks and weight at maturity. The influence of body size of the Bobwhite quail at hatching on its subsequent growth is of considerable importance from the standpoint of selection for rapid growth rate. This possibly also would influence the feed conversion by the Bobwhites; however, no data were collected on this in the present experiment.

TABLE 5.-The correlation between the weight of a one-day-old chick and its weights up to eight weeks of age (mixed sexes of Bobwhite quail)

Simple Correlation	Average body weight of the birds (grams)									
	One-day-old chicks		Age of birds (in weeks)							
			Two		Four		Six		Eight	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	6.3	1.0	19.1	4.5	48.5	13.0	90.7	16.5	116.5	10.8
	One-day-old		2 weeks old		4 weeks old		6 weeks old		8 weeks old	
One-day-old	1.00		0.70**		0.04		-0.02		-0.02	
2 weeks old			1.00		0.18**		0.10		-0.02	
4 weeks old					1.00		0.37		0.26**	
6 weeks old							1.00		0.53**	
8 weeks old									1.00	

** Significant at the 0.01 level.

TABLE 6.—The correlation between the weight of a one-day-old chick and its weights from ten to 18

TABLE 8.-The correlation between the weight of a one-day-old chick and its weight from ten to 18 weeks of age for female Bobwhite quail

Simple Correlation	Average body weight of the birds (grams)											
	One-day-old chick		Age of the birds (in weeks)									
			Ten		Twelve		Fourteen		Sixteen		Eighteen	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	6.4	1.1	160.4	12.0	170.5	7.7	176.2	4.8	180.2	4.7	187.9	7.2
	One-day-old		10 weeks old		12 weeks old		14 weeks old		16 weeks old		18 weeks old	
One-day-old	1.00		0.01		0.22		0.11		0.30**		0.54**	
10 weeks old			1.00		0.81**		0.73**		0.58**		0.18	
12 weeks old					1.00		0.88**		0.85**		0.51**	
14 weeks old							1.00		0.91**		0.57**	
16 weeks old									1.00		0.76**	
18 weeks old											1.00	

* Significant at the 0.05 level.
** Significant at the 0.01 level.

TABLE 9.-The correlation between the weight of a one-day old chick and its weights up to eight weeks

TABLE 7.-The correlation between the weight of a one-day-old chick and its weight up to eight weeks of age for female Bobwhite quail

Simple Correlation	Average body weight of the birds (grams)									
	One-day-old chick		Age of the birds (in weeks)							
			Two		Four		Six		Eight	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	6.4	1.1	18.5	4.1	45.9	12.6	86.3	17.1	114.9	11.5
	One-day-old		2 weeks old		4 weeks old		6 weeks old		8 weeks old	
One-day-old	1.00		0.71**		0.08		-0.16		-0.18*	
2 weeks old			1.00		0.29**		0.06		-0.08	
4 weeks old					1.00		0.50**		0.17**	
6 weeks old							1.00		0.54**	
8 weeks old									1.00	

* Significant at the 0.05 level.
** Significant at the 0.01 level.

TABLE 9. The correlation between the weight of a one-day old chick and its weights up to eight weeks

TABLE 9.-The correlation between the weight of a one-day-old chick and its weights up to eight weeks of age for male Bobwhite quail

Simple Correlation	Average body weight of the birds (grams)									
	One-day-old chick		Age of the birds (in weeks)							
			Two		Four		Six		Eight	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	6.2	0.8	18.7	4.2	49.1	12.6	91.7	16.0	117.3	10.9
	One-day-old		2 weeks old		4 weeks old		6 weeks old		8 weeks old	
One-day-old	1.00		0.58**		0.09		0.13		0.04	
2 weeks old			1.00		0.09		0.09		-0.06	
4 weeks old					1.00		0.29**		0.27**	
6 weeks old							1.00		0.54**	
8 weeks old									1.00	

** Significant at the 0.01 level.

TABLE 10.-The correlation between the weight of a one-day-old chick and its weights from ten to 18 weeks of age for male Bobwhite quail

Simple Correlation	Average body weight of the birds (grams)											
	One-day-old chick		Age of the birds (in weeks)									
			Ten		Twelve		Fourteen		Sixteen		Eighteen	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	6.2	0.8	135.9	14.1	159.7	7.9	168.7	7.0	174.1	5.6	179.9	5.8
	One-day-old		10 weeks old		12 weeks old		14 weeks old		16 weeks old		18 weeks old	
One-day-old	1.00		-0.01		0.14		0.31**		0.40**		0.53**	
10 weeks old			1.00		0.47**		0.325**		0.26**		0.07	
12 weeks old					1.00		0.83**		0.69**		0.44**	
14 weeks old							1.00		0.90**		0.70**	
16 weeks old									1.00		0.85**	
18 weeks old											1.00	

** Significant at the 0.01 level.

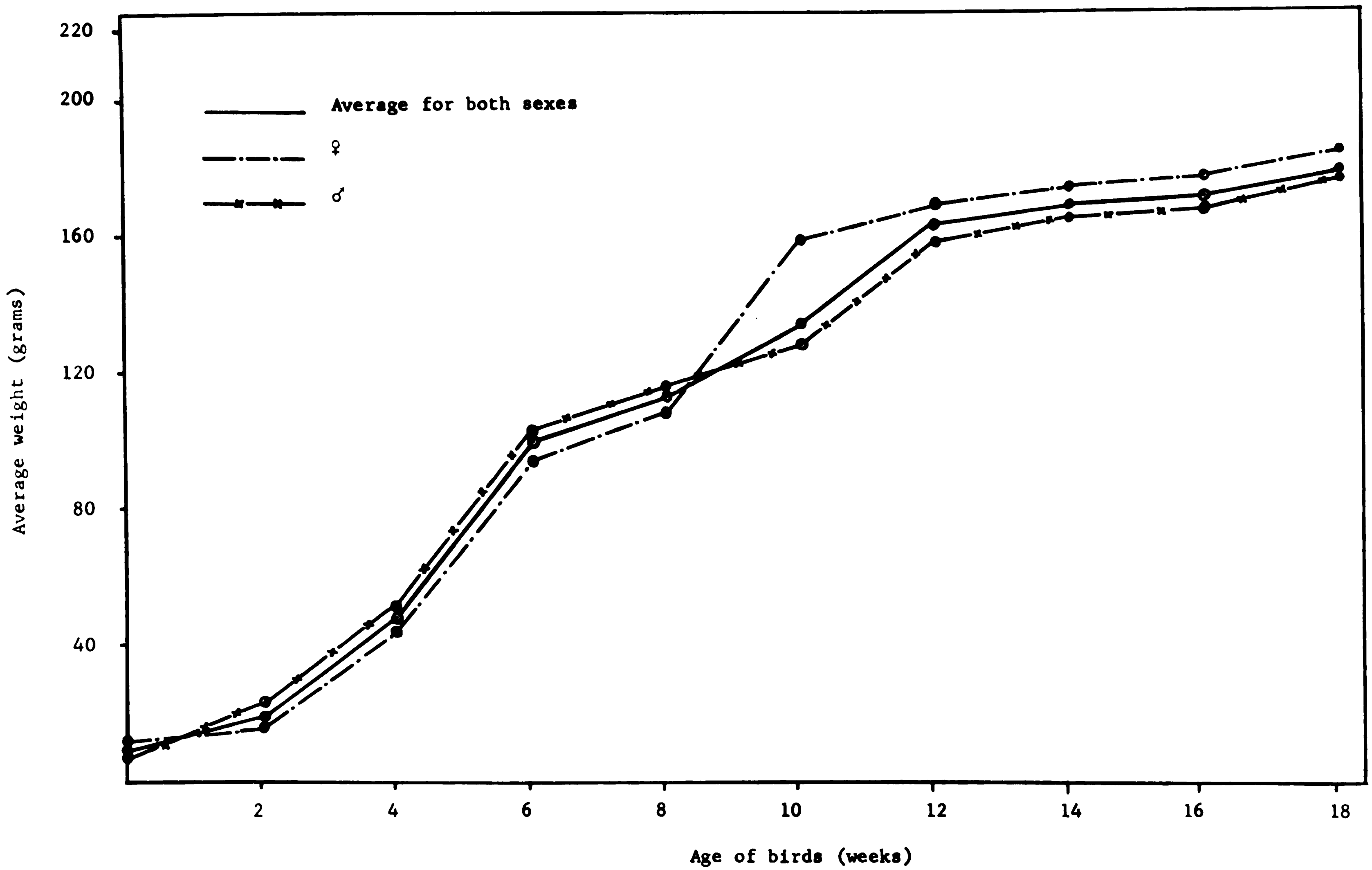

Fig. 2. The average body weight of Bobwhite quail from hatching to 18 weeks of age

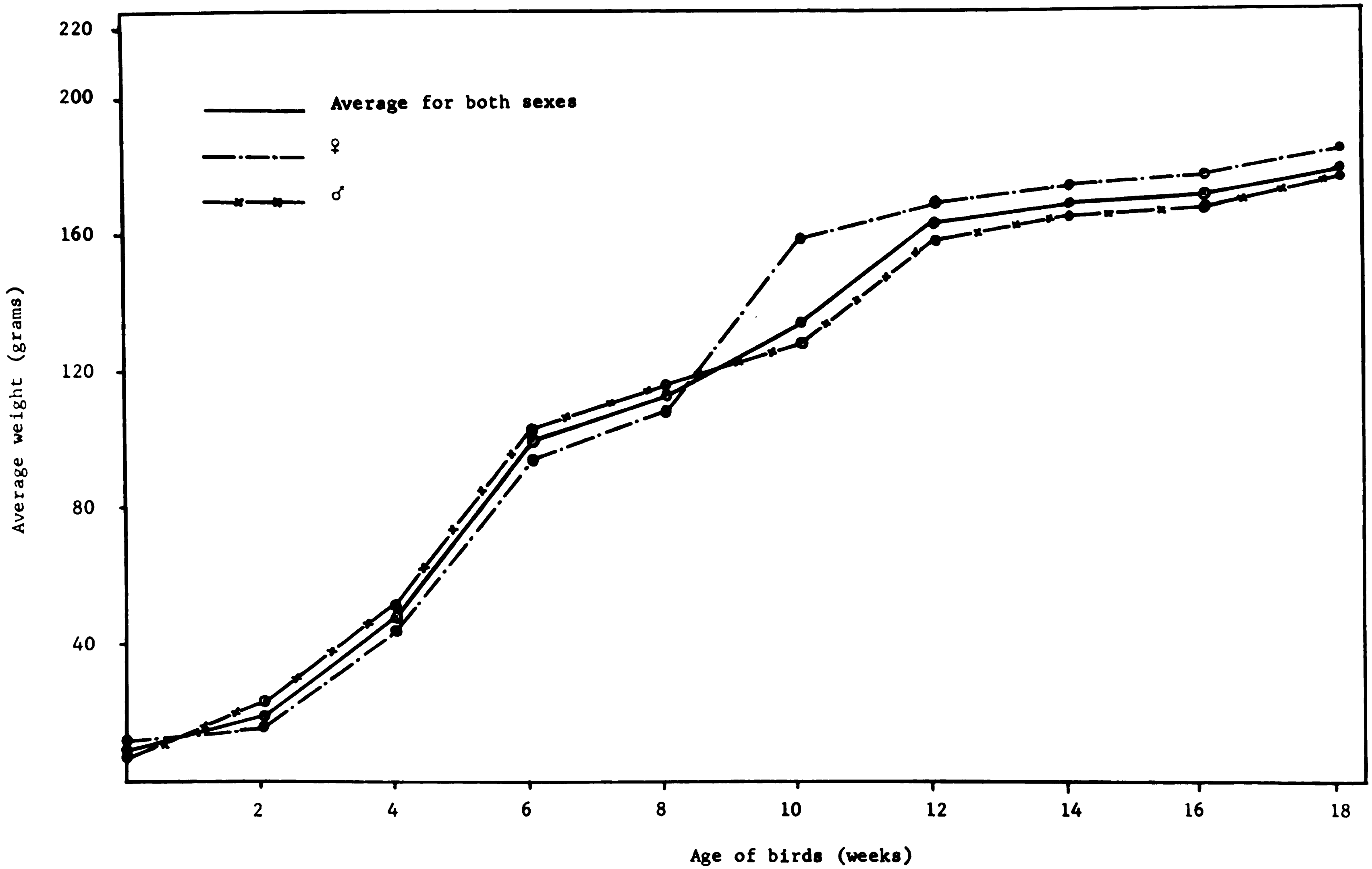

Fig. 2. The average body weight of Bobwhite quail from hatching to 18 weeks of age

The growth of Bobwhites as reported by Baldini (1951) showed that the birds in his experiment gained weight rapidly up to 8 weeks of age and had attained 73 percent of the adult weight by that age. Results to 8 weeks in the present experiment agree to a great extent with those reported by Baldini. In the experiment herein reported, growth rate tended to decline after 12 to 14 weeks of age, despite the fact that the Bobwhites continued to gain weight up to at least 18 weeks of age. Female Bobwhites gained more weight than did the males ($\alpha = 0.01$). These results confirm the observations made by Stoddard (1931) and many others that mature female Bobwhite quail weigh more than do mature males.

SUMMARY AND CONCLUSIONS

1. An attempt was made to determine the correlation between the weight of one-day-old Bobwhite chicks and their subsequent weights up to 18 weeks of age. The chicks hatched in Experiment 1 were wing banded and weighed to the nearest 0.1 gram at 1 day of age. Chicks were raised to 18 weeks of age in batteries. Birds were weighed at two week intervals to the nearest gram.

2. It appears that the size of the Bobwhite chick at hatching time influences its subsequent growth. There was a high correlation (0.7) between body weight of the Bobwhites at hatching time and at 2 weeks of age ($\alpha = 0.01$). High correlations were also noted between body weight at 10 weeks of age and its subsequent growth. Similar correlations held true with respect to different sexes.

3. Although growth rate tended to decline after 12 to 14 weeks of age, the Bobwhites were still gaining weight up to 18 weeks of age. Female Bobwhites gained more weight than did the males ($\alpha = 0.01$).

4. The influence of body size of the Bobwhite quail chicks at hatching time on their subsequent growth should be of considerable importance from the standpoint of selection for rapid growth rate.

EXPERIMENT III

THE INFLUENCE OF FLOOR SPACE ON GROWTH AND LIVABILITY OF BOBWHITE QUAIL

It is generally accepted that many management factors influence the early growth of Bobwhite quail. Floor space is one management factor which conceivably might exert an influence. It is evident that a more accurate evaluation of the influence of floor space on the growth of quail would be made if all other environmental factors could be kept on a per bird basis. This would include the type and the amount of feeder and waterer space and the relationship of feeder and waterer space to floor space, type of feed and surrounding temperature and humidity. No documented report concerning the influence of floor space on the growth and livability of Bobwhites could be located. Furthermore, there is very little information in the literature on floor space allowances for chicksn and turkeys. Studies of this type on chickens and turkeys might be handicapped by limits in budget, time and space.

This study was undertaken in an attempt to determine the effects of floor space on the growth and livability of Bobwhite quail. Such information might be useful either for a pilot study for chickens or turkeys in experiments of this type, or for the proper raising of the Bobwhite in captivity as a profitable bird.

<u>Objectives:</u>

1. To determine the effect of different allowances of floor space on the growth and livability of Bobwhite quail between 2 weeks and 16 weeks of age.
2. To observe the incidence, if any, of cannibalism among Bobwhite quail due to crowding.

EXPERIMENTAL PROCEDURE

The Bobwhite quail chicks in this experiment were raised in Petersime starting batteries. The chicks were reared on paper for three weeks. At this time, the paper was removed and the chicks were held in the battery until 16 weeks of age. Birds were wing-banded and individually weighed at 2 weeks of age and were randomly divided into three experimental groups. Three replications were raised at each concentration. Experimental groups were randomly distributed into two batteries. Floor space of 0.06 square feet per bird, 0.12 square feet per bird and 0.24 square feet per bird was provided for the three different groups, respectively. There were 16, 32 and 64 birds in each replicate at 0.24, 0.12 and 0.06 square feet per bird, respectively; thus, a total of 336 birds were utilized at the beginning of this experiment. All groups were provided with equal feeder and waterer space per bird. All groups were allowed 0.4 linear inch of feeder space and 0.2 linear inch of drinking space per bird. Feed and water were kept before the various groups at all times. Insofar as possible, equal heat was provided for the different experimental groups. All groups received continuous (24 hr.) lighting.

To keep population density constant, birds which died were immediately replaced with non-wing-banded Bobwhite quail of the same age which had been reared in the same battery. These replacements were not included in the data on body weight or mortality. Birds were weighed each 14 days for the first 10 weeks of age. A daily record of mortality was kept.

Feed consumption was measured each day. At two week intervals average feed consumption per bird per day was calculated. Average body weight gain per bird per day was computed for the same interval. Average daily feed conversion for the two week period was derived by dividing average daily feed consumption by average daily body weight gain.

RESULTS AND DISCUSSION

1. Body Weight

The mean body weights of birds grown at the three population densities which were compared in this experiment are shown in Table 11. No significant differences could be demonstrated between the body weight gains of the three groups up to 16 weeks of age. Although the average body weight of the female and male birds at the beginning of the experiment was not significantly different, the mean weight of the females was shown to be significantly greater than the mean weight of the males at 16 weeks of age (α- 0.01). Differences in body weight due to sex are shown in Figure 3. The correlation between body weight at 2 weeks of age and subsequent growth of the Bobwhite quail raised on different allowances of floor space are shown in Tables 12, 13 and 14.

No incidence of poor feathering as reported by Ernst (1963) in Coturnix quail was noted. Growing Bobwhite females at every floor space level were significantly heavier than the males at 16 weeks of age (α - 0.01). This agrees with what is found in the literature with respect to raising Bobwhite either in captivity (Nestler, 1943, 1949; Nestler et al., 1942; Baldini, 1951; Baldini et al., 1953; Kirkpatrick and Leopold, 1952; and Kirkpatrick, 1964) or in the wild state (Stoddard, 1931; Ripley, 1960).

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TABLE 11.-Effect of different floor space allowances on body weight gain of Bobwhite quail.

