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Some Effects of Photoperiodicity on the Temperatures and Weights of Bobwhites

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SOME EFFECTS OF PHOTOPERIODICITY ON THE TEMPERATURES AND WEIGHTS OF BOBWHITES

by

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INTRODUCTION

In recent years there have been a number of studies that have dealt with body temperature and body weight variations in gallinaceous birds under various field or controlled conditions. Wilson (1948) studied the reactions of pullets to different environmental temperatures. In a laboratory experiment Bajpai (1962) observed that a change in the cloacal temperature of adult Rhode Island Red males was effected by manipulating the photoperiod. In a report on the sexual maturation of *Coturnix* quail Wilson *et al.* (1962) discussed several aspects of variation in body weight, which resulted from changes in photoperiod. Hamilton (1957) studied the weights of bobwhites *(Colinus virginianus)* under field conditions. A laboratory experiment was employed by Kirkpatrick (1957) to determine the influence of different photoperiods on weight gains in young bobwhites. It appears, however, that no comprehensive studies have been undertaken to determine the effect that a change in photoperiod has on the internal temperatures and body weights of bobwhites, when the environmental temperature is maintained constant. This study was initiated in an attempt to partially fill this apparent gap in knowledge.

A concurrent objective was to determine the time lapse between the abrupt initiation of a stimulatory

photoperiod and the attainment of reproductive condition. Such information appears to be limited to two separate studies on reproduction in turkeys (*Meleagris gallopavo*) (McCartney *et al.*, 1961; and Marsden *et al.*, 1962), although a considerable volume of data is available on the reproductive response to incremental increase of photoperiod (Warren and Scott, 1936; Robinson, 1963; Burger, 1940; Roberts and Carver, 1941; Benoit, 1950; Padgett and Ivey, 1959; and many others).

METHODS

Data were collected from a group of 18 bobwhites housed in a controlled environment laboratory. Temperature in the laboratory was maintained at 73°F (±3°), and relative humidity at 56 per cent (±4 per cent). Illumination was provided by an overhead rack of fluorescent lights operating on 60 cycle current. Each bird received light of 500-footcandle intensity which, for this species, is below the upper tolerance limit (Robinson, 1957:66).

Birds were housed individually in cages 11½ inches long, 8½ inches wide, and 7½ inches high, and made of ½ inch hardware cloth. The removable cage bottom and the water fountain base were of stainless steel. Cages were positioned 4 to 6 inches apart on shelves, with females and males alternating.

The birds were maintained on a diet of game bird finisher (No. 5425) made by the Ralston Purina Company.

Composition, according to Company analysis, included 20 per cent crude protein, 2.5 per cent crude fat, and 6 per cent crude fiber. Grit in the form of crushed granite was also provided. Scott and Heuser (1957) found that the addition of granite or feldspar to the diets of turkeys and chickens (Gallus gallus) enhanced development, egg-laying, and feed utilization. In the present study neither the food nor the grit was weighed. It was increased or decreased in quantity according to the needs of each bird, as determined by the amount of feed remaining in each pan each time the birds were checked. Water was also provided ad necessitatem.

Handling the birds was kept to a minimum by checking half of the birds about noon ($\pm$2 hours) each 24 hour period. Noon was approximately in the middle of the light period for both the 9-hour and the 15-hour photoperiods. The bobwhites received light from 8:15 AM to 5:15 PM during the 9-hour period, and from 5:15 AM to 8:15 PM during the longer photoperiod. As a result of this procedure, data were collected and recorded for each individual of the population every 2 days. Cloacal temperature was taken immediately after each bird was removed from its cage. This was accomplished by inserting a thermistor-tipped stainless steel probe approximately ½ inch into the cloaca of the bird. The temperature was registered on a battery-operated metering device (Yellow Springs Instrument Company, Ohio). Each bobwhite was weighed to

tenths of grams by employing a double-pan balance. White paper tray liners facilitated the counting of fecal material. The quantitative fluctuation of droppings served as a crude indicator of alimentary tract activity.

The experimental birds were purchased on March 14, 1962, from a commercial game breeder in Holland, Michigan, and were placed in the controlled environment laboratory on the same day. Eight of the 18 birds had been hatched in the summer of 1960. This group was composed of 4 females and 4 males. The remaining 10 birds were hatched during the summer of 1961, and consisted of 4 females and 6 males. For convenience, the birds will be referred to as old and young birds, although the birds of both groups were adults.