Weights in grams	0.24 sq. ft./ bird		0.12 sq. ft./ bird		0.06 sq. ft./ bird	
	Male	Female	Male	Female	Male	Female
Av. init. wt. (2 wks. old)	16.9	18.0	19.1	20.7	19.8	17.9
Standard deviation	2.9	3.3	2.4	4.2	5.3	4.7
Av. wt. (16 wks. old)	160.0	185.4	165.0	180.5	159.1	175.1
Standard deviation	9.6	2.4	13.7	11.4	33.6	8.8
Av. body wt. gain	143.1	167.4	145.9	159.8	139.3	157.2

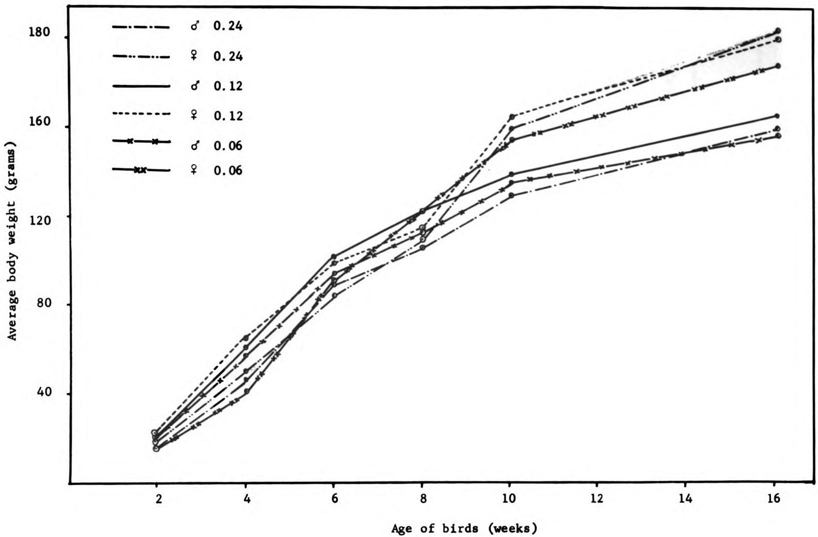

Fig. 3. Influence of floor space on growth of Bobwhite quail

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TABLE 12.-The correlation between the initial and 16-week-old body weights for Bobwhite quail raised on floor space of 0.24 square feet per bird.

Males

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	-0.31	-0.11	0.01	-0.26	-0.15
Four		1.00	0.17	0.51	0.55*	0.40
Six			1.00	0.82**	-0.30	-0.17
Eight				1.00	-0.55**	-0.45
Ten					1.00	-0.68**
Sixteen						1.00

Females

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	-0.15	-0.11	0.01	0.50	0.13
Four		1.00	0.56	0.77*	0.50	0.33
Six			1.00	0.64	-0.25	-0.18
Eight				1.00	0.40	-0.32
Ten					1.00	0.37
Sixteen						1.00

* Significant at the 0.05 level.
** Significant at the 0.01 level.

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TABLE 13.-The correlation between the initial and 16-week-old body weights for Bobwhite quail raised on floor space of 0.12 square feet per bird.

Males

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	0.44	0.62*	0.43*	0.42	0.42
Four		1.00	0.20	0.80**	-0.10	-0.07
Six			1.00	0.42	0.25	0.35
Eight				1.00	-0.10	-0.02
Ten					1.00	0.81**
Sixteen						1.00

Females

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	0.30	0.19	-0.04	-0.03	0.03
Four		1.00	0.47	0.01	0.29	0.01
Six			1.00	0.62*	0.10	-0.07
Eight				1.00	0.27	0.33
Ten					1.00	0.82**
Sixteen						1.00

* Significant at the 0.05 level.
** Significant at the 0.01 level.

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TABLE 14.-The correlation between the initial and 16-week-old body weights for Bobwhite quail raised on floor space of 0.06 square feet per bird

Males

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	-0.06	-0.10	-0.12	-0.01	-0.10
Four		1.00	0.42*	-0.13	0.03	0.41*
Six			1.00	0.11	0.05	0.01
Eight				1.00	-0.14	-0.08
Ten					1.00	-0.35
Sixteen						1.00

Females

Age of birds (weeks)	Two (initial)	Four	Six	Eight	Ten	Sixteen
Two (initial)	1.00	0.18	0.07	0.11	-0.23	0.08
Four		1.00	0.41	0.25	0.03	-0.35
Six			1.00	0.42*	0.14	-0.27
Eight				1.00	-0.10	-0.22
Ten					1.00	0.41
Sixteen						1.00

* Significant at the 0.05 level.

The ability of these quail to grow under what were considered to be very crowded conditions was expected, in light of Ernst's report (1963).

2. Feed Conversion

Feed conversion measured for two week intervals from 6 to 16 weeks of age for Bobwhite quail in this experiment is shown in Table 15. Average feed conversion ranged from a high of 8.00 grams of feed per gram of weight gain to a low of 4.30 grams of feed per gram of weight gain. Feed conversion was less efficient at 16 weeks of age than at 6 weeks of age. No remarkable differences were noted in feed conversion with respect to population densities.

The feed conversion of the Bobwhites in this experiment was poorer than that reported for Coturnix involved in a floor space study by Ernst (1963). The results herein reported were expected in light of the reports by many investigators under different experimental conditions (Nestler et al., 1942; Nestler, 1943; DeWitt, 1949; Baldini, 1951; Baldini et al., 1950, 1953; and many others). Accurate feed consumption figures are somewhat difficult to obtain with growing quail because small amounts of feed are involved and the quail bill out feed to a considerable extent unless particular care is taken to prevent feed wastage. The magnitude of feed conversion figures which reached almost eight grams of feed per gram body weight gain suggests that unlike Coturnix quail,

TABLE 15.-Effect of different floor space allowances on average feed conversion of Bobwhite quail

Treatment	Grams of feed/gram body weight gain/bird			
	6 wk. old	8. wk. old	10 wk. old	16 wk. old
0.24 sq. ft./bird	4.6	5.8	4.8	6.5
0.12 sq. ft./bird	4.3	7.6	4.8	7.8
0.06 sq. ft./bird	4.5	5.7	5.2	8.0

Bobwhite quail are not very efficient in the utilization of feed. Two factors should be kept in mind in considering the feed conversion figures. First, the feed conversion was measured from 6 to 16 weeks of age. Secondly, the composition of the ration fed in this study might have had an influence on these figures (Table 1 Appendix).

3. Livability

The effect of population density on mortality of growing quail in this experiment is shown in Table 16. Mortality was lowest at a population density of 0.24 square feet per bird. Although this was shown to be significantly different from that in either of the more dense populations (0.12 and 0.06 square feet per bird) ($\alpha = 0.01$), no significant differences could be detected between the latter groups.

The overall mortality was rather high. Forty (40) percent mortality is not unusual (Nestler et al., 1942; Bass, 1939, 1941, 1942; and Berstrand and Kimstra, 1962). In this experiment, the least mortality was found among the least dense group (0.24 square feet per bird). No incidence of cannibalism was noted under these overcrowded conditions. These results agree with the findings of Baldini et al. (1950) who stated that Bobwhite quail can be reared in battery brooders in close confinement without

TABLE 16.-Effect of different floor space allowances on the mortality of growing Bobwhite Quail (2 to 16-wk. old)

Treatment	Replicates (1)	(2)	(3)	Birds died Total	Percent
0.24 sq. ft./bird	6	8	5	19	39.6**
0.12 sq. ft./bird	19	18	12	49	51.0
0.06 sq. ft./bird	38	32	36	106	55.2

** Significant at the 0.01 level.

evidence of cannibalism, provided the diet is adequate. Floor space of 27 to 29 square inches per bird was provided in Baldini's experiments.

Since sex could not be detected from differences in external features before 15 to 16 weeks of age, mortality with respect to sex was not determined as no attempt was made to distinguish between sex anatomically among dead birds.

SUMMARY AND CONCLUSIONS

1. Bobwhite quail were raised in concentrations of 0.24 square foot per bird, 0.12 square foot per bird and 0.06 square foot per bird. No significant reduction in growth occurred as a result of different floor space allowances.
2. The overall feed conversion of the Bobwhite quail in this experiment was very poor. Poorer feed conversion was noted at 16 weeks of age than at 6 weeks of age.
3. Mortality was significantly higher in the more dense groups compared to the least dense group ($\alpha = 0.01$). No incidence of cannibalism was noted under these conditions.
4. These results indicate that growing Bobwhite quail can be raised in a population density as heavy as one bird per 0.06 square foot; however, decision-making should be left to the manager or the quail breeder to choose between alternatives concerning floor space on one hand and mortality on the other hand.

EXPERIMENT IV

THE INFLUENCE OF FLOOR SPACE ON EGG PRODUCTION, FERTILITY AND HATCHABILITY OF BREEDER BOBWHITE QUAIL

Floor space recommendations for laying chickens are largely based on hearsay. The floor space requirements suggested by commercial management publications need to be placed on a scientific basis. Pilot studies with Bobwhite quail would possibly have some useful application in this area. No documented reports concerning the influence of floor space on the reproduction of the Bobwhites could be located. From a practical standpoint, such information might also be of value to a quail breeder.

Objectives:

1. To determine the effect of different allowances of floor space on the onset of sexual maturity of Bobwhite quail.
2. To determine the effect of different allowances of floor space on egg production of Bobwhite quail.
3. To determine the effect of different allowances of floor space on size of eggs produced by Bobwhite quail.
4. To determine the effect of different allowances of floor space on fertility and hatchability of Bobwhite quail.
5. To determine the effect of different allowances of floor space on livability of Bobwhite quail.

EXPERIMENTAL PROCEDURE

Sixteen (16)-week-old Bobwhite quail were placed in Petersime starting batteries. Birds were randomly divided into three experimental groups. Three replications were housed at each concentration: 0.06 square foot per bird (64 birds per replicate), 0.12 square foot per bird (32 birds per replicate) and 0.24 square foot per bird (16 birds per replicate). Male to female ratio at the beginning of the experiment was 1:3 in all replicates. Eggs were gathered daily and weighed once each week. Eggs were classified as clean, clean-check, dirty or dirty-check as shown in Table 18. Eggs were candled to detect checks and were set in Jamesway 252 forced-draft incubators. Incubation procedures as given under General Experimental Procedures were followed.

On the 24th day of incubation the quail chicks were removed and the eggs which failed to hatch were candled, and, if necessary, broken out to determine fertility macroscopically.

To keep population density constant, birds which died were immediately replaced with male quail of the same age, if needed to correct the male:female ratio, or by female Coturnix quail. Coturnix eggs which could be easily distinguished from Bobwhite eggs, were not included in the data.

This experiment was conducted for a period of approximately four months. Prior to the end of the experimental period, the crowded groups were distributed in different compartments. All groups were allowed 0.24 square foot of floor space per bird. Coturnix females were used in some of the compartments to provide equal floor space per bird for all groups. Only data for egg production were obtained for all groups after they were redistributed. These data were collected for a period of two weeks.

RESULTS AND DISCUSSION

1. Onset of Sexual Maturity

Age at sexual maturity either as indicated by the first egg(s) laid or by the age of the birds when they reached a level of more than 30 percent egg production is shown in Table 17. One bird in one of the least dense replicates laid at 114 days of age. This was not influenced by the floor space allowancy as the bird had been randomized into the treatment groups only two days prior to this time. At least one bird was laying in each of the least dense replicates by 122 days of age. No bird in any replicate of either of the other two treatments laid before 132 days of age. A more meaningful index of the effect of the different floor space allowances on age at sexual maturity would be age at which birds attained a given level of production--such as 30 percent.

Birds in the less dense group (0.24 sq. ft./bird) reached sexual maturity earlier than the other two groups whether with respect to the first egg(s) laid or the level of more than 30 percent production ($\alpha = 0.01$). As indicated by the age of birds at the first egg(s) laid, the two more dense groups reached sexual maturity at about the same age. None of the replicates of the heaviest concentration group (0.06 sq. ft./bird) reached a level of 30 percent egg production during the experimental period. When these birds were redistributed and given an allowance of 0.24

TABLE 17.-Effect of different floor space allowances on age of sexual maturity of Bobwhite quail

Treatment	Average age at sexual maturity (days) First egg(s) produced	More than 30% production
0.24 sq. ft./bird	118.0 (114-122)	141.3 (138-145)
0.12 sq. ft./bird	137.0 (133-141)	169.0 (167-172)
0.06 sq. ft./bird	137.7 (132-146)	? *

* None of the replicates reached a level of 30 percent egg production during the experimental period.

sq. ft./bird they averaged 28 percent egg production for the two weeks tested (Table 18).

The reproductive organs of mature Bobwhite females on 16 hours constant light (7:00 to 12:00) weighed about 4,562 mg. and 4,886 mg, for the ovary and the oviduct, respectively, (Kirkpatrick, 1964). In his different studies, the average weight of the nonproductive ovary was shown to range from 270 to 1,350 mg. and that of the nonproductive oviduct from 1,200 to 2,490 mg. Therefore, individual body weight records might be used to determine approximately when a quail reaches sexual maturity. In the present experiment, egg production (whether as indicated by the first egg(s) laid, or by the level of more than 30 percent egg production), was the only index used to determine sexual maturity of the females. Sexual maturity was delayed about four weeks when birds were allowed 0.06 or 0.12 sq. ft./bird as compared to 0.24 sq. ft./bird. These results do not agree with those of Ernst (1963) in Coturnix quail, but they do agree with those of Wilson et al. (1961) who also worked with Coturnix quail. It was observed in the present experiment that female Bobwhite quail might have reached the age of sexual maturity about three weeks earlier than did the males since no fertile eggs were obtained in the first three sets (Table 20). This could have possibly been due to the reluctance of males to mate under the artificial conditions imposed in this experiment. In earlier experiments with Bobwhite quail, Kirkpatrick (1955) reported that at the end of 164 days, males exposed to a 15-minute interruption, and females exposed to a 20-minute interruption, of a 14-hour daily dark period produced sperm and eggs, respectively. Baldini et al. (1952) stated that under continuous lighting, the Bobwhite quail may attain sexual maturity as early as 139 days of age. Comparatively speaking, it appears that some individual female Bobwhites in this experiment reached sexual maturity at an age earlier than that reported by many workers.

These results indicate that selection for earlier age of sexual maturity might be effective with respect to Bobwhite quail raised in captivity.

2. Egg Production

Egg production measured as egg/bird/day for the experimental period is shown in Table 18. Average egg production was lowest (0.10 egg/bird/day) in the most dense population ($\alpha = 0.01$). Average egg production of birds in the least dense group (0.24 sq. ft./bird) was 0.32 egg/bird/day and was higher than that of birds in the intermediate group (0.12 sq ft./bird) which averaged 0.14 egg/bird/day. None of the replicates in the most dense group (0.06 sq. ft./bird) reached more than 17 percent production during the experimental period. When the influence of crowding was removed, egg production increased immediately in both the intermediate and the most dense group (Table 18).

TABLE 18a.-Effect of different floor space allowances on egg production and external quality of eggs produced by Bobwhite quail

	0.24 sq. ft./bird				
Month	Tot. egg bird/day	Clean %	Clean-check %	Dirty %	Dirty-check %
Oct.[1]	0.01	100	0	0	0
Nov.	0.38	45.7	48.6	0	5.7
Dec.	0.39	30.6	61.2	2.0	6.1
Jan.	0.33	34.4	62.5	3.1	0
Feb.[1]	0.46	37.2	55.8	4.7	2.3
Average	0.32	36.5	57.2	2.5	3.8
Feb.[2]	0.36	50.0	33.0	8.3	8.3

[1]The month of October counts only for three weeks and February for two weeks only.
[2]The influence of crowding was removed.

TABLE 18b.-Effect of different floor space allowances on egg production and external quality of eggs produced by Bobwhite quail.

	0.12 sq. ft./bird				
Month	Tot. egg bird/day	Clean %	Clean-check %	Dirty %	Dirty-check %
Oct.	0	0	0	0	0
Nov.	0.19	62.5	37.5	0	0
Dec.	0.16	38.5	38.5	15.4	7.7
Jan.	0.14	36.4	27.3	18.2	18.2
Feb.	0.23	41.7	16.7	8.3	33.3
Average	0.14	43.2	29.5	11.4	15.9
Feb.	0.37	38.8	32.4	21.6	8.8

TABLE 18c.-Effect of different floor space allowances on egg production and external quality of eggs produced by Bobwhite quail.

	0.06 sq. ft./bird				
Month	Tot. egg bird/day	Clean %	Clean-check %	Dirty %	Dirty-check %
Oct.	0	0	0	0	0
Nov.	0.09	14.3	14.3	28.6	42.9
Dec.	0.10	28.6	14.3	0	57.1
Jan.	0.17	27.3	18.2	9.1	49.5
Feb.	0.14	22.2	0	33.3	44.4
Average	0.10	23.5	11.8	17.6	47.1
Feb.	0.28	35.3	52.9	5.9	5.9

Egg production expressed on a bird/day basis shows, in general, a downward trend with increased population density. It appears from these results and those cited in the Review of Literature that a level of 30 percent egg production may be about average for Bobwhite quail in captivity. In nutritional studies, Nestler (1943) reported egg production per hen per day to be 0.348 and 0.361 when salt levels in the diets of Bobwhites were 0.5 and 2.0 percent, respectively. Similar results concerning egg production level of Bobwhite quail have been reported by several workers (Nestler _et al._, 1944; DeWitt _et al._, 1949; and Baldini _et al._, 1952).

The percent of the total eggs which were checked or dirty, as well as sound eggs, is shown in Table 18. The overall checked eggs of all groups in this study were very high. Clean-checked eggs ranged from a high of 62.5 percent to a low of zero percent. Birds of the most dense group (0.06 sq. ft./bird) produced a greater percentage of dirty eggs than did birds of the two other groups (α = 0.05). The incidence of clean-checked eggs was very high in the less dense group (0.24 sq. ft./bird) compared to the other groups (α = 0.05). The large number of checked eggs from all treatments indicates that it is undesirable to confine birds in batteries where eggs are left on the floor for any period of time. A great number of eggs is cracked during gathering. Sloping floors where eggs would roll away from the birds might be useful. Nests might be of great value in that aspect also.

3. Egg Size

The effect of population density on egg weight is shown in Table 19. Although there were significant differences in egg weight at the first laying period ($\alpha = 0.05$), eggs from the less dense group (0.24 sq. ft./bird) did not vary considerably, weight-wise, compared to the eggs from the two other groups at the end of the experimental period.

Regardless of the different treatments, size of eggs produced by birds in the different groups was in the neighborhood of 10.5 grams at the end of the trial. This average weight was derived from weighing a random sample of clean, sound eggs. Considerable variation in egg size was noted at the beginning of production. Part of this variation might have been due to the differences in age at which birds from the different groups reached sexual maturity. While it took the less dense group (0.24 sq. ft./bird) about nine weeks to produce eggs weighing approximately 10.5 grams, it took the more dense group a longer time to produce eggs of the same size. Funk et al. (1941) reported that Bobwhite quail in captivity laid eggs of increasing size until approximately the fifth week of production, after which time the egg weight was fairly uniform.

TABLE 19.-Effect of different floor space allowances on average weight of eggs produced by Bobwhite quail

	Average egg weights (grams)					
Month	0.24 sq ft/ bird	s.d.	0.12 sq ft/ bird	s.d.	0.6 sq ft/ bird	s.d.
November	8.9	0.86	6.8	0.24	6.8	0.36
December	9.6	0.55	8.9	0.95	8.7	0.87
January	10.5	0.62	10.3	0.88	10.0	0.82
February	10.4	0.48	10.9	0.71	10.5	0.92

The overall average egg size in the present experiment was slightly above the averages previously reported (Stoddard, 1931; Funk et al., 1941; and Romanoff and Romanoff, 1949).

4. Fertility and Hatchability

The percent fertility and hatchability of eggs produced by birds in the three treatments is shown in Table 20. The overall fertility in this trial was rather poor. Eggs produced by the most dense group (0.06 sq. ft./bird) showed a lower fertility than those produced by the two other groups of birds ($\alpha = 0.01$), while no significant differences were noted between eggs produced by the intermediate group and the less dense group. No fertile eggs were obtained in the first month (November). There was appreciable improvement in fertility of eggs from each of the three different groups as the experiment progressed; however, the highest fertility of about 28 percent obtained from eggs produced by the least dense group of birds (0.24 sq. ft./bird) is considered rather low in light of previously reported results. Hatchability was highest for eggs produced by the less dense group and lowest for eggs produced by the most dense group. The difference between these two groups was highly significant ($\alpha = 0.01$).

The overall fertility and hatchability of all treatments in this experiment was very low (Stoddard, 1931; Funk et al., 1941; Nestler, 1943; Nestler et al., 1944; and many others). Funk et al. (1941) reported that in

TABLE 20.-Effect of different floor space allowances for breeder Bobwhite quail on fertility and hatchability of eggs they produced.

Month	0.24 sq. ft./bird No. eggs set	0.24 sq. ft./bird Fertility	0.12 sq. ft./bird No. eggs set	0.12 sq. ft./bird Fertility	0.06 sq. ft./bird No. eggs set	0.06 sq. ft./bird Fertility
November	98	0.0	84	0.0	63	0.0
December	112	38.4	92	32.6	75	5.3
January	84	40.5	69	44.9	86	18.6
February	38	44.7	41	34.1	35	34.3
Total eggs set	332		286		259	
Av. Fertility		28.3		26.2		12.4
Av. Hatchability		83.4		50.0		33.2

their experiment, the lowest percentage of hatchability was 41.3 percent and the highest 94.7 percent. There was a marked variation in fertility ranging from about 96.5 to zero percent (Funk et al., 1941).

Dirty eggs might be a logical explanation for the high embryonic mortality seen in eggs laid by the more dense group. Embryonic mortality in eggs produced by the most crowded group (0.06 sq. ft./bird) was found to be higher than in eggs laid by the least dense group (0.24 sq. ft./bird). There seems to be a positive relationship between dirty eggs set and embryonic mortality. Bacterial contamination and the increased number of dirty-checked eggs missed during sorting could have resulted in higher embryo mortality in these groups.

Fertility was expressed as a percentage of sound eggs and hatchability was expressed as a percentage of fertile eggs. The decrease in fertility with increased crowding agrees with the results of Ernst (1963) in the Coturnix quail. An attempt was made to make the male to female ratio about the same in all groups (1:3). In the extremely crowded pens (0.06 sq. ft./bird) interference during mating was often observed and this may have caused a decrease in fertility.

5. Livability

Mortality (Table 21) was highest in the birds at a population density of 0.06 square foot per bird; however, mortality was significantly higher in both the 0.06 and 0.12 square foot per bird group than in the 0.24 square foot per bird group and was significantly higher in the 0.06 than in the 0.12 square foot per bird group ($\alpha = 0.01$).

The overall mortality of the least dense group was very light. It reached an average of 2.1 percent at the end of the experimental period. While mortality reached an average of 15.6 percent for the intermediate group, it averaged in the neighborhood of 23 percent for the most dense group. No information concerning the mortality of adult Bobwhite quail raised under conditions similar to those in the present experiment could be found in the literature.

TABLE 21.-Effect of different floor space allowances on the mortality of breeder Bobwhite quail during the experimental period

Treatment	Replicates (1)	(2)	(3)	Total male	female	Percent**
0.24 sq. ft./bird	0	1	0	1	-	2.1
0.12 sq. ft./bird	4	8	3	8	7	15.6
0.06 sq. ft./bird	20	10	15	23	22	23.4

** All significantly different at the 0.01 level.

SUMMARY AND CONCLUSIONS

1. Breeder Bobwhite quail were placed in concentrations of 0.24 square foot per bird, 0.12 square foot per bird and 0.06 square foot per bird. An attempt was made to keep both population density and male to female ratio constant. Data concerning livability, egg production, external egg quality, fertility and hatchability were gathered and statistically analyzed.

2. Birds in the least dense group (0.24 square foot per bird) reached the age of sexual maturity earlier than birds in the other two groups whether with respect to the first egg(s) laid or the level of more than 30 percent production ($\alpha = 0.01$).

3. Average egg production was lowest (0.10 eggs per bird per day) in the most dense population group ($\alpha = 0.01$). Average egg production was highest (0.32 eggs per bird per day) for the least dense group. Birds housed at 0.12 square foot per bird averaged 0.14 eggs per bird per day. Birds of the most dense population (0.06 square foot per bird) produced a greater percentage of dirty eggs than did birds of the two other groups. No significant differences in egg weight between the three groups was noted at the end of the experimental period.

4. The overall fertility in this trial was rather poor. Eggs produced by the most dense group showed lower fertility

than those produced by the two other groups of birds ($\alpha = 0.01$). Hatchability was highest for eggs produced by the least dense group and lowest for eggs produced by the most dense group ($\alpha = 0.01$).

5. Breeder Bobwhite quail should be allowed at least 0.24 square foot of floor space per bird, and possibly more, if best results concerning egg production, egg quality, fertility and hatchability are to be obtained.

EXPERIMENT V

EFFECT OF RESTRICTED WATER CONSUMPTION ON GROWING QUAIL

Chickens as well as many laboratory animals cannot survive very long when deprived of water. Observations in the field concerning the adaptation of Bobwhite quail to water restriction made it essential to determine the effects of increasing regimens of water restriction upon body weight, feed consumption and mortality of Bobwhite quail. From an experimental standpoint, such information might contribute to a better understanding of the quail. It would be especially beneficial if the Bobwhite proves to be a good pilot animal for use in studies, the results of which are to be applied to experiments with chickens and/or turkeys. From a practical standpoint, such information might help in the process of decision-making where Bobwhites are being raised commercially.

Objectives:

1. To determine the average water consumption for growing Bobwhite quail.
2. To determine the effect of water restriction on the growth of quail.
3. To determine the effect of water restriction on livability of growing quail.

EXPERIMENTAL PROCEDURE

A total of 192 one-week-old Bobwhite quail were used in a trial which is herein referred to as a pre-experiment. An equal number of one-week-old Japanese quail were also used for comparison in the trial. Both groups hatched on July 1, 1965. Birds from each species (mixed sex) were divided into the following treatment groups (32 birds each):

1. No drinking water
2. 10 percent drinking water
3. 25 percent drinking water
4. 50 percent drinking water
5. 75 percent drinking water
6. Control (water _ad libitum_)

Birds were brooded in Petersime starter batteries. All birds received feed (dry mash) _ad libitum_ throughout the experimental period (Table 1 - Appendix). Birds were individually weighed at the beginning of the trial (one-week-old), at two weeks of age, four weeks of age, six weeks of age, eight weeks of age, 10 weeks of age and 12 weeks of age. Birds were wing-banded at two weeks of age. Water allowance to restricted groups was based on the previous day's water consumption by the control and was calculated on the basis of numbers of birds. Mortality and water consumption were recorded daily. Average amount of water evaporated was measured daily by using the same kind of waterers used in the trial, under the same experimental conditions, in the absence of the birds. Water loss through evaporation was ignored when water consumption was calculated. Some of the data were treated by the analysis of covariance.

After the beginning of the pre-experiment, another trial was begun. No Coturnix were included. Some experimental groups (0, 10 and 25 percent drinking water) were not included in this trial. The water restriction program started at three weeks of age instead of the one week of age which had been the case in the pre-experiment.

A total of 150 three-week-old Bobwhite quail were used in this experiment. Birds were hatched August 3, 1965. Birds were divided into the following treatment groups (duplicate 30 birds each, mixed sex):

1. 50 percent drinking water
2. 75 percent drinking water
3. Control (water *ad libitum*)

The same procedures used in the pre-experiment were followed. Weekly average feed consumption for each group was also calculated. Birds were wing-banded and weighed at two weeks of age. At three weeks of age, birds were weighed and treatment groups were eliminated to 25 birds in each group instead of 30 birds due to the mortality in this period. Birds were weighed each 14 days up to 11 weeks of age. After birds were weighed at 11 weeks of age, the 50 percent and the 75 percent groups were also given a continuous supply of drinking water and were weighed two weeks later. Although no data was collected after this period, birds were kept up to 16 weeks of age in order to distinguish between the sexes.

RESULTS AND DISCUSSION

1. Average Water And Feed Consumption:

Table 22 shows that the average water consumption of the growing Bobwhite quail was about one-third that of the Coturnix quail in the pre-experiment. While Bobwhite quail consumed an average of 8.5 ml. of water per bird per day in the first week of the trial, Coturnix quail consumed about 27 ml. of water per bird per day. There was a trend of increased water consumption as the birds aged (Figure 4). A marked increase in water consumption by the Coturnix quail was noticed when they started egg production.

Table 23 shows the average water and feed consumption of Bobwhite quail in trial which followed the pre-experiment.

Data concerning feed consumption was available only after birds were five weeks old due to the difficulty in obtaining accurate data before this period. When starting the quail, feed was spread on paper which made it extremely difficult to accurately weigh the remaining feed feces-and-moisture-free. Even when feed was provided in feeders, data were not very accurate in this respect due to the fact that birds billed out certain amounts of feed which could not be measured with a great accuracy. The overall feed consumption was considered to be fairly high for all treatment groups. Feed consumption for the control groups agreed to a great extent with that reported by Nestler *et al.*, (1942) and Nestler (1943). Relatively speaking, the most water restricted group consumed more feed in

TABLE 22.-Average water consumption of control birds (in ml)

Week	Bobwhites Average	Bobwhites Range	Coturnix Average	Coturnix Range	Percent water loss through evaporation Average	Percent water loss through evaporation Range
1st	8.5	6.3 - 13.6	27.0	25.0 - 33.3	11.3	10.2 - 12.4
2nd	12.9	10.6 - 14.0	38.6	33.3 - 48.3	9.8	7.9 - 12.3
3rd	15.0	9.4 - 18.5	37.8	30.1 - 40.7	10.8	9.2 - 12.2
4th	18.7	15.4 - 19.2	37.3	33.3 - 48.1	11.3	9.8 - 13.2
5th	28.2	26.2 - 30.8	52.9[1]	44.4 - 59.3	9.8	7.5 - 11.3
6th	32.9	30.8 - 34.6	65.6	62.9 - 66.7	10.4	8.5 - 12.2
7th	36.2	30.8 - 38.2	70.2	64.2 - 72.4	11.2	9.6 - 12.4
8th	38.0	37.5 - 38.2	73.4	65.6 - 74.8	?	? ?
9th	39.2	38.2 - 41.3	74.2	67.8 - 76.2	?	? ?
10th	35.8	29.9 - 38.2	64.8	63.9 - 65.7	?	? ?
11th	36.2	34.7 - 39.2	70.3	65.4 - 73.2	?	? ?

[1]Coturnix started egg production

TABLE 23.-Average water and feed consumption of control and water-restricted growing Bobwhites

Age of birds	Control: Water ml/bird/day	Control: Feed gm/bird/day	Water/feed ratio: Control	Water/feed ratio: 75% water	Water/feed ratio: 50% water
4-wk-old	13.9	--	--	--	--
5-wk-old	18.6	13.6	1.4	1.5	1.2
6-wk-old	27.9	13.2	2.1	2.3	1.5
7-wk-old	33.4	11.5	2.9	2.8	1.8
8-wk-old	35.8	11.6	3.1	2.9	2.1
9-wk-old	36.2	12.1	3.0	3.1	2.1
10-wk-old	35.8	11.4	3.1	2.9	2.2
11-wk-old	34.9	10.7	3.3	2.9	2.0

comparison to water consumption than did either the control group or the 75 percent group. The water to feed ratio ranged from a high of 3.3 at 11 weeks of age in the control group to a low of 1.2 at five weeks of age in the 50 percent water restriction group. Despite the fact that some of the birds in the restricted group were almost blind, feed consumption in the most restricted group was relatively high.

In growing chickens, the average water:feed ratio was 1.37 for eight-week-old birds which were receiving water and feed *ad libitum* (Kellerup et al., 1965). They found that reducing water intake 20 percent or more had a deleterious effect on feed conversion. Water reduction resulted in a decrease in the water:feed ratio (Kellerup *et al.*, 1965).

Reduction in water:feed ratio was also noted when water intake of Bobwhite quail was decreased in the present experiment. Water to feed ratio also increased as birds became older. This increase in the water to feed ratio was not uniform.

2. Body Weight

Tables 24 and 25 show the effect of water restriction on the body weight of Bobwhites and Coturnix quail, respectively, inthe pre-experiment. Although data concerning the growth rate of the Coturnix quail was subjected to an analysis of covariance, no attempt was made to analyze the data concerning the Bobwhites due to the heavy mortality

TABLE 24.-Effect of water restriction on body weight of the Bobwhites in the pre-experiment

	Control		75% water		50 % water	
Age	Av. body wt. gms.	Av. gain gms.	Av. body wt. gms.	Av. gain gms.	Av. body wt. gms.	Av. gain gms.
1 wk.[1]	8.8	--	9.4	--	9.8	--
2 wk.	15.4	6.6	13.0	3.6	14.3	4.5
4 wk.	43.1	27.7	27.4	14.4	31.1	16.8
6 wk.	86.2	43.1	63.7	36.3	61.0	29.9
8 wk.	120.4	34.2	103.8	40.1	102.8	41.8
10 wk.	155.8	35.4	138.0	34.2	144.8	42.0
12 wk.	170.5	14.7	150.0	12.0	156.3	11.5

[1]Beginning of the experiment.

TABLE 25a.-Effect of water restriction on body weight of Coturnix quail with respect to sex

Treatment	Control		75% water		50% water	
	Male	Female	Male	Female	Male	Female
1 wk. old:						
(Av. body wt., gms.)	(12.3)		(12.3)		(12.4)	
Av. gain	--		--		--	
2 wk. old:						
(Av. body wt., gms.)	30.6	33.1	21.1	22.0	18.8	21.5
Av. gain, gms.						
4 wk. old:						
(Av. body wt., gms.)	74.8	80.9	52.4	54.2	43.7	46.2
Av. gain, gms.	44.2	47.8	31.3	32.2	24.9	24.7
6 wk. old:						
(Av. body wt., gms.)	97.5	118.4	77.1	81.3	64.4	67.7
Av. gain, gms.	22.7	37.5	24.7	27.1	20.7	21.5
8 wk. old:						
(Av. body wt., gms.)	103.3	126.4	91.2	94.6	77.1	82.6
Av. gain, gms.	5.8	8.0	14.1	13.3	12.7	13.9
10 wk. old:						
(Av. body wt., gms.)	105.5	127.5	107.2	118.9	97.3	112.8
Av. gain, gms.	2.2	1.1	16.0	24.3	20.2	30.2
12 wk. old:						
(Av. body wt., gms.)	114.4	135.9	91.4	97.9	102.3	122.0
Av. gain, gms.	8.9	8.4	-15.8	-21.0	5.0	9.2
14 wk. old:[1]						
(Av. body wt., gms-restricted)	--	--	81.6	90.3	78.1	86.6
(Av. body wt., gms-water ad lib)			110.	123.3	110.4	119.8

[1]Half of the birds were given water ad lib. after 12 weeks of age

TABLE 25b.-Effect of water restriction on body weight of Coturnix quail with respect to sex

Treatment	25% water		10% water	
	Male	Female	Male	Female
1 wk. old:				
(Av. body wt., gms.)	(11.9)		(13.4)	
Av. gain	--		--	
2 wk. old:				
(Av. body wt., gms.)	15.6	15.9	12.3	14.3
Av. gain, gms.	(3.9)		(0.5)	
4 wk. old:				
(Av. body wt., gms)	37.7	41.2	30.3	37.7
Av. gain, gms.	22.1	25.3	18.0	23.4
6 wk. old:				
(Av. body wt., gms.)	57.4	51.7	46.5	53.1
Av. gain, gms.	19.7	10.5	16.2	15.4
8 wk. old:				
(Av. body wt., gms.)	73.9	71.5	67.0	71.3
Av. gain, gms.	16.5	19.8	20.5	18.2
10 wk. old:				
(Av. body wt., gms.)	89.4	105.0	86.3	91.8
Av. gain, gms.	15.5	33.5	19.3	20.5
12 wk. old:				
(Av. body wt., gms)	89.4	100.3	79.5	95.0
Av. gain, gms.	0	-4.7	-6.8	3.2
14 wk. old:[1]				
(Av. body wt., gms-restricted)	61.0	104.0	78.3	88.0
(Av. body wt., gms-water *ad lib*)	117.7	130.4	143.0	130.7

[1]Half of the birds were given water *ad lib*. after 12 weeks of age.

among this group of birds. Significant differences were obtained in body weight ($\alpha = 0.01$) when the Coturnix quail were given different amounts of drinking water.