The population of bobwhites, used in the present experiment, were obtained at the termination of an egg production study (see Robinson, 1963:215-220). The group consisting of the old birds had completed two breeding seasons, the most recent of which had been an artificial period. The young group had never been in breeding condition prior to being placed in the laboratory, but had completed one artificially induced breeding period.

The study was conducted for a period of approximately 7 months, during which time the only known variable was photoperiod. On August 10, 1962, the birds were receiving 9 hours of light. They were maintained at this level for 2 months to obtain sufficient base-level data.

On October 13, 1962, length of day was increased to 15 hours without intervening increments. The population was kept on this daily cycle for 3 months. Twenty-four hours after the termination of this segment of the study, photoperiod was immediately decreased to 9 hours.

The population studied was certainly not typical of a bobwhite population, which would ordinarily be encountered in the field. As a result, the applicability of the findings to bobwhites in general is undetermined.

RESULTS AND DISCUSSION

Temperature and weight data for each group were averaged for the 9-hour photoperiod (72 days), for the period during which the birds received 15 hours of light per day (66 days), for a transition period of 36 days following the increase to 15 hours, and for a short transition period (18 days) following the termination of the 15-hour photoperiod. Because the change from the 9-hour to the 15-hour photoperiod was immediate rather than incremental, the first 36 days of the 15-hour period were arbitrarily chosen as the transition period. It was hoped that data from the transition period would provide some insight into the physiological shift made by the birds in attaining breeding condition. The transition period was of long enough duration that, at its termination, many of the birds were in apparent breeding condition.

For each group the t-test was employed to check for

possible significance between the means for the three periods studied (see Snedecor, 1956). The F-test was utilized to determine whether the ratio of each set of variances could be attributed to chance.

Weight

Both groups of males gained weight during the transition, and this increase was statistically significant (Tables 2, 4). The weight increase might be partially accounted for by the added weight of enlarged testes. It is known that the maximum size of avian gonads may be 200 to 300 times larger during the breeding season than at any other time. Benoit (1950) found that the maximum weight of the testes in a duck (*Anas platyrhynchos*) may approximate one-tenth of the bird's total body weight, and Mackie and Buechner (1963) found the testes of the male chukar partridge (*Alectoris graeca*) to be approximately 70 times heavier during breeding condition than they were prior to the breeding season. Kendeigh (1941) has stated that there appear to be no drastic demands made on the energy budget of birds for the complete maturation of testes and incomplete maturation of ovaries. He indicated that the slight demands might be met by higher food intake. This may not apply, however, to birds subjected to an immediate change in photoperiod.

During the 15-hour photoperiod the males lost weight, the young males nearly approximating their 9-hour weight,

the old males operating at a lower weight than that during the 9-hour photoperiod. It is possible that energy requirements for sustaining breeding condition may have been so great that the males were not able to metabolize enough additional energy to maintain their previous weights.

When the photoperiod was returned to 9 hours of light per day, the old males made a slight increase in weight, but this change was not statistically significant. During the same period, however, the young male bobwhites lost weight, and this loss was significant at the 1 per cent level. Mackie and Buechner (1963) found that the testes of young chukar males undergo an initial rapid regression, followed by a period of slower change. The testes of the young male bobwhites may have undergone a more rapid regression than those of the old males, and this would partially account for the loss in total weight.

The old and young female bobwhites gained weight when the photoperiod was increased to 15 hours, and they maintained this weight increase throughout the breeding season (Table 2). Some or all of the weight gain during the 15-hour photoperiod can be attributed to the additional weight contributed by the enlarged gonads and developing eggs. Mackie and Buechner (1963), in a study of reproduction in the chukar, found that the ratio of breeding ovary weights to non-breeding ovary weights was approximately 155:1, and the ratio for oviduct weights was 64:1.

When the photoperiod was decreased to 9 hours, both groups of female bobwhites lost the weight they had previously gained. As a result of extensive experimentation on the eastern house wren (Troglodytes aedon aedon), Baldwin and Kendeigh (1938) stated that enlarged gonad weights contribute more significantly to body weight in females than in males. Thus, if very rapid initial regression of ovaries and oviducts did occur in the present study, as Mackie and Buechner (1963) found it did in the female chukar, the total body weight loss by the female bobwhites at the termination of the 15-hour photoperiod would be understandable.