In the trial which followed the pre-experiment, significant differences ($\alpha = 0.01$) were obtained in 11-week body weights of growing Bobwhite quail given different allowances of drinking water from three weeks to 11 weeks of age (Table 26). Although not shown in the Table, the control birds were significantly heavier ($\alpha = 0.01$) than either of the restricted groups at five, seven and nine weeks of age. Growth curves for mixed sexes on the different treatments are shown in Figure 5. Water restriction reduced growth rate in both male Bobwhite quail. After all groups of birds were given a continuous supply of drinking water for a period of two weeks, beginning at 11 weeks of age, no significant differences in body weight of the male birds were obtained at 13 weeks of age. Females did not respond to the continuous supply of drinking water to the same extent as did the males.

The depression in growth rate of water restricted growing Bobwhite quail in this experiment was similar to that reported for chickens by Ross (1960), Kellerup <u>et al</u>. (1965), Bierer <u>et al</u>. (1965) and many others. These results indicate that growing Bobwhite quail must have an adequate supply of water, if best results are to be obtained. These results, on the other hand, disagree with the observation

TABLE 26.-Means of initial weights and the weights of 11- and 13-week-old water restricted Bobwhite quail[1]

Treatment	Mean initial wt. (3-week-old) (grams)		Mean weight at 11-week-old (grams)[2]				Mean weight at 13-week-old (grams)			
			Actual		Adjusted		Actual		Adjusted	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
50% water	25.8	27.5	106.0	110.2	106.2	111.6	160.8	146.0	161.5	146.3
75% water	25.9	27.8	120.8	111.0	121.1	112.1	165.4	140.6	166.0	151.0
Control (water *ad libitum*)	28.5	30.4	159.3	159.5	157.3	157.8	169.9	168.7	169.1	168.1

[1]All groups were given water ad libitum from one to three and from 11- to 13-weeks of age.

[2]Control groups were significantly different from the two other groups (L = 0.01)

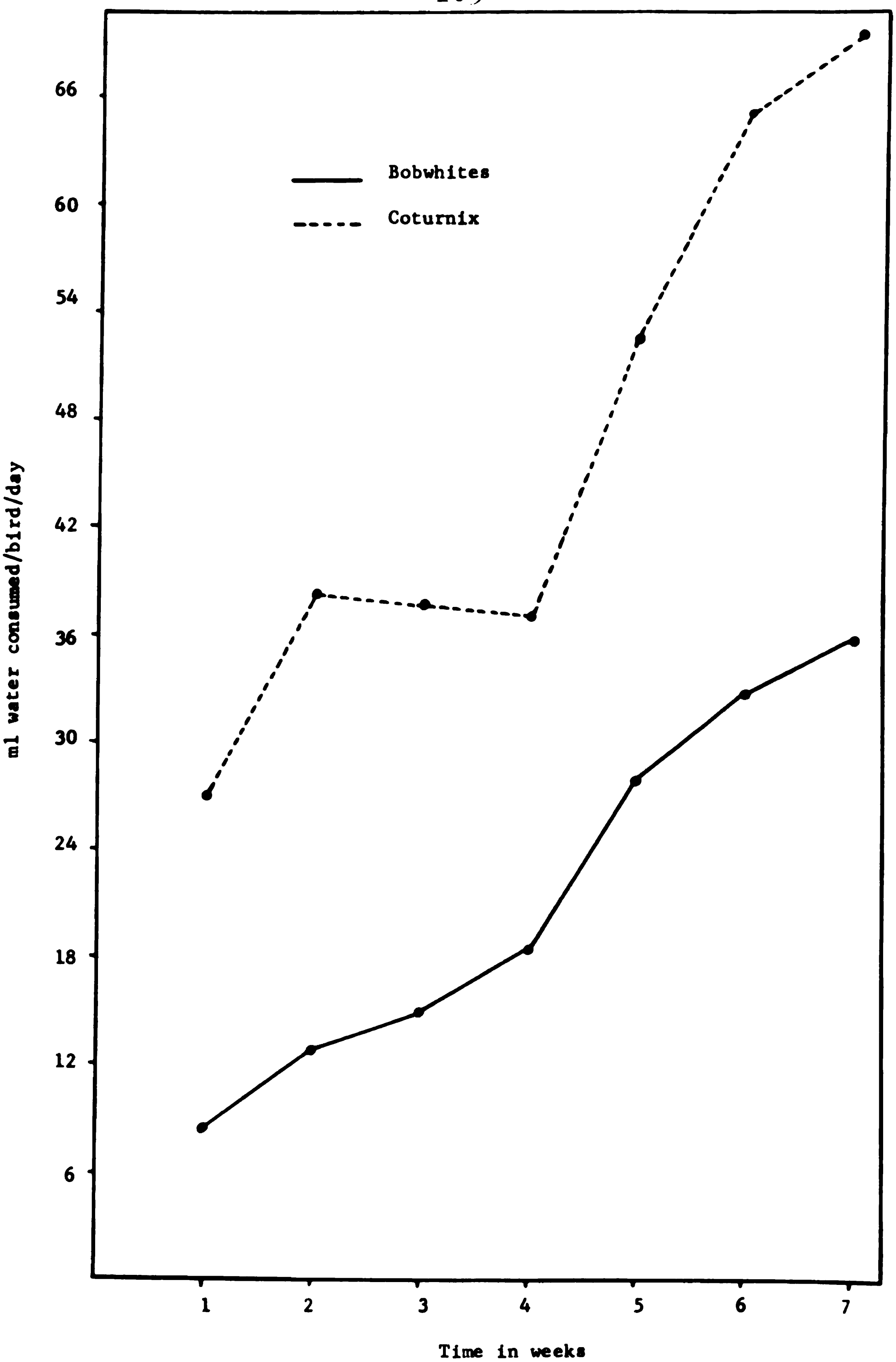

Fig. 4. Average water consumption of control birds (water and feed *ad lib*.)

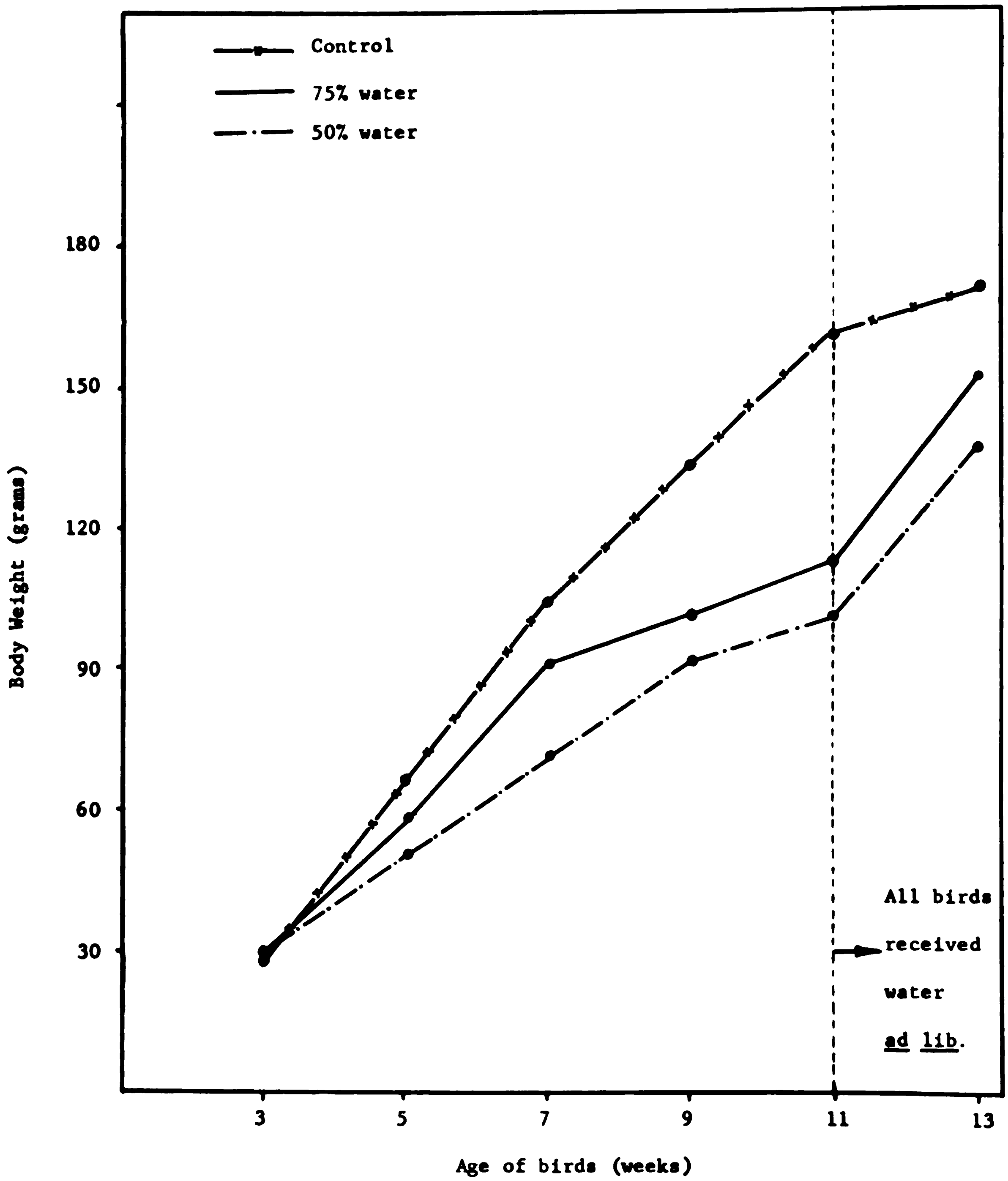

Fig. 5. The effect of water restriction on the body weight of growing Bobwhite quail

of Davidson (1949). In order to remove the conflict between these different results, it should be kept in mind that on ranches where water-containing plants and insects are available, birds might have a better chance to resist water restriction than under the environmental conditions imposed on the birds in this experiment.

3. Onset of Sexual Maturity

Since Coturnix quail reach sexual maturity as early as 39 days of age, data concerning the onset of sexual maturity were collected for the Coturnix in the pre-experiment. Water restriction delayed the age of sexual maturity up to 84 days (Table 27). When one-half of the water restricted birds was given a continuous supply of water beginning at 12 weeks of age, they reached a level of at least 50 percent egg production within three to seven days after the increase in water allowance.

4. Livability

Table 28 shows that in the pre-experiment only two out of 32 birds survived to eight weeks of age when Bobwhite quail chicks received only 75 percent of the amount of drinking water consumed by controls. Since the groups of Bobwhites which received 25 percent, 10 percent and zero percent drinking water started to dehydrate at the beginning of the trial, these treatments had to be discontinued. Although the Coturnix showed better livability in this trial than did the Bobwhites, some birds in the Coturnix groups

TABLE 27.-Effect of water restriction on the age of sexual maturity of the Coturnix in the pre-experiment

Treatment	Earliest age at sexual maturity	Age of birds when reached more than 50% egg production[1] (Water *ad libitum*)
Control	39	45
75% water	59	88
50% water	63	89
25% water	65	92
10% water	84	88

[1]Half of the birds in each of the water restriction groups was given water *ad libitum* beginning at 12-weeks-old. None of the birds remaining on the water restriction regime attained 50 percent egg production during the experimental period.

TABLE 28.-Effect of water restriction on livability of Bobwhite and Coturnix chicks

Treatment	Pre-experiment				Trail which followed pre-experiment	
	Coturnix		Bobwhite		Bobwhite	
	No.	%	No.	%	No.	%
Control (water *ad libitum*)	24	75.0	13	40.6	31	62.0
75% drinking water	20	62.5	2	6.3	27	54.0
50% drinking water	22	68.7	4	12.5	14	28.0

which received 10 to 25 percent drinking water showed extreme dehydration at the beginning of the trial and were removed.

Although birds which received a continuous supply of water in the trial which followed the pre-experiment showed better livability than those given restricted amounts of water (Table 28), mortality among the control group was somewhat high (38 percent). Figure 6 shows that the highest mortality was in the first week of the trial with respect to all treatment groups. Mortality was highest (72 percent) in the birds which were allowed 50 percent of the amount of drinking water consumed by the control. Mortality level in the 75 percent group was intermediate (46 percent).

Better livability was obtained in the experiment where water restriction started at three weeks of age than in the pre-experiment where the restriction started when birds were one week old. In the experiment mortality reached almost zero percent in all treatment groups after birds reached an age of ten weeks old (Fig. 6).

The age at which the restriction starts, the period of the trial and the severity of the restriction are undoubtedly important factors in determining how adverse the results of water restriction will be; however, it may be concluded that, like the chicken and turkey, Bobwhite quail reared in confinement require a continuous supply of drinking water, if best results are to be obtained. Bobwhite quail, like the turkey and chicken, are affected by the restriction of water.

TABLE 29.-Average water and feed consumption of water-restricted adult Bobwhite quail

Treatment	Av. water consumed ml/bird/day	s.d.	Av. feed consumed ml/bird/day	s.d.	Water:feed ratio
Control	29.3	4.6	9.9	0.7	2.9
75% water	--	--	--	--	2.6
50% water	--	--	--	--	2.7

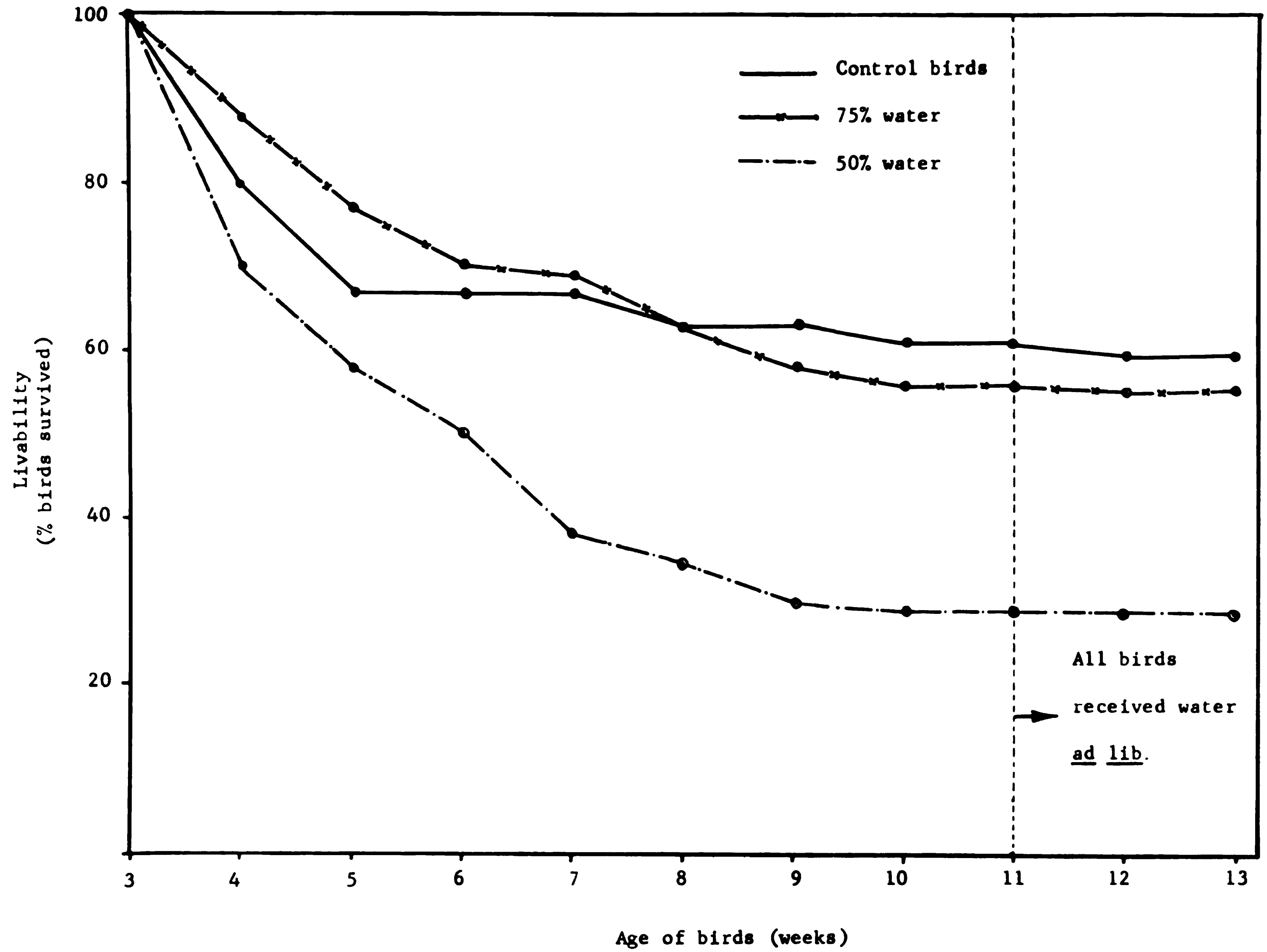

Fig. 6. The influence of water restriction on the livability of growing Bobwhite quail

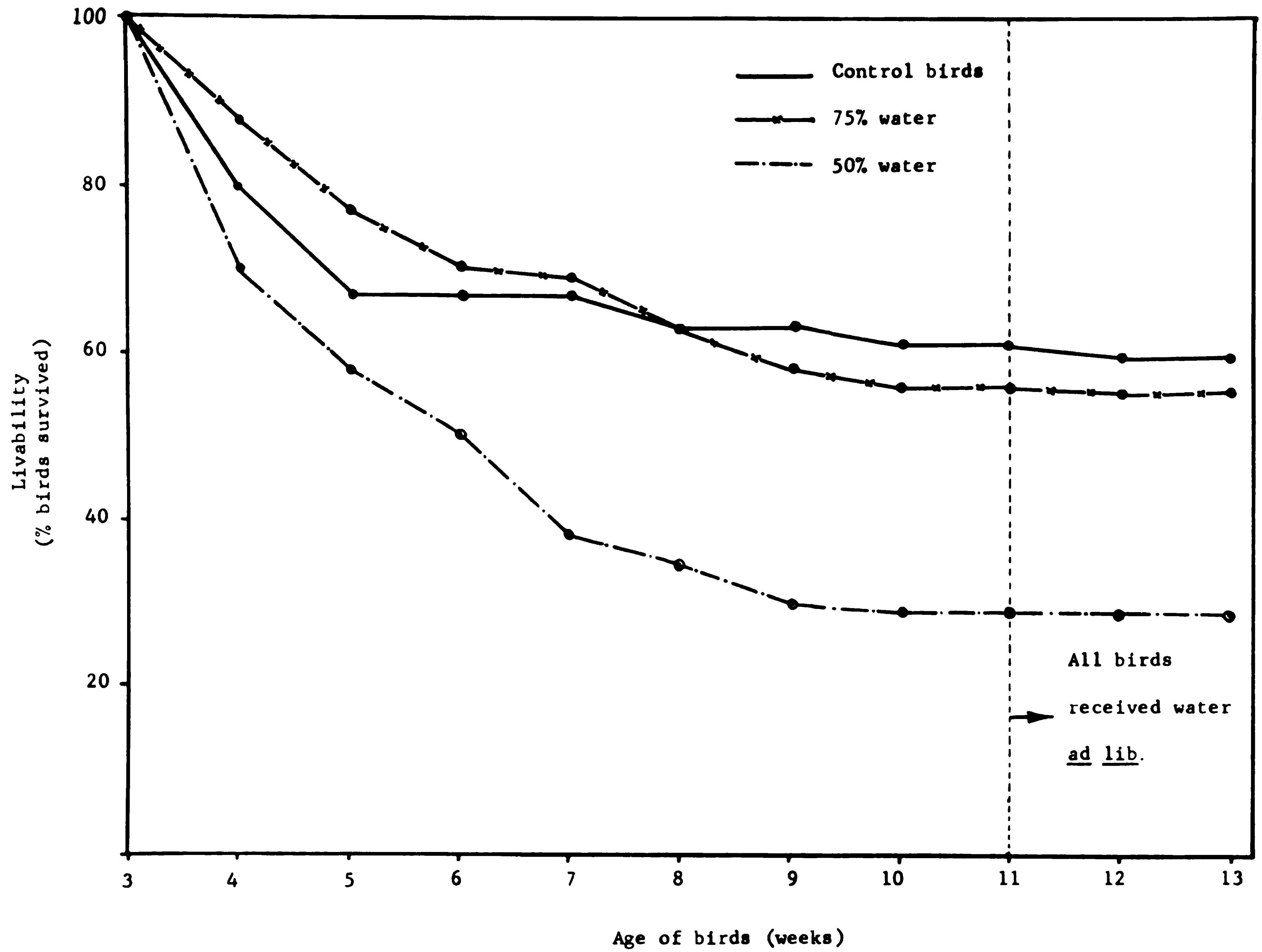

Fig. 6. The influence of water restriction on the livability of growing Bobwhite quail

SUMMARY AND CONCLUSIONS

1. An attempt was made to study the effect of water restriction on the growth and mortality of Bobwhite quail. For comparison, Coturnix quail were also utilized. Birds were given different amounts of drinking water varying from zero percent to 100 percent (continuous supply of water).
2. While growing Bobwhite quail consumed an average of 8.5 ml. of water per bird per day in the first week of the trial, Coturnix quail consumed as much as three times this amount in the same period. There was a trend of increased water consumption as birds aged.
3. Significant differences ($\alpha = 0.01$) in body weight in both growing Coturnix and Bobwhite quail where shown between treatments which received different amounts of drinking water.
4. Water restriction delayed the age of sexual maturity of the Coturnix quail up to 84 days.
5. There were significant differences ($\alpha = 0.01$) with respect tothe mortality of both growing Coturnix and growing Bobwhite quail on the different restricted water regimes.
6. It may be concluded that, like chickens and turkeys, growing Bobwhite and Coturnix quail raised in confinement require an adequate supply of drinking water, if best results are to be obtained.

EXPERIMENT VI

EFFECT OF RESTRICTED WATER CONSUMPTION ON BREEDER BOBWHITE QUAIL

Water restriction has sometimes been practiced by poultrymen as a means for forcing a molt in chickens. It was hypothesized by Nestler and Bailey (1941) that a lapse of 24 hours without food would not appreciably check the laying of Bobwhite quail, but that the same interval without water might cause complete cessation of egg production. No documented report could be located concerning the effect of water restriction on the reproduction and the mortality of laying Bobwhite quail. This study was undertaken to determine the effect of increasing regimes of water restriction upon the body weight, egg production and mortality of breeder Bobwhite quail. From an experimental standpoint, such information might be of value if Bobwhites are to be used as pilot animals in experiments of this type. From a practical standpoint, this information might be of value to quail breeders.

Objectives:

1. To determine the average water and feed consumption of breeder Bobwhite quail.
2. To determine the effect of water restriction on body weight of adult Bobwhites.
3. To determine the effect of water restriction on egg production of sexually mature female Bobwhites.
4. To determine the effect of water restriction on the livability of adult Bobwhite quail.

EXPERIMENTAL PROCEDURE

A total of 132 adult Bobwhite quail were used in this experiment (81 females and 51 males). All female birds were in production at the beginning of the experiment. Birds were divided into the following treatment groups (12 birds in each replicate).

(1) No drinking water (one replicate of 12 males)

(2) Neither water nor feed (one replicate of 12 males)

(3) 50 percent drinking water (three replicates of three males and nine females each)

(4) 75 percent drinking water (three replicates as (3)

(5) Control (continuous supply of water) (three replicates as (3)

Birds were individually weighed and randomized into treatment groups which, in turn, were randomly placed in Petersime starting batteries. Water allowance to restricted groups was based on the previous day's consumption by control birds and was calculated on the basis of number of birds. All birds except the second group received feed (dry mash) *ad libitum* throughout the experimental period. Mortality, water consumption and egg production were recorded daily. After 12 weeks on the treatments birds were again individually weighed. Certain data were subjected to the analysis of covariance.

RESULTS AND DISCUSSION

1. Average Water and Feed Consumption

Table 29 shows that the average water and feed consumption per day by the control birds was, respectively, 29.3 ml. and 9.9 gm. and that the water:feed ratio ranged from a high of 2.9 for the control birds to a low of 2.6 for the 75 percent water group. The most restricted group had a water:feed ratio of 2.7. Less variation was found in water:feed ratios between different treatments in this experiment than had been noted between different treatments in the similar experiment with growing quail (Experiment V). It is possible that the water-restricted groups in the present experiment were given more water in proportion to their maintenance requirements than were the restricted groups in the growing quail. It is an established fact that eggs contain a high percentage of water. It is also possible that, in addition to the water in the egg, the physiological process of egg formation *per se* might increase the water requirement of a bird in production. In the present experiment, the water-restricted groups of birds ceased production shortly after the water restriction regimens began. Many of the females in the control groups continued to lay throughout the experiment. Since water restriction was based on the water consumption of the controls, the amount of water received by the water-restricted groups might have been close to the maintenance requirement of non-laying adult Bobwhite quail. The great increase noted in Experiment V in the water consumption by Coturnix quail as they reached sexual maturity tends to add credence to this conclusion.

2. Body Weights

Birds on water restriction significantly lost weight ($\alpha = 0.01$) when compared with the control (Table 30). Body weight loss was noted in both sexes when birds were given restricted amounts of drinking water. As can be noted in Table 30, birds in the 50 percent water-restriction group lost more weight than did birds in the 75 percent group. Since all birds in both of these groups ceased egg production shortly after restriction commenced, all of the water allowance was available for maintenance requirements; therefore, this result was to be expected. The weight loss by the birds in the water-restricted groups in this experiment agrees with the results of Wilson and Edwards (1955) and Sunde (1962) in chickens.

3. Egg Production

Significant differences in egg production were noted ($\alpha = 0.01$) from birds which were given restricted amounts of drinking water, when compared with production from those birds given a continuous supply of drinking water (Table 31). All females in the restricted group ceased production shortly after restriction began. Although egg production was calculated as egg per bird per day, a statistical analysis ("t" test) was made for the absolute number of eggs

TABLE 30.-Mean of initial and final weight of adult Bobwhite quail given different amounts of drinking water (Length of trial=twelve weeks)

Treatment	Mean of init.wt. (grams)	Mean weight at end of the trial (gms.) Actual	Adjusted	S. E. for adjusted mean
50% water	232.4	219.4	214.2	0.43
75% water	215.7	212.6	223.8	0.42
Control**	233.9	234.9	228.3	0.42

** Significantly lost less weight than other treatments ($\alpha = 0.01$)

TABLE 31.-The influence of water restriction on egg production and livability of Bobwhite quail

Treatment	Egg/bird/day	No. of birds at beginning	Percent Livability
50% water	0.02	33	91.7
75% water	0.12	36	100.0
Control (water *ad lib.*)	0.48**	35	97.2

** Significant at the 0.01 level.

produced. The loss in egg production noted in the water-restricted birds in this experiment agrees with the results of Wilson and Edwards (1955), Sunde (1962) and Bierer *et al.* (1965) in chickens.

4. Livability

No significant differences with respect to mortality were noted between any of the treatment groups (Table 31). As previously mentioned, the water-restriction regimens in this experiment were possibly less drastic than those in the experiments with growing quail, insofar as meeting body maintenance requirements were concerned. This would at least partially explain the much lower mortality experienced in the breeder quail as compared to that in the growing birds. In the present experiment, mortality (8.3 percent) in the 50 percent restricted group occurred only in the last week of the trial. Semi-blind birds were also observed in the last week of the trial in both restricted groups. The two groups of male birds (those deprived of water and those deprived of both water and feed) started to dehydrate at the sixth and the fifth day of the trial, respectively. These two treatment groups were discontinued at that time.

SUMMARY AND CONCLUSIONS

1. A study was made of the influence of water restriction on body weight, livability and egg production of adult Bobwhite quail.
2. Average water consumption of breeder Bobwhite quail was in the neighborhood of 29 ml. per bird per day. The feed to water ratio was 2:9, 2:6 and 2:7 for control, 75 percent and 50 percent groups, respectively.
3. No significant differences in mortality were found when breeder Bobwhite quail received different amounts of drinking water.
4. Significant differences ($\alpha = 0.01$) in body weight loss between the control and the water-restricted groups were noted at the end of the trial.
5. Egg production from birds in all water-restricted groups ceased shortly after restriction began.
6. It may be concluded that, like chickens and turkeys, mature Bobwhite quail require an adequate supply of drinking water, if egg production is to be obtained.

EXPERIMENT VII

CERTAIN FACTORS INFLUENCING FERTILITY AND HATCHABILITY OF BOBWHITE QUAIL

Little is known about the factors which may influence fertility and hatchability of Bobwhite quail. From the reported observations made by some researchers concerning the wide variation between individual Bobwhite quail with respect to fertility and hatchability, it would seem that more studies are needed in this area. Whether Bobwhite quail are considered monogamous birds or polygamous is still questionable. On the other hand, the age at which laying commences is not debatable with respect to its importance. Accumulation of such information should be useful in the process of decision making if best results are to be obtained in fertility and hatchability of the Bobwhite quail. Some of the factors which might influence the fertility and the hatchability of the Bobwhite eggs were investigated.

Objectives:

1. To determine the variation, if any, in fertility and hatchability between individual Bobwhite quail.
2. To determine the effect of single male-flock (pen) mating and multiple male-flock (mass) matings on the fertility and percent hatch of Bobwhite quail.
3. To determine the effect of male to female ratio on the fertility of Bobwhite quail eggs.
4. To determine the age of female Bobwhite quail at sexual maturity.

EXPERIMENTAL PROCEDURE

1. Variation Between Individual Quail

Little, if anything, is known about the variation between individual female Bobwhite quail with respect to fertility and hatchability. This study was undertaken in an attempt to ascertain if variation exists and if so, the scope of this variation. If wide variations exist, it is very possible that selection and breeding for increased fertility and hatchability of Bobwhite eggs would be effective.

Information from incubation of eggs produced by the 92 Bobwhite quail in Experiment I was analyzed in this experiment. Individual records were kept for fertility and hatchability. An attempt was made to compare fertility and hatchability of eggs laid by birds in their first season of production with that of eggs laid by birds in their second season and also with that of eggs laid by birds in their third season of production. Eggs were gathered daily and set in a Jamesway incubator once each week.

2. The Effect of Male to Female Ratio on the Fertility and Hatchability of Quail

Despite the common belief that Bobwhite quail are monogamous, some attempts have been made to utilize single male breeding flocks by some investigator working with Bobwhite quail. The size of the flock has as yet not been well established. This study was undertaken to determine

the optimum number of females per male in both pen and mass matings of Bobwhites.

A total of 348 Bobwhite quail were used in this experiment, 288 of which were in mass matings and 60 in single male matings. Mass mated birds were divided into 6 experimental groups, with four replicates of each, as follows:

1. Two males and 10 females
2. Three males and 9 females
3. Four males and 8 females
4. Five males and 7 females
5. Six males and 6 females
6. Seven males and 5 females

Birds were randomized into Petersime starter-type batteries in the selected male:female ratios. Data were collected for a period of 12 weeks.

The other 60 birds were divided into five experimental groups, with three replicates, each, as follows:

1. One male and 1 female
2. One male and 2 females
3. One male and 3 females
4. One male and 4 females
5. One male and 5 females

Birds were randomly placed in wire cages in the selected male:female ratios. These cages had a sloping floor and ranged from 30 to 25 cm. in height from front to back and were 30 cm. in each length and width. Data were collected for the same 12-week experimental period.

For comparative purposes, a total of 288 Coturnix quail were divided into six experimental groups identical to those of the mass mated Bobwhites. These birds were also randomly placed in Petersime batteries.

Eggs were gathered daily and set in Jamesway incubators once each week. Analysis of covariance was the most common statistical procedure used in analyzing the data collected in this experiment.

3. Age at Sexual Maturity

The age in days at which laying commences is not debatable with respect to its importance. On the other hand, age at which male Bobwhites reach sexual maturity could be of great importance since the primary use of Bobwhite eggs is in the production of Bobwhite chicks. This study was undertaken in an attempt to determine the variation in age, if any, at which both female and male Bobwhite quail reach sexual maturity. Information from this kind of study might be of value in selecting and breeding for this economical character.

Fifty-five (55) pairs of Bobwhite quail were used in this experiment. Each pair was housed in an individual wire cage which had a sloping floor which ranged from 16 to 20 cm. in height from front to back and which was 23 cm. in length and 15 cm. in width. All birds had been reared on continuous light and were continued on this lighting regimen throughout the experiment. Birds were approaching sexual maturity at the beginning of the experiment (112 days old). Sexual maturity of the female Bobwhites was detected by the date of the first egg laid. Sexual maturity of the male was detected by the date of the first fertile egg laid.

RESULTS AND DISCUSSION

1. Variation Between Individual Quail

Average fertility and hatchability for the Bobwhites used in the experiment is shown in Table 32. Individual fertility and hatchability varied considerably. The lowest hatchability for eggs produced by an individual quail was 48.0 percent and the highest was 100 percent.

There was a marked variation in fertility of the Bobwhite eggs. Individual fertility ranged from a high of 100 percent to a low of zero percent. An attempt was made to improve fertility by changing the male in certain of the matings which had shown zero percent fertility. This attempt met with no success.

The results concerning the wide variation in fertility and hatchability of Bobwhite quail eggs agree to a great extent with those observations made by Funk *et al.* (1941). The economic loss resulting from poor fertility and low hatchability in chicken and, especially, turkey breeding flocks is a serious problem. Whatever can be done, therefore, to secure a higher percentage of fertile eggs and a higher percentage of hatchability should be of direct benefit to poultry breeders and hatchery operators. Possibly studies with this species would yield information which could be applied to chickens and/or turkeys.

TABLE 32.-Selected records showing individual variation in fertility and/or hatchability in Bobwhite quail

Bird No.	No. of eggs set	Percent fertility	Percent Hatchability
114	62	100	100
38	32	93.2	100
53	18	88.9	56.3
135	34	73.2	48.0
5	22	59.1	53.8
58	41	34.2	85.7
28	37	11.1	100
151	78	0.0	---
Total of all birds in experiment	1102	35.7	74.7

2. The Effect of Male to Female Radio on the Fertility and Hatchability of Quail

Table 33 shows fertility and the hatchability of the different experiment groups (different male:female ratio groups). Data on fertility is shown graphically in Figures 7 and 8. Single male (pen) mating resulted in higher fertility than did mass mating ($\alpha = 0.01$). Fertility obtained from incubated Coturnix quail eggs in this experiment was higher than that obtained from eggs produced by mass mated Bobwhite ($\alpha = 0.01$). Highest fertility in Bobwhites was obtained when the ratio was one male to one female in single-male matings and six males to six females in mass matings ($\alpha = 0.01$). The six males:six females ratio also resulted in the highest fertility in Coturnix; however, deviations from this ratio did not result in as drastic a reduction in fertility in Coturnix as was experienced in Bobwhites.