The old bobwhites, males and females, weighed more, at any given time, than the young birds. Although all groups were comprised of adult birds, the old males and females were a year older than the young birds. It is well-known that old animals tend to have lower basal metabolic rates than their younger counterparts. It is also well-known that the weight of an organism tends to vary inversely with the metabolic intensity of the organism. It seems reasonable that if the older bobwhites did indeed operate at a slower metabolic pace than the younger birds, the difference might be reflected in higher body weights.

Old female bobwhites weighed more than old males. This difference was most pronounced under the 15-hour photoperiod, when eggs and enlarged ovaries and oviducts contributed to the weights of the females.

It seems worth mentioning that all the old bobwhites weighed more during their third breeding season than they had during their second breeding season (see Robinson, 1963). The young birds also weighed more during their second breeding period than they had during their first period, but the young females were not as heavy as the older females had been during their second breeding season. Assuming reproductive condition after a lapse of only 4 months between simulated breeding seasons may have imposed greater physiological stress on the young female bobwhites than was experienced by the old females.

Variability in weight was less, in general, for the bobwhites during the 15-hour photoperiod than during the 9-hour photoperiod (see Table 2). Intermediate values were recorded for the transition period. With the exception of the 9-hour photoperiod the variation about the mean was much greater for the old females during all periods than for any other group of bobwhites. A great amount of variation in the weights of the old females occurred during the 15-hour photoperiod, and the least occurred during the 9-hour photoperiod. A higher rate of egg production in the old females and larger size individual eggs might provide an explanation for this phenomon.

TEMPERATURE

In the chicken (hen) the lower limit of the thermoneutral zone has been recorded by Mitchell and Haines

(1927) and Dukes (1947) to be about 61.7°F. Dukes (1947) and Wilson (1948) have reported that the upper limit of the thermoneutral zone in chickens is approximately 81°F. It seems reasonable to assume that the thermoneutral limits of the bobwhite are similar to those of the chicken. In the present study the environmental temperature of 72°F was well within the aforementioned limits.

The temperature of both male and female bobwhites decreased significantly during the change from the 9-hour to the 15-hour photoperiod, and the low temperatures were maintained throughout the simulated breeding season (Table 1). *A priori*, it might seem that body temperatures would be higher during this period due to increased heat production from such activities as pacing, restlessness, whistling, and sperm and egg production. A possible explanation for the lower temperatures which were actually found is this: the decrease in body temperature may be an adaptation allowing the diversion of energy to breeding activities rather than maintaining higher temperatures. An additional advantage for the males would be a body temperature more favorable for sperm production. It is also possible, however, that the bobwhites may not have been able to divert the necessary energy to reproductive functions and still maintain higher temperatures.

The average temperatures of all groups of bobwhites were lower in this investigation than they had been in the previous study (see Robinson, 1963). Perhaps the

lower temperatures indicate that the reproductive capabilities of the males and females decreased with age: this would be a reasonable supposition if the second hypothesis put forward above were true. Because the testes and ovaries were not examined at the termination of this study, one line of evidence bearing on the point is unavailable. On the basis of time required to reach reproductive condition (see "Attainment of Reproductive Condition") reproductive capabilities increased with age, while body temperature, as stated, decreased. This relationship provides support for the hypothesis that a lowered body temperature allows more efficient marshalling of energy for reproductive activities.

The variances of the mean temperatures for all of the groups of bobwhites seemed to follow the same general trend as the weight variances. Temperature variability for all groups was greatest during the 9-hour photoperiod, and least during the 15-hour photoperiod, with intermediate values during the transition period (Table 1). The variation about the mean was, in general, slightly greater for the male bobwhites than for the females during most periods (Table 1).

The diminution of variation in temperature and weight for all bobwhite groups during the transition period merits emphasis. Variability was significantly less during the transition than it was for the 9-hour photoperiod. This fact suggests that the physiological shift from a

non-breeding to a breeding condition was made by all groups with no difficulty. Further, variability was least under the 15-hour photoperiod, indicating that the birds were more highly attuned physiologically than during any other period. The closer regulation of body functions would be advantageous to the bobwhite during such a critical period in its life cycle as the breeding season.