Wide variation was noted in hatchability of fertile eggs. Hatch of total eggs set was calculated for all treatments. It is obvious that this parameter is influenced by level of fertility and is rather meaningless from a research standpoint. More meaningful are the differences in hatchability of fertile eggs between the single-male (pen) matings and the multiple-male (mass) matings ($\alpha = 0.01$). These differences can at least partially be attributed to management. Eggs produced by birds in the

TABLE 33.-Effect of male:female ratios on fertility and hatchability of Bobwhite and Coturnix quail eggs

Male:Female Ratio	No. Eggs Set	Fertility (Percent)	Hatchability (Percent)	
			All Eggs	Fertile Eggs
Bobwhites				
Single-male flock				
1:05	113	46.9	32.7	75.5
1:04	108	44.4	38.0	85.4
1:03	76	39.5	31.6	80.0
1:02	58	60.3	41.4	68.6
1:01	42	88.1	73.8	83.8
Multiple-male flock				
2:10	352	45.5	20.2	44.4
3:09	555	53.3	28.6	53.7
4:08	352	48.9	27.3	55.8
5:07	154	49.4	24.7	50.0
6:06	186	80.6	55.4	68.7
7:05	232	50.4	28.9	57.3
Coturnix				
Multiple-male flock				
2:10	595	64.2	40.8	63.6
3:09	462	71.4	45.2	63.3
4:08	502	68.1	38.8	57.0
5:07	512	67.6	39.5	58.4
6:06	456	78.7	41.4	52.6
7:05	384	78.1	50.5	64.7

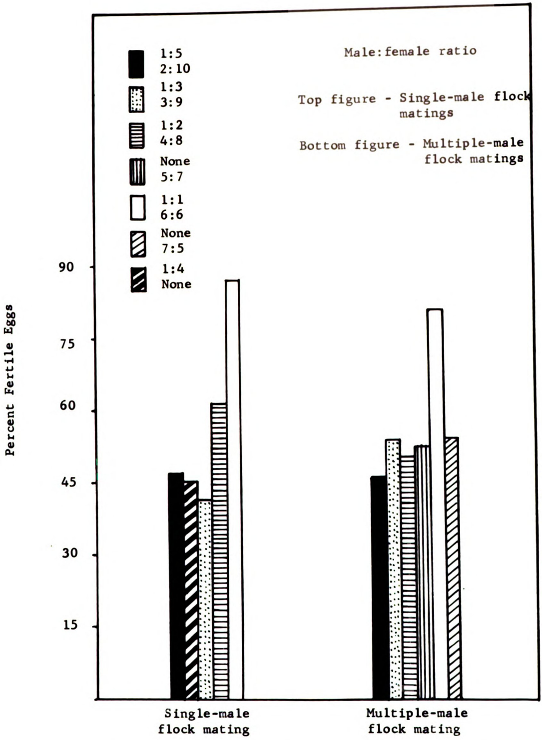

Fig. 7. The influence of different male:female ratios on fertility in single-male flock matings and multiple-male flock matings of Bobwhite quail

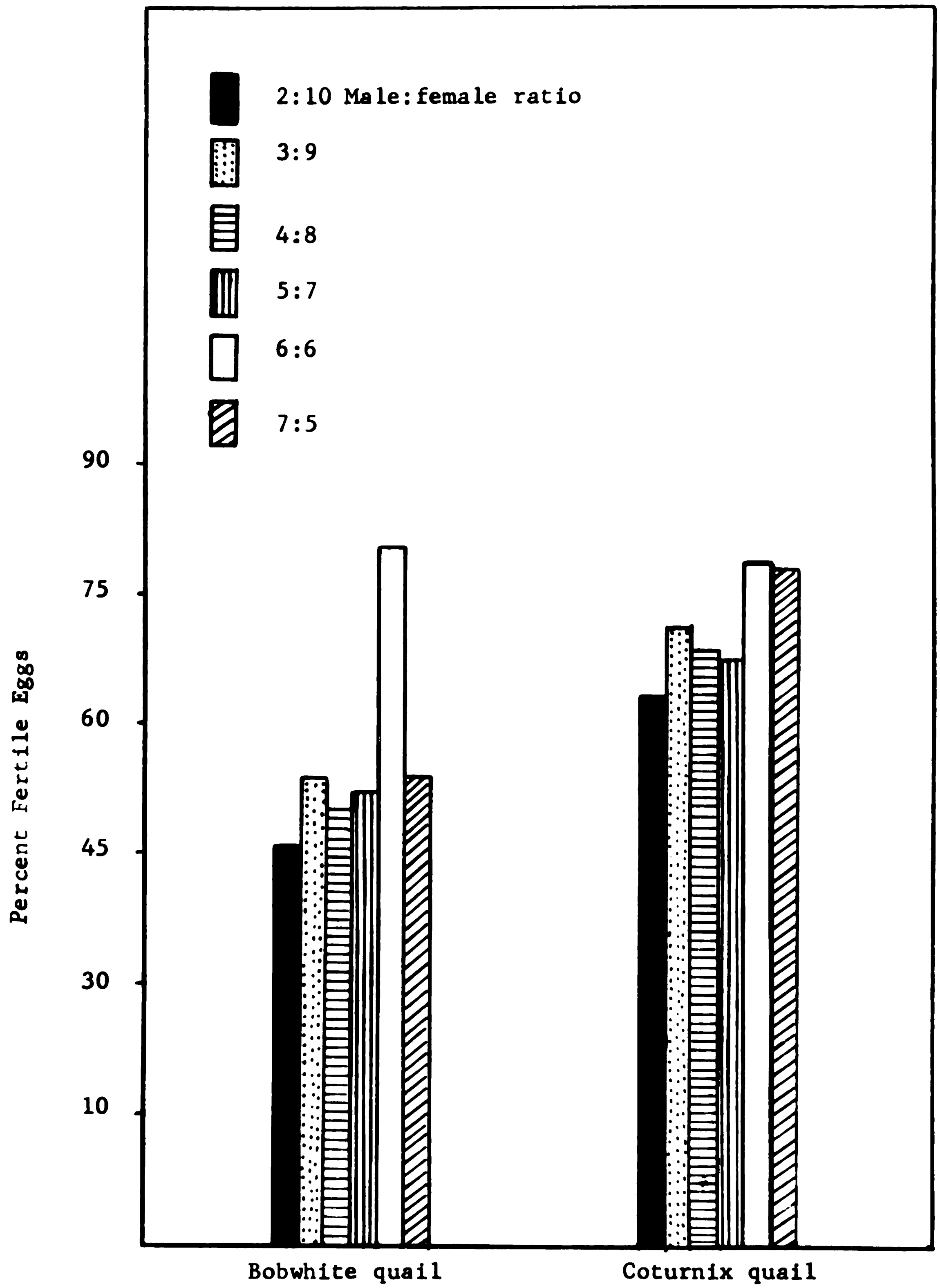

Fig. 8. Comparison between fertility of eggs produced by multiple-male quail flock matings of Bobwhites and Coturnix quail

pen matings were immediately removed from contact with the birds by the act of rolling outside the cage as the cages housing these birds had "roll-away" floors. A portion of the eggs produced by the mass-mated birds were exposed to direct contact with the birds for as much as 24 hours. Although checked eggs were discarded when detected, it is recognized that some eggs with hairline or blind checks probably escaped detection. Eggs showing excessive moisture loss at the termination of the incubation period were also excluded from the data. From personal observation it is known that, depending upon the severity of the check, embryo development in fertile Bobwhite eggs that are checked may progress to varying stages and that, in fact, checked eggs may occasionally hatch. Consequently, some checked eggs not detected before eggs were set were included in the data. No doubt the number of such eggs was greater from the mass matings than from the pen matings. Differences in cleanliness of eggs from the two types of matings could possibly have also been responsible for a portion of the difference in hatchability.

Although Bobwhite quail are monogamous in the wild, where observations made in the field by Stoddard (1931) showed that Bobwhite quail usually pair off, they could be made polygamous in captivity (Stoddar, 1931; Funk _et al_, 1941; and Baldini _et al_., 1952). The results of the present experiment suggest that despite the fact that a male quail can fertilize the eggs of several hens, Bobwhite quail should be mated in a ratio of one male:one female if best results are to be obtained. Some of these results do not agree with those reported by Funk et al. (1941), who stated that fertility was as high in eggs produced by females mated in the ratio of four males to 12 females as it was in eggs from individual matings. In the present experiment, fertility was not increased by mass matings as compared to pen matings. Like chickens and turkeys, the ratio of males to females in Bobwhites and Coturnix quail undoubtedly influences the percentage of fertile eggs produced.

3. Age at Sexual Maturity

Table 34 shows the average age at sexual maturity of both female and male Bobwhite quail in this experiment. Assuming that the date of first fertile egg laid could be an index for determining sexual maturity of the Bobwhite males, it may be stated that the female Bobwhite quail reached the age of sexual maturity earlier than did the males.

Detecting the age at which males reach sexual maturity by means of the first fertile egg laid could be a misleading index. However, none of the eggs produced before the birds were 130 days of age were fertile. No report could be located in the literature which intimated that

TABLE 34.-Age at sexual maturity of female and male Bobwhite quail

Days at sexual maturity	Female		Male[1]	
	No.	%	No.	%
Less than 120	1	1.8	0	0
120-129	3	5.5	0	0
130-139	15	27.3	1	1.8
140-149	22	40.0	9	16.4
150-159	6	10.9	8	14.5
160-169	2	3.6	17	30.9
170-179	1	1.8	5	9.1
Did not reach sexual maturity up to 190 days	5	9.1	15	27.3

[1]Sexual maturity was determined by the first fertile egg laid.

female Bobwhites may possibly reach sexual maturity at an earlier age than do male Bobwhites. More studies are needed in this area.

Female Bobwhite quail were reported to reach sexual maturity at from four to six months of age (Baldini *et al*., 1952; Kirkpatrick, 1955, 1964; and Robinson, 1963).

SUMMARY AND CONCLUSIONS

1. A study was made of the influence of certain factors such as variation between individual quail, the effect of male to female ratio and age at sexual maturity on fertility and, in some cases, hatchability of Bobwhite quail eggs.

2. Studies involving 92 Bobwhite quail shoed that fertility and hatchability of eggs produced by these birds varied considerably. The lowest hatchability of eggs produced by an individual quail was 48.0 percent and the highest was 100 percent. Fertility ranged from a high of 100 percent to a low of zero percent.

3. When 348 Bobwhite quail and 288 Coturnix quail were used to study the effect of male to female ratio on fertility and hatchability, best results were obtained when the male to female ratio was 1:1 whether in mass matings or in single male matings. When calculated as a percentage of all eggs set, hatchability was influenced by the male to female ratio. In Bobwhites, higher fertility was obtained in single male flock matings as compared to multiple male flock matings ($\alpha = 0.01$).

4. Considerable variation in age at which laying began was noted in 55 pairs of Bobwhite quail. None of the eggs produced before the birds were 130 days of age were fertile.

5. Since considerable individual variation was noted in most of the factors studied in this experiment, additional studies to determine the heritabilities of these factors are in order. This information would not only be useful to quail breeders but would also greatly enhance the potential value of the Bobwhite quail as a pilot research animal.
6. That the one to one male to female ratio reportedly employed by most quail reproducers at the present time is the optimum one seems to be borne out by the results of this experiment.

EXPERIMENT VIII

A STUDY OF CERTAIN CHARACTERISTICS OF BOBWHITE QUAIL EGGS

It is evident that egg quality is of great importance. The intact avian egg possesses various external qualities by which it may be identified. Among these attributes are its size and shape. There is considerable variation in these characteristics among the eggs of all birds, both wild and domesticated (Romanoff and Romanoff, 1949). There are many factors which may influence the size of the egg. Some of these factors that were investigated in this experiment with quail eggs were the size of the egg in relation to progressed production, egg size in relation to position of the egg in the cycle and the effect different temperatures on the weight loss of stored eggs.

The total weight of the bird's egg is not always distributed in the same way among the three chief component parts, which are yolk, albumin and shell (with membranes) (Romanoff and Romanoff, 1949). In the present experiment measurements of the proportions of these components in both Bobwhite and Coturnix eggs were also made.

An attempt was made to document facts about Bobwhite quail eggs which would possibly be useful where this species is being used for pilot studies. For purposes of comparison, data concerning Coturnix eggs were collected in certain experiments.

Objectives:

1. To document facts about certain physical characteristics of Bobwhite quail eggs.
2. To determine the influence of progressing egg production on size of eggs produced by Bobwhite quail in the period immediately following sexual maturity.
3. To determine the influence of the position of the egg in a cycle on its size.
4. To determine the loss in weight of Bobwhite and Coturnix eggs stored at different temperatures.
5. To compare the proportion of component parts of Bobwhite and Coturnix eggs.

EXPERIMENTAL PROCEDURE

A. Egg Size

More than 1,000 Bobwhite quail eggs produced by more than 100 females were weighed to the nearest 0.001 gram. From these measurements, the average agg size of the Bobwhite quail used in these experiments was determined. These data were also used for other experimental purposes.

1. The Influence of Progressing Egg Production on Size of Eggs Produced by Bobwhite Quail in the Period Immediately Following Sexual Maturity

Fifty-five (55) female Bobwhite quail which were approaching sexual maturity were used in this part of the experiment. When the birds started production, eggs were gathered and weighed daily to the nearest 0.001 gram for a period of about six months. Individual records were made for each bird. Regression analysis and analysis of co-variance were utilized in statistically analyzing data collected in this particular part of the experiment.

2. The Size of the Egg in Relation to its Position in the Cycle

Thirty-seven (37) mature female Bobwhite quail in their second and third years of egg production were used in this part of the experiment. Individual egg production records for each female were made. Attempts were made to gather the eggs at the same time each day. Eggs were weighed to the nearest 0.001 gram on the same day that they were collected. This was done for a period of approximately eight months. Both actual and relative weights for the eggs were used for statistical analysis. Chi-waure was the most common analysis used in this part of the experiment.

3. The Loss in Weight of Bobwhite and Coturnix Eggs Stored at Different Temperatures

A total of 232 Bobwhite eggs were used for this study. One hundred twenty-eight (128) eggs of the total were stored at room temperature (approximately 70° F.) for a period of 12 weeks. Eggs were weighed to the nearest 0.001 gram seven different times (when fresh and when one, two, three, four, eight and 12 weeks old). The rest of the eggs (104) were stored in a low temperature environment (approximately 35° F.) during the same 12-week period. They were weighed in the same manner as the first group. No attempt was made to control or to measure environmental humidity.

For purposes of comparison, a total of 219 Coturnix eggs were used in this study. While 122 eggs were kept at room temperature, 97 eggs were kept at the low temperature (35° F.) for the same period. Analysis of covariance was the most common statistical analysis utilized in this part of the experiment.

B. Proportions of Component Parts of Bobwhite and Coturnix Eggs

The three chief different component parts of Bobwhite quail eggs are the albumin, the yolk and the shell and its membranes.

A total of 115 Bobwhite quail eggs were used to study the relative proportions of these component parts. For comparative studies, a total of 119 Coturnix quail eggs were treated in the same manner. Simple regression analysis was the most common statistical procedure utilized in this study.

1. The Albumin and Yolk

Since Haugh unit tables are not available for such small size eggs, no attempt was made to measure the albumin height of the quail eggs. Albumin from each egg was weighed individually to the nearest 0.1 gram. A graduate cylinder was used to measure the albumin volume. Albumin was manually separated from the other components of the eggs. Albumin weight and volume were recorded as a proportion of egg weight and egg volume, respectively.

The yolk was separated and measured in the same way as the albumin. No attempt was made to measure the yolk height or the yolk color. The albumin:yolk ratio was calculated for each egg.

2. The Shell and Shell Membranes

The weight of the shell and shell membranes was derived as the product resulting from the addition of the yolk to the albumin and subtracting the total from egg weight. A micrometer was used to measure shell thickness with the shell membranes intact. The membranes were manually removed and the shell thickness was measured again. The difference between the shell thickness with the shell membranes and the shell thickness alone was considered as thickness of the shell membranes. No attempts were made to study the microscopic structure of the shell. In order to study the correlation between shell thickness and the specific gravity of the same eggs, specific gravity of the entire egg was calculated from its weight and the weight of an equal volume of water (as described by Romanoff and Romanoff, 1949). Thus a graduate cylinder was partially filled with distilled water and eggs were dropped gently into the cylinder. The difference between the water level reading on the cylinder scale before and after dropping the egg into the cylinder was considered to be the weight of an equal volume of water. Specific gravity was calculated as:

$$\frac{\text{Weight of the egg}}{\text{Weight of equal volume of distilled water}}$$

Simple correlation analysis was the most common statistical procedure used in this study.

RESULTS AND DISCUSSION

A. Egg Size

Eggs laid by the same bird were by no means uniform in size. Giant eggs, weighing up to 16.894 grams, as well as dwarf eggs weighing as little as 2.897 grams, were observed. Generally speaking, Bobwhite eggs for this particular group of birds weighed an average of approximately ten grams each.

1. The Influence of Progressing Egg Production on Size of Eggs Produced by Bobwhite Quail in the Period Immediately Following Sexual Maturity

Bobwhite quail laid eggs of increasing size until about the fourth week of production (Table 35). Variation in zie of eggs produced by an individual bird also became less as the bird progressed from her initial egg to her fourth or fifth week of production.

Birds were grouped into four categories according to the weight of their initial egg (Table 36). All subsequent eggs produced by an individual bird in a particular category were classified to that particular category. In other words, a bird's category was fixed by initial egg weight and did not change even though subsequent egg size increased as production progressed. An analysis of data that had been classified on the foregoing basis showed that egg size increased at a similar rate regardless of initial egg size. That is, a bird which laid a small first (initial) egg usually continued to lay relatively smaller

TABLE 35.-The correlation between weight of initial eggs laid and the subsequent weight of eggs laid by Bobwhite quail in the period immediately following sexual maturity**

	Initial		2nd week		3rd week		4th week		5th week		6th week		7th week	
	gm	s.d.	gm	s.d.	gm	s.d.	gm	s.d.	gm	s.d.	gm	s.d.	gm	s.d.
Av. egg wt.	8.7	0.87	9.0	0.95	9.3	1.13	9.5	1.14	9.6	1.13	9.6	1.14	9.7	1.08

Simple Correlation	Initial	2nd week	3rd week	4th week	5th week	6th week	7th week
Initial	1.00	0.81	0.78	0.79	0.78	0.80	0.78
2nd wk.		1.00	0.97	0.95	0.95	0.93	0.93
3rd wk.			1.00	0.97	0.96	0.92	0.94
4th wk.				1.00	0.97	0.97	0.97
5th wk.					1.00	0.97	0.95
6th wk.						1.00	0.96
7th wk.							1.00

** All are significant at the 0.01 level.

TABLE 36.-The influence of progressing egg production on the size of eggs produced by Bobwhites in the period immediately following sexual maturity

Range of	Mean weight (gms) and standard error for the adjusted mean of Bobwhite eggs									
	Initial	Second week			Third week			Fourth week		
(Init. egg size)	egg	Actual	Adjusted	S.E.	Actual	Adjusted	S.E.	Actual	Adjusted	S.E.
< 8 grams	7.7	8.1	8.2	0.18	8.3	9.4	0.23	8.5	9.5	0.23
8.0 - 8.9 grams	8.7	9.2	9.2	0.09	9.5	9.5	0.11	9.6	9.5	0.11
9.0 - 9.9 grams	9.5	9.7	9.0	0.18	10.0	9.0	0.23	10.3	9.3	0.23
> 9.9 grams	10.1	10.3	9.2	0.29	10.6	9.0	0.37	10.9	9.2	0.37

Range of	Mean weight (gms) and standard error for the adjusted mean of Bobwhite eggs								
	Fifth week			Sixth week			Seventh week		
(Init. egg size)	Actual	Adjusted	S.E.	Actual	Adjusted	S.E.	Actual	Adjusted	S.E.
< 8 grams	8.6	9.6	0.23	8.6	9.6	0.23	8.8	9.8	0.22
8.0 - 8.9 grams	9.8	9.7	0.11	9.7	9.7	0.11	9.7	9.7	0.11
9.0 - 9.9 grams	10.3	9.4	0.23	10.5	9.6	0.23	10.5	9.6	0.22
> 9.9 grams	11.1	9.6	0.37	11.2	9.7	0.37	11.2	9.8	0.36

eggs than did birds which laid a large first (initial) egg. This not only held true as egg size increased during the first few weeks of egg production but also remained evident as egg size plateaued between the fifth and seventh weeks of production. Table 35 shows that high correlations existed between weights of initial eggs and weights of subsequent eggs produced by the birds in this experiment ($\alpha = 0.01$).

Comparatively speaking, the results in this experiment agree to a great extent with the observation made by Funk *et al.* (1941) that Bobwhites raised in captivity laid eggs of increasing size until approximately the fifth week of production after which less variation in egg size was noted.

2. The Size of the Egg in Relation to its Position in the Cycle

Figure 9 shows the relationship between the size of eggs produced by Bobwhite quail and their position in the cycle. From this figure and Tables 37 - 40, it seems that Bobwhite quail do not follow a definite pattern with respect to the size of the eggs they produced in relation to their position in the cycle. In chickens, there is a general tendency for the first egg of the cycle to be the heaviest, and for the succeeding eggs to decrease gradually in size. However, the weight of the successive eggs may not decrease with perfect regularity and often the last egg is somewhat heavier than the egg immediately preceding it. In long cycles, the decline in weight is less rapid than in short cycles (Bennion and Warren, 1933 and many others). In the case of the eggs produced by

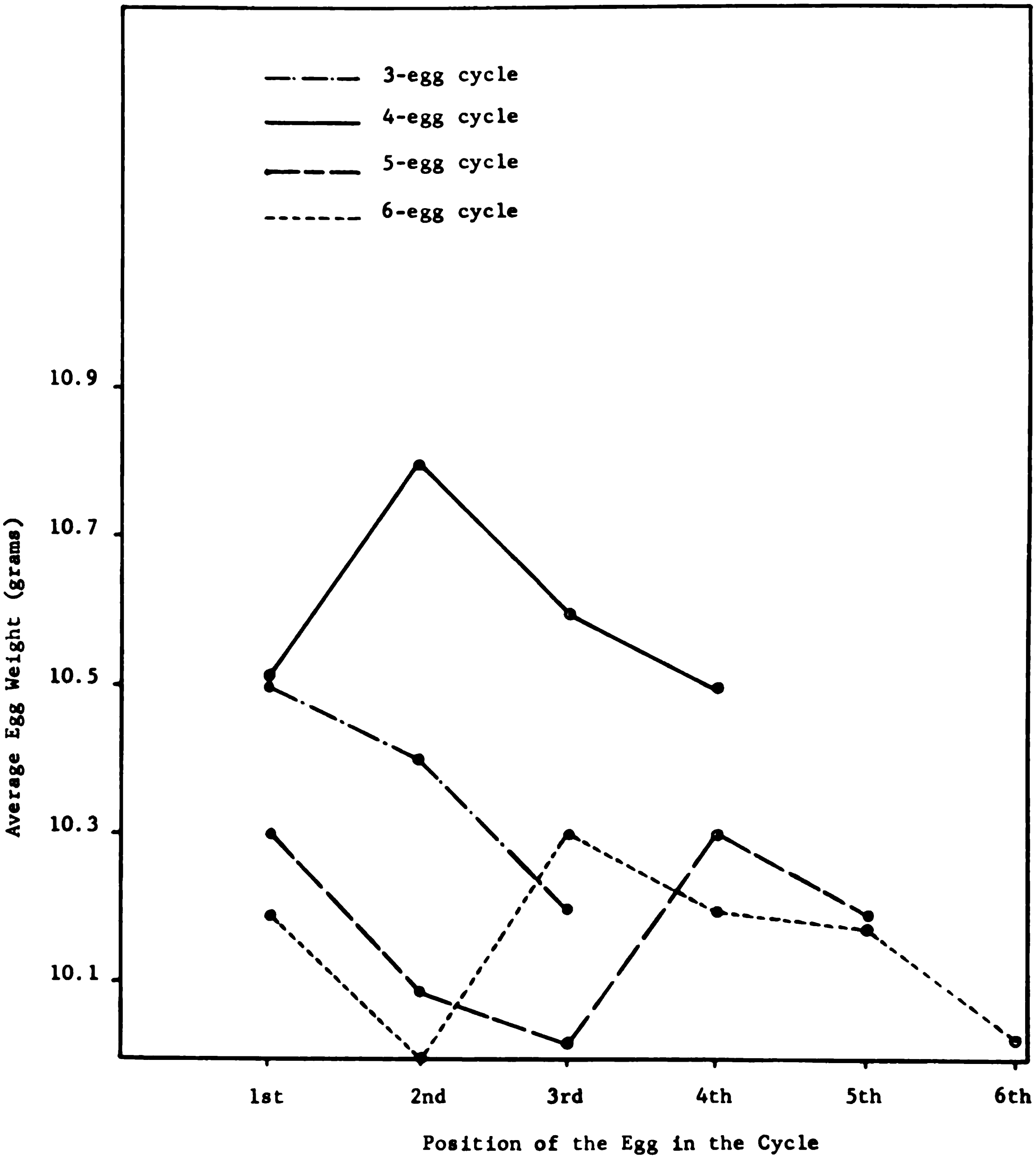

Fig. 9. The average size of Bobwhite eggs in relation to their position in the cycle

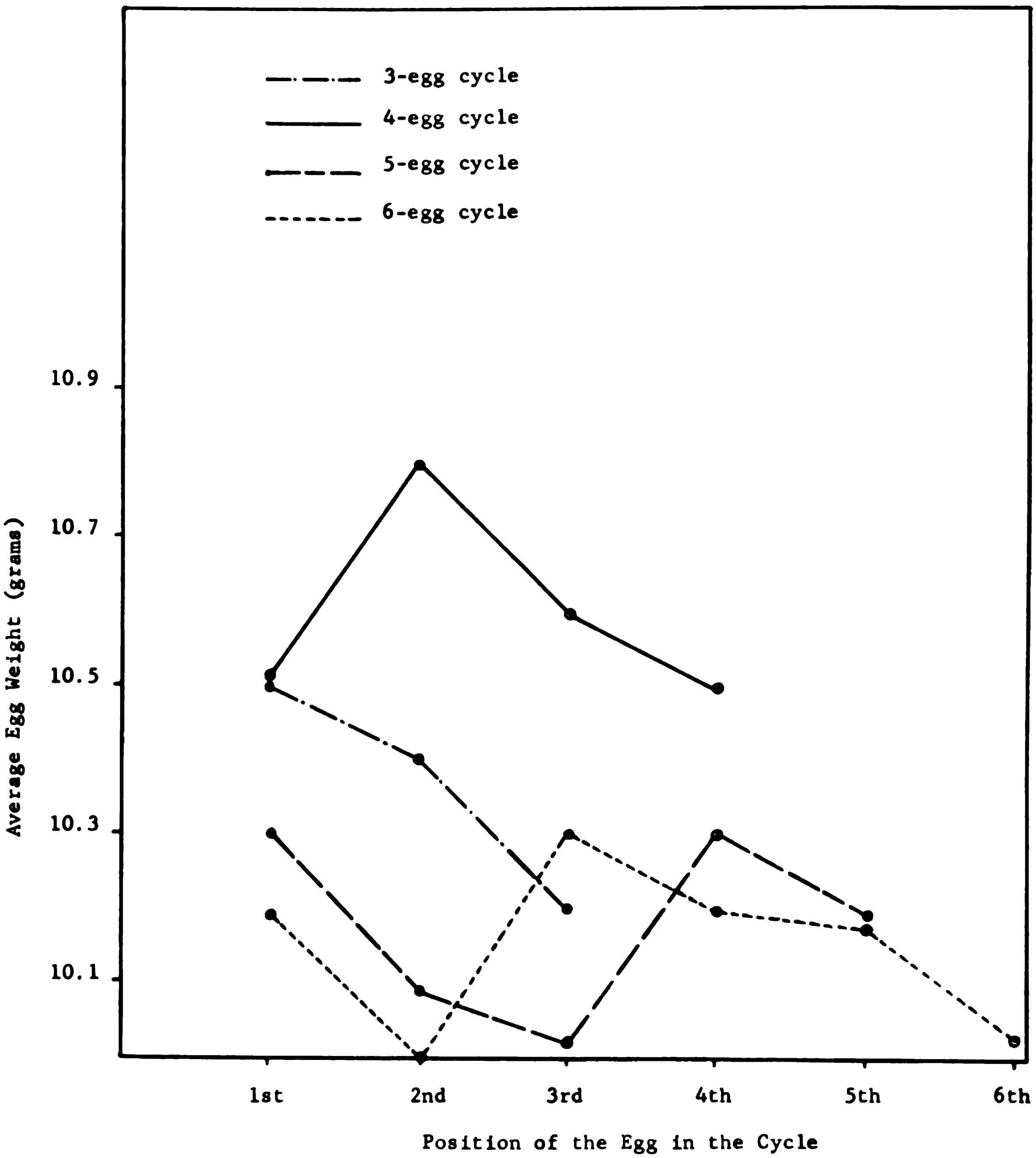

Fig. 9. The average size of Bobwhite eggs in relation to their position in the cycle

TABLE 37.-Mean weights of and the interrelationship between, eggs of three-egg cycle[1] of the Bobwhite quail

	Mean weight (grams) and standard deviation					
	First Egg in the cycle		Second Egg in the cycle		Third Egg in the cycle	
	grams	s.d.	grams	s.d.	grams	s.d.
	10.5	0.97	10.4	0.84	10.2	0.89

Simple Correlation	First Egg	Second Egg	Third Egg
First egg	1.00	0.91**	0.87**
Second egg		1.00	0.92**
Third egg			1.00

1 N = 45

** Significant at the 0.01 level.

TABLE 38.-Mean weights of, and the interrelationship between, eggs of a four-egg cycle[1] of the Bobwhite quail

	Mean weight (grams) and standard deviation							
	First egg in the cycle		Second egg in the cycle		Third egg in the cycle		Fourth egg in the cycle	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	10.5	1.02	10.8	0.82	10.6	0.75	10.5	0.92

Simple Correlation	First Egg	Second Egg	Third Egg	Fourth Egg
First egg	1.00	0.92**	0.79**	0.86**
Second egg		1.00	0.85**	0.86**
Third egg			1.00	0.94**
Fourth egg				1.00

1 N = 32

** Significant at the 0.01 level.

TABLE 39.-Mean weights of, and the interrelationship between, eggs of a five-egg cycle[1] of the Bobwhite quail

	Mean weight (grams) and standard deviation									
	First egg in the cycle		Second egg in the cycle		Third egg in the cycle		Fourth egg in the cycle		Fifth egg in the cycle	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	10.3	0.78	10.1	0.46	10.0	0.34	10.3	0.53	10.2	0.59

Simple Correlation	First egg	Second egg	Third egg	Fourth egg	Fifth egg
First egg	1.00	0.69**	0.84**	0.53	0.70**
Second egg		1.00	0.51	0.85**	0.68**
Third egg			1.00	0.45	0.55
Fourth egg				1.00	0.79**
Fifth egg					1.00

[1] N = 9
** Significant at the 0.01 level.

TABLE 40.-Mean weights of, and the interrelationship between, eggs of a six-egg cycle[1] of the Bobwhite quail

	Mean weight (grams) and standard deviation											
	First egg in the cycle		Second egg in the cycle		Third egg in the cycle		Fourth egg in the cycle		Fifth egg in the cycle		Sixth egg in the cycle	
	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.	grams	s.d.
	10.2	0.57	10.0	0.89	10.3	0.37	10.2	0.39	10.2	0.31	10.1	0.40

Simple Correlation	First egg	Second egg	Third egg	Fourth egg	Fifth egg	Sixth egg
First egg	1.00	0.93**	0.77*	0.73**	0.95**	0.92**
Second egg		1.00	0.53	0.70**	0.84**	0.95**
Third egg			1.00	0.71**	0.73**	0.48**
Fourth egg				1.00	0.61**	0.48**
Fifth egg					1.00	0.87**
Sixth egg						1.00

[1] N = 6

** Significant at the 0.01 level.

Bobwhite quail in the present experiment, the three egg cycle, in general, followed the same pattern reported for chicken eggs in that the first egg in the cycle was usually the heaviest and the third egg was the smallest. In a two-egg cycle where more than 50 cycles were tested, no definite pattern could be established. In approximately one-half of these cycles, the second egg was the larger of the two. In four-egg cycles, the general tendency was for the second egg of the cycle to be the largest of the cycle whereas, the last egg was usually the smallest and the first was usually larger than the third egg. Based on averages of the nine five-egg cycles observed, the first and fourth eggs were of the same size and were the largest eggs in the cycle; whereas, the third egg was the smallest. The last egg of the cycle was larger than the second. Likewise, on the basis of averages of the six six-egg cycles on which data was collected, the third egg of the cycle was the largest; whereas the second was the smallest. The sixth egg of the cycle was slightly larger than the second; while the first, fourth and fifth eggs were approximately the size and slightly larger than the sixth egg. As cycle size increased, tendency toward definite patterns became less distinct. The small number of the long cycles (more than six eggs in the cycle), made it impossible to draw any conclusion about the pattern of these cycles.

The size of cycles observed in this experiment suggests that Bobwhite, in their second and third years of lay, tend to produce in cycles of one, two, three or four eggs.

3. The Loss in Weight of Bobwhite and Coturnix Eggs Stored at Different Temperatures

Eggs stored for 12 weeks at room temperature (approximately 70° F.) lost significantly more weight ($\alpha = 0.01$) than those stored at a lower temperature (approximately 35° F.) (Table 41). This held true for both Bobwhite and Coturnix eggs. There were no significant weight loss differences between Bobwhite and Coturnix eggs within treatments. Information concerning storage of quail eggs at different temperatures could not be found in the literature. Jaap et al. (1954) reported an "evaporation loss" ranging from an average of 6.4 to 8.9 percent when infertile chicken eggs were incubated for 14 days. In the present experiment, the average weight loss of both Bobwhite and Coturnix eggs after two weeks storage at room temperature was 6.9 percent; whereas at the lower temperature it was 1.0 percent and 1.4 percent, respectively, for Bobwhite and Coturnix eggs.

It should be kept in mind that in addition to temperature and time, which were the only variables investigated in the present experiment, factors such as humidity, air movement and barometric pressure may affect water loss from eggs (Romanoff and Romanoff, 1949).

TABLE 41.-The effect of storage temperature on quail egg weight loss

Storage temperature	Storage period	Mean weight of eggs (grams) and standard error of adjusted mean: Bobwhite eggs, Actual	Bobwhite eggs, Adjusted	Bobwhite eggs, S.E.	Coturnix eggs, Actual	Coturnix eggs, Adjusted	Coturnix eggs, S.E.
Room Temperature (approx. 70° F.)	Fresh eggs	10.1	---	---	10.2	---	---
	One week	9.7	9.8	0.01	9.8	9.8	0.01
	Two weeks	9.4	9.5	0.02	9.5	9.5	0.02
	Three weeks	9.1	9.2	0.02	9.2	9.1	0.02
	Four weeks	8.7	8.8	0.02	8.8	8.8	0.03
	Eight weeks	7.6	7.6	0.04	7.7	7.6	0.04
	Twelve weeks	6.0	6.1	0.55	7.2	7.1	0.57
Low Temperature (approx. 35° F.)	Fresh eggs	10.3	---	---	10.3	---	---
	One week	10.2	10.2	0.00	10.2	10.2	0.00
	Two weeks	10.2	10.1	0.00	10.1	10.1	0.01
	Three weeks	10.1	10.0	0.01	10.0	10.0	0.01
	Four weeks	9.9	9.9	0.01	9.9	9.9	0.01
	Eight weeks	9.7	9.7	0.03	9.7	9.7	0.03
	Twelve weeks	9.4	9.4	0.02	9.3	9.3	0.02

The major objective of this study was to compare weight loss of Bobwhite and Coturnix eggs stored in the same environment; therefore, it is felt that this objective was accomplished.

B. Proportion of Component Parts of Bobwhite and Coturnix Eggs

1. The Albumen and Yolk

Table 42 shows the average proportions that the albumen and the yolk contribute to the total weight of Bobwhite and Coturnix eggs. In this experiment, on the average, about 41 percent of the weight of a Bobwhite egg was albumen and about 40 percent was yolk; whereas, the albumen contributed about 47 percent and the yolk about 32 percent on the average, of Coturnix quail eggs. Thus it is obvious that the albumen:yolk ratio of Bobwhite eggs (approximately 1:1) differed from that of Coturnix eggs (approximately 1.5:1) in this experiment. There was a negative correlation between yolk weight and albumen to yolk ratio in eggs produced by both species. Table 43 shows the proportion of albumen and yolk volume in relation to egg volume for Bobwhite eggs and Coturnix eggs, respectively. In eggs of both species the albumen:yolk ratio computed on the basis of volume was essentially the same as that which had been computed on the basis of weight. A statistical analysis of the data showed that there was a significant negative correlation ($\alpha = 0.01$) between yolk volume and albumen to yolk ratio in eggs produced by both species.