Temperature-Weight Relationships

The relationship which exists between metabolic intensity, body weight, and the internal temperature of a homoiotherm is very complex. Several authors have commented on the inverse proportionality between body mass and the rate of metabolism in warm-blooded animals (Brody, 1945; Rodbard, 1950; Sturkie, 1954:141; King and Farner in Marshall, 1961:227). In a short paper Rodbard (1950) noted that an inverse relationship also exists between body weight and body temperature, when species of various weights are compared.

Average temperatures and weights were calculated for each 6-day period of the study for each group of bobwhites. Inspection of the temperature-weight data (Tables 1, 2) suggests an inverse relationship between the average cloacal temperatures and the body weights for all groups. The relationship is even clearer when 6-day plots of temperature versus weight for the 9-hour photoperiod are examined (Figs. 1 to 4). The existence of this inverse

weight-temperature relationship within a species has not been previously reported. It is apparent, further, that the temperature-weight relationship breaks down under the conditions of a 15-hour photoperiod. Although any discussion must be hypothetical, several comments seem appropriate at this time. If a lowered body temperature has the importance in channeling reproductive energy ascribed to it in a previous section, then, a closer regulation under breeding conditions than under non-breeding conditions would be expected and this is, in fact, what occurs. More detailed studies will be necessary before it can be determined if these results are applicable to other populations of bobwhites and other species.

Attainment of Reproductive Condition

With the exception of one bird (No. 6), the old female bobwhites laid their first eggs slightly earlier than the young females (Table 5). It appears that the old females were more adept than their young counterparts at making the physiological shift dictated by the increased photoperiod. One bird (No. 6) laid her first egg only after a very long time lapse (87 days). This same female, however, had not been induced to lay a single egg in a previous simulated breeding season (see Robinson, 1963).

Stoddard (1950:103) is of the opinion that the "ah-bob-white" call is restricted to those males who have attained breeding condition. This call was used in the

present study as a criterion of male breeding condition. The first call was heard on October 30, 1962, 17 days after the initiation of the 15-hour photoperiod. Benoit (1950) reported that the testes of male ducks in a non-breeding condition will undergo full development in 12 to 15 days, when the photoperiod is maintained at 15 hours per day.

SUMMARY AND CONCLUSIONS

Temperature and weight data were collected from a group of 18 bobwhites housed individually in cages in a controlled environment laboratory, where the only known variable was photoperiod. The bobwhites were divided into two age groups. The individuals of the old groups were a year older than those of the young groups, although all birds were adults. Cloacal temperatures and body weights were recorded for half of the population each 24-hour period.

After 72 days at a 9-hour photoperiod, the bobwhites were immediately subjected to a 15-hour photoperiod. All of the male bobwhites lost weight during the 15-hour photoperiod, while the females made significant increases. It appears that the males were not able to metabolize enough energy to sustain breeding functions and still maintain previous weights. The burden could have been as great for the females, but may have been partially masked by additional weight contributed by enlarged ovaries,

oviducts, and developing eggs.

All of the birds operated at lower temperatures during the longer photoperiod. The old bobwhites had lower temperatures than the birds in the young groups. The hypothesis is advanced that a lowered body temperature under long-day conditions may represent an adaptation allowing diversion of a certain amount of energy away from temperature maintenance to breeding activities. The ability to make this adjustment may increase with age. The male bobwhites could derive an additional advantage of having body temperatures more favorable to the production of viable sperm.

An inverse temperature-weight relationship existed for all groups of bobwhites during the 9-hour photoperiod. Apparently the existence of this type of relationship within a species has not been previously reported. The relationship did not appear to exist during the 15-hour photoperiod. Two hypothetical explanations seem plausible. The birds may have been able to regulate their temperatures more closely during the 15-hour photoperiod. It is reasonable that this should be so if a lowered body temperature has the importance for breeding here ascribed to it. It is also feasible that lower body temperatures might result without any noticeable change in body weights if some of the energy had to be diverted to reproductive functions.

The old female bobwhites, in general, laid their

first eggs slightly earlier than the young females. All of the data suggest that the old females were more adept at attuning themselves to the increased photoperiod.