TABLE 42.-The interrelationship between egg weight, albumen weight and yolk weight of eggs produced by Bobwhite and Coturnix quail

Bobwhite	Av. egg weight		Av. albumen weight		Av. yolk weight		Av. alb/yolk weight ratio	
	grams	s.d.	% of egg weight	s.d.	% of egg weight	s.d.		s.d.
	10.4	0.82	40.8	1.43	39.8	1.66	1.0	0.03

Simple Correlations	Egg weight	Albumen weight	Yolk weight	Alb/yolk weight
Egg weight	1.00	0.13	0.09	0.04
Albumen weight		1.00	0.77**	0.10
Yolk weight			1.00	-0.56**
Alb/yolk ratio				1.00

Coturnix	Av. egg weight		Av. albumen weight		Av. yolk weight		Av. alb/yolk weight ratio	
	grams	s.d.	% of egg weight	s.d.	% of egg weight	s.d.		s.d.
	10.0	0.95	47.4	1.56	31.9	1.10	1.5	0.07

Simple Correlations	Egg weight	Albumen weight	Yolk weight	Alb/yolk weight
Egg weight	1.00	-0.04	-0.16	0.10
Albumen weight		1.00	0.19	0.62**
Yolk weight			1.00	-0.65**
Alb/yolk ratio				1.00

** Significant at the 0.01 level.

TABLE 43.-The interrelationship between egg volume, albumen volume and yolk volume of eggs produced by Bobwhite and Coturnix quail

Bobwhite	Av. egg volume		Av. albumen volume		Av. yolk volume		Av. alb/yolk/volume ratio	
	ml	s.d.	% of egg volume	s.d.	% of egg volume	s.d.		s.d.
	9.5	0.83	40.9	1.32	39.9	1.57	1.0	0.03

Simple Correlations	Egg volume	Albumen volume	Yolk volume	Alb/yolk ratio
Egg volume	1.00	0.17	0.11	0.44
Albumen volume		1.00	0.76**	0.08
Yolk volume			1.00	-0.59**
Alb/yolk ratio				1.00

Coturnix	Av. egg volume		Av. albumen volume		Av. yolk volume		Av. alb/yolk/volume ratio	
	ml	s.d.	% of egg volume	s.d.	% of egg volume	s.d.		s.d.
	7.5	0.90	47.5	1.80	31.8	1.30	1.5	0.10

Simple Correlation	Egg volume	Albumen volume	Yolk volume	Alb/yolk ratio
Egg volume	1.00	0.02	-0.13	?
Albumen volume		1.00	0.17	0.57**
Yolk volume			1.00	-0.51**
Alb/yolk ratio				1.00

** Significant at the 0.01 level.

Compared to chicken eggs, which have been reported to consist, on the average, of 32 percent yolk and 56 percent albumen, by weight (Romanoff and Romanoff, 1949), both the Coturnix and Bobwhite eggs in the present experiment consisted of a lower proportion of albumen to yolk.

2. The Shell and Shell Membranes

Table 44 shows the shell thickness, shell membrane thickness and specific gravity for Bobwhite and Coturnix eggs. While the shells of Coturnix quail eggs in this experiment were significantly thicker than those of the Bobwhites ($\alpha = 0.01$), shell membranes of the Bobwhite eggs were significantly thicker than those of the Coturnix ($\alpha = 0.01$). The shell thickness of the Coturnix eggs was in the neighborhood of 0.197 mm. compared to 0.173 mm. for those of the Bobwhites. Shell membranes of the Bobwhite eggs averaged 0.067 mm., whereas those of Coturnix eggs averaged about 0.063 mm. Shell weight accounted for 19.4 percent and 20.7 percent of total weight of Bobwhite and Coturnix eggs, respectively. There was a high correlation between shell thickness and the specific gravity of eggs produced by both species ($\alpha = 0.01$). Average specific gravity computed from data in this experiment was 1.09 for the eggs of both Bobwhite and Coturnix quail.

Comparatively speaking, the thickness of the shell of the chicken egg and quail egg was reported to average

TABLE 44.-The interrelationship between shell thickness and specific gravity of Bobwhite and Coturnix egg

Bobwhite	Av. egg weight		Av. shell thickness		Av. shell membrane thickness		Av. specific gravity	
	grams	s.d.	mm	s.d.	mm	s.d.		s.d.
	10.4	0.80	0.173	0.02	0.067	0.00	1.09	0.04

Simple Correlation	Egg weight	Shell thickness	Specific gravity
Egg weight	1.00	-0.01	-0.06
Shell thickness		1.00	0.81**
Specific gravity			1.00

Coturnix	Av. egg weight		Av. shell thickness		Av. shell membrane thickness		Av. specific gravity	
	grams	s.d.	mm	s.d.	mm	s.d.		s.d.
	10.0	1.00	0.197	0.01	.063	0.00	1.09	0.04

Simple Correlation	Egg weight	Shell thickness	Specific gravity
Egg weight	1.00	0.01	0.02
Shell thickness		1.00	0.87**
Specific gravity			1.00

** Significant at the 0.01 level.

approximately 0.31 and 0.13 mm., respectively (Romanoff and Romanoff, 1949). Thickness of shell membranes of quail eggs was also reported by the same authors to be approximately 0.067 mm.; 0.06 mm. for the outer membrane and 0.008 for the inner membrane; whereas average thickness of the shell membranes of chicken eggs was reported to be 0.065 mm. The kind of quail was not indicated by Romanoff and Romanoff. The high correlation between shell thickness for both Bobwhite and Coturnix eggs and specific gravity in the present experiment agreed to a great extent with that reported in the literature for the chicken egg (Romanoff and Romanoff, 1949).

Results from the present experiment, together with data from Romanoff and Romanoff (1949), indicated that while the shell of the chicken egg is roughly twice as thick as that of either the Bobwhite or the Coturnix egg, shell membranes of eggs produced by all three of these species are approximately equal in thickness.

From personal observation, it is known that Bobwhite eggs dropped onto a concrete floor from a height of four feet will usually not splatter. The outer shell will be crushed but the shell membranes will generally not be damaged to such an extent that leakage occurs. This is not the result obtained when either a chicken egg or a Coturnix egg is treated in this manner. Almost without exception the membranes, as well as the shell, are damaged to such an extent that leakage (and usually splattering) occurs. In the case of chicken eggs, the greater mass, as compared to eggs of the two quail species, would be a contributing factor. Since it has been shown in the present experiment that the shell membranes of the Coturnix egg are thinner than those of the Bobwhite egg, it seems logical to conclude that this factor at least partially accounts for the different results when eggs of the two species are dropped.

The results of the experiment involving weight loss in Bobwhite and Coturnix eggs stored at room temperature, coupled with the information concerning thickness of shell and shell membranes of eggs laid by these two species, leads to the conclusion that both the shell and shell membranes act as barriers to loss of moisture from the egg as the thinner shell of the Bobwhite egg coupled with the thicker shell membranes was as effective in preventing this loss as was the thicker shell and thinner shell membranes, comparatively speaking, of the Coturnix egg.

SUMMARY AND CONCLUSIONS

1. An attempt was made to compile information concerning certain characteristics of Bobwhite eggs to add to the small amount of information presently in the literature. In some cases information was gathered on Coturnix eggs for comparative purposes. The increase in size of Bobwhite eggs as laying progressed at the beginning of production, the size of the egg in relation to its position in the cycle, and the effect of storing Bobwhite eggs and Coturnix eggs at room temperature (approximately 70° F.) and low temperature (approximately 35° F.) on the weight of the egg, were studied. A study was made to determine the proportions of component parts of Bobwhite and Coturnix quail eggs.
2. Eggs laid by the same bird in this experiment were by no means uniform in size. Giant eggs, weighing up to 16.894 grams, as well as dwarf eggs, weighing as little as 2.897 grams, were observed.
3. In the period immediately following sexual maturity, the Bobwhite quail in this experiment, laid eggs of increasing size until approximately the fourth week of production. Variation in egg size became less as birds progressed in egg production. Egg size plateaued between the fifth and seventh weeks of production. A high correlation was found between

weight of initial egg and weights of subsequent eggs produced by the same bird.

4. The size of Bobwhite eggs in relation to their position in the cycle did not follow as definite a pattern as had been reported in chickens, especially for the longer cycles; however, the three egg cycle of the quail in this experiment, in general, followed the same pattern reported for the three egg cycle in chickens.
5. No significant differences could be demonstrated between egg weight loss of Bobwhite and Coturnix eggs stored at the same temperatures.
6. While the albumen of the Coturnix eggs in this experment contributed, on the average, 47 percent of the egg weight and the yolk contributed 32 percent of the egg weight; Bobwhite eggs contained, by weight, on the average, 41 percent albumen and 40 percent yolk. The shells of Coturnix eggs, which averaged 0.197 mm. thick, were significantly thicker than those of Bobwhite eggs, which averaged 0.173 mm. On the other hand, shell membranes of Bobwhite eggs, which averaged 0.067 mm. in thickness, were significantly thicker than those of Coturnix eggs which averaged 0.063 mm.
7. It may be concluded that Bobwhite eggs vary somewhat from Coturnix eggs with respect to the proportion of component parts and that eggs of both of these species vary from chicken eggs in this respect.

GENERAL SUMMARY AND CONCLUSIONS

1. Several experiments were undertaken in an attempt to accumulate information concerning the effect of certain management practices such as the influence of floor space, the effect of restricted water consumption and the effect of male to female ratio, on growth and/or reproduction of Bobwhite quail. In addition, the relationships between dam weight, egg weights and one-day-old chick weights, as well as between body weight at hatching time and subsequent growth, were studied. Observations concerning certain variations between individual quail, including fertility, hatchability and age at sexual maturity were made. For comparative purposes, Coturnix quail were used in certain experiments. Observations were also made on certain physical properties of Bobwhite and Coturnix eggs.

2. There was a significant correlation ($\alpha = 0.01$) between body weight and egg weight on one hand (0.36) and between egg weight and the weight of Bobwhite chicks at hatching time (0.84) on the other hand. Although the correlation between the first two variables was much influenced by the age of the female breeder birds, the correlation between the second two variables was not influenced by the age of the female parent.

When hatching eggs were grouped on the basis of their weight, average weight of chick hatched as a percentage of egg weight ranged from a high of 66.2 percent to a low of 51.1 percent. Relatively speaking, the smaller the Bobwhite egg, the smaller was the chick weight as a percentage of egg weight. Possibly the smaller chicks hatched earlier and had dehydrated more than had the larger chicks.

There was a high correlation (0.7) between body weight of the Bobwhites at hatching time and at two weeks of age ($\alpha = 0.01$). There was also a significant correlation ($\alpha = 0.01$) between the weight of Bobwhite chicks at hatching time and their weight at 16 weeks of age for both sexes. High correlations were also noted between body weight at 10 weeks of age and subsequent growth of the bird. The same correlation held true with respect to both sexes.

Although the growth rate tended to decline after 12 to 14 weeks of age, the Bobwhites did gain weight at least up to 18 weeks of age. Female Bobwhites gained more weight than did the males ($\alpha = 0.01$).

3. No significant reduction in growth occurred as a result of crowding under three different allowances of floor space (0.24 sq. ft. per bird; 0.12 sq. ft. per bird and 0.06 sq. ft. per bird). Mortality was significantly ($\alpha = 0.01$) higher in more dense groups compared to the least dense group in trials of both growing and breeding quail. No incidence of cannibalism was noted under these

overcrowded conditions. The overall feed conversion was noted to be very poor, but poorer feed conversion was noted at 16 weeks of age than had been observed at six weeks of age.

Birds in the least dense group (0.24 sq. ft. per bird) reached the age of sexual maturity earlier ($\alpha = 0.01$) than did the birds of the other two groups whether with respect to the first egg(s) laid or to the level of more than 30 percent production.

Average egg production was lowest (0.10 eggs per bird per day) in the most dense population ($\alpha = 0.01$). Average egg production was highest (0.32 eggs per bird per day) for the least dense group. Birds allowed 0.12 sq. ft. per bird averaged 0.14 eggs per bird per day.

Birds of the most dense population (0.06 sq. ft. per bird) produced a greater percentage of dirty eggs than did birds of the two other groups. No significant differences in egg weight between eggs produced by the three groups of birds were noted at the end of the experimental period.

The overall fertility in this trial was rather poor. Eggs produced by the most dense group showed lower fertility than those produced by the two other groups of birds ($\alpha = 0.01$). Hatchability was highest for eggs produced by the least dense group and lowest for eggs produced by the most dense group ($\alpha = 0.01$).

4. Bobwhite and Coturnix quail showed a marked response in growth, egg production and mortality when they were allowed different amounts of drinking water ranging from zero percent to 100 percent (continuous supply of drinking water).

While growing Bobwhite quail consumed an average of 8.5 ml. of water per bird per day in the first week of the trial, Coturnix quail consumed three times as much in the same period. There was a trend of increased water consumption as birds aged. Average water consumption of breeder Bobwhite quail was approximately 29 ml. per bird per day. The water to feed ratios for breeder quail were 2.9, 2.6 and 2.7 for the control (water <u>ad libitum</u>), 75 percent water and 50 percent water groups, respectively.

Significant differences ($\alpha = 0.01$) in body weight were noted when both growing quail and breeder quail received different amounts of drinking water.

Water restriction delayed the age of sexual maturity of the Coturnix quail up to 84 days. Laying Bobwhite quail ceased egg production shortly after being subjected to water restriction.

Although no significant differences in mortality could be demonstrated when breeder Bobwhite quail received different amounts of drinking water (100, 75 and 50 percent), there were significant differences ($\alpha = 0.01$) with respect to the mortality of growing Bobwhite and growing Coturnix quail which received different amounts of drinking water.

5. Studies of the influence of certain factors on fertility and hatchability of quail eggs showed differences in fertility and hatchability between individual Bobwhites. The lowest hatchability for an individual quail was 48.0 percent and the highest was 100 percent. Fertility ranged from a high of 100 percent to a low of zero percent.

Best results in fertility and hatchability of Bobwhite eggs (both mass and pen matings tested) and Coturnix eggs (only mass matings tested) were obtained when the male to female ratio was 1:1 in pen matings and 6:6 in mass matings; however, higher fertility was obtained from eggs produced by Bobwhite in pen matings (1:1) than from mass matings (6:6).

Considerable variation in age in days at which laying began was noted. Even though egg production started as early as 114 days of age, none of the eggs produced before the birds were 130 days of age were fertile.

6. Bobwhite eggs laid by the same bird were by no means uniform in size. Giant eggs, weighing almost 17 gms., as well as dwarf eggs, weighing as little as 3 gms., were observed.

In the period immediately following sexual maturity, Bobwhite quail laid eggs of increasing size until approximately the fourth week of production. Variation in egg size became less as birds progressed in egg production. Egg size plateaued between the fifth and seventh weeks of production. A high correlation was found between weight of initial egg and weights of subsequent eggs produced by the same bird.

The size of Bobwhite eggs in relation to their position in the cycle did not follow as definite a pattern as had been reported in chickens, especially for the longer cycles; however, the three-egg cycle of the quail, in general, followed the same pattern for the three-egg cycle in chickens.

No significant differences could be demonstrated between egg weight loss of Bobwhite quail and Coturnix eggs when stored at the same temperature.

While the albumen of Coturnix eggs contributed, on the average, 47 percent of the egg weight and the yolk contributed 32 percent of the egg weight; Bobwhite eggs contained by weight, on the average, 41 percent albumen and 40 percent yolk. The shells of Coturnix eggs, which averaged 0.197 mm. thick, were significantly thicker ($\alpha = 0.01$) than those of Bobwhite eggs, which averaged 0.173 mm. On the other hand, shell membranes of Bobwhite eggs, which averaged 0.067 mm. in thickness, were significantly thicker ($\alpha = 0.01$) than those of Coturnix eggs, which averaged 0.063 mm.

7. From the results of these experiments, it seems logical to conclude that selection of hatching eggs on the basis of size would be an effective tool for increasing growth rate to 16 weeks of age in the Bobwhites used in these experiments.

The floor space restrictions utilized in these experiments did not significantly affect growth rate; whereas, reproduction was significantly reduced when floor space allowance was reduced from 0.24 sq. ft. to 0.12 sq. ft. per bird, therefore, it is concluded that breeder Bobwhite quail require more floor space than do growing Bobwhite quail.

Both growing and mature Bobwhite quail should receive an adequate supply of drinking water if best results are to be obtained.

On the basis of these experiments, it is concluded that matings of both Bobwhite and Coturnix quail should be in the ratio of one male to one female if best fertility is to be obtained and that pen mating of Bobwhites is superior to mass mating.

Bobwhite eggs vary somewhat from Coturnix eggs with respect to the proportion of component parts and eggs of both of these species vary from chicken eggs in this respect.

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TABLE 1.-Composition of quail ration used in all experiments

Ingredients		Percent of ration
Ground yellow corn		41.25
Soybean oil meal, dehulled, 50%		37.00
Alfalfa meal, 17% protein		5.00
Dried whey		2.50
Meat and bone scraps, 50%		2.50
Fish meal, Menhaden, 60%		2.50
Dicalcium phosphate		1.50
Ground limestone		5.00
Salt, iodized		0.50
Vitamin premix*		0.25
Fat		2.00
	Total	100.00
Calculated analysis:		
Protein	%	25.66
Fiber	%	3.47
Fat	%	4.27
Calcium	%	2.84
Phosphorus	%	0.83
Arginine	%	1.55
Glycine	%	1.39
Methionine	%	0.50
Cystine	%	0.37
Lysine	%	1.46
Tryptophan	%	0.298
Productive energy, Cal/lb.		835.63

* Nopcosol M-4, Nopco Chemical Company, Harrison, New Jersey