The first "ah-bob-white" call was heard only 17 days after the change in photoperiod, and this call was employed as a criterion of male breeding condition.

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Table 1. Cloacal temperature for four groups of bobwhites for different photoperiods. Photoperiods in hours, means in degrees Fahrenheit.

Group	Photoperiod	Sample size	Mean	Variance	Standard error
Males					
old	9	144	108.5	3.36	0.15
young	9	216	109.0	2.72	0.11
Females					
old	9	144	108.7	2.71	0.14
young	9	144	109.1	2.29	0.13
Males					
old	trans.I (15)	72	106.5	1.19	0.13
young	trans.I (15)	108	107.0	1.77	0.13
Females					
old	trans.I (15)	72	107.2	1.10	0.12
young	trans.I (15)	72	107.2	0.91	0.11
Males					
old	15	128	106.7	0.81	0.08
young	15	198	107.1	1.51	0.09
Females					
old	15	128	107.1	0.76	0.08
young	15	132	107.1	0.67	0.07
Males					
old	trans.II (9)	36	107.8	1.41	0.20
young	trans.II (9)	54	108.2	1.99	0.19
Females					
old	trans.II (9)	36	108.1	1.48	0.20
young	trans.II (9)	36	107.8	1.23	0.18

Table 2. Body weight for four groups of bobwhites for different photoperiods. Photoperiods in hours, means in grams.

Group	Photoperiod	Sample size	Mean	Variance	Standard error
Males					
old		144	202.4	89.98	0.79
young		216	193.0	45.32	0.46
	9				
Females					
old		144	218.0	90.13	0.79
young		144	193.5	170.47	1.09
Males					
old		72	205.7	71.42	1.00
young	trans.I (15)	108	199.0	31.03	0.54
Females					
old		72	223.0	167.63	1.53
young		72	200.6	23.91	0.58
Males					
old		128	196.0	16.91	0.36
young		197	193.7	39.16	0.45
	15				
Females					
old		128	228.9	446.52	1.87
young		132	206.5	21.75	0.41
Males					
old		36	196.2	61.57	1.31
young	trans.II (9)	54	186.1	41.81	0.88
Females					
old		36	211.8	514.78	3.78
young		35	188.3	86.54	1.57

Table 3. t values obtained from the comparison of various sets of temperature means, and F-test results from the comparison of variances of the means. Numbers lacking asterisks not significant at the 0.05 level.

	Males				Females			
	Old		Young		Old		Young	
Ratio	t	F	t	F	t	F	t	F
9 hr.-trans.I	8.17*	2.82**	11.24*	1.54*	7.00*	2.46*	9.40*	2.52*
trans.I-15 hr.	1.57	1.47	0.21	1.17	0.36	1.45	0.86	1.36
9 hr.-15 hr.	10.24*	4.15*	13.43*	1.80*	9.35*	3.57*	14.29*	3.42*
15 hr.-trans.II	1.58	1.74**	1.34	1.32	6.71*	1.95**	4.59*	1.84**

*Significant at 0.01 level of probability.
**Significant at 0.05 level of probability.

Table 4. t values obtained from the comparison of various sets of weight means, and F-test results from the comparison of variances of the means. Numbers lacking asterisks not significant at the 0.05 level.

	Males				Females			
	Old		Young		Old		Young	
Ratio	t	F	t	F	t	F	t	F
9 hr.-trans.I	2.50**	1.26	8.01*	1.46**	3.34*	1.86*	7.77*	7.13*
trans.I-15 hr.	10.90*	4.22*	7.42*	1.22	2.32**	2.66*	8.49*	1.10
9 hr.-15 hr.	7.03*	5.32*	1.26	1.16	6.30*	4.95*	10.84*	7.84*
15 hr.-trans.II	0.23	3.64*	7.86*	1.07	4.43*	1.15	16.27*	3.98*

*Significant at 0.01 level of probability.
**Significant at 0.05 level of probability.

Table 5. Duration of time from the beginning of the 15-hour photoperiod until the first egg for each female. The longer photoperiod was initiated on October 13, 1962. Numbers assigned to individuals for identification purposes.

Group	Female (Ident. No.)	No. of days prior to 1st egg
Old	4	47
	6	87
	8	38
	10	45
Young	12	46
	14	64
	16	48
	18	50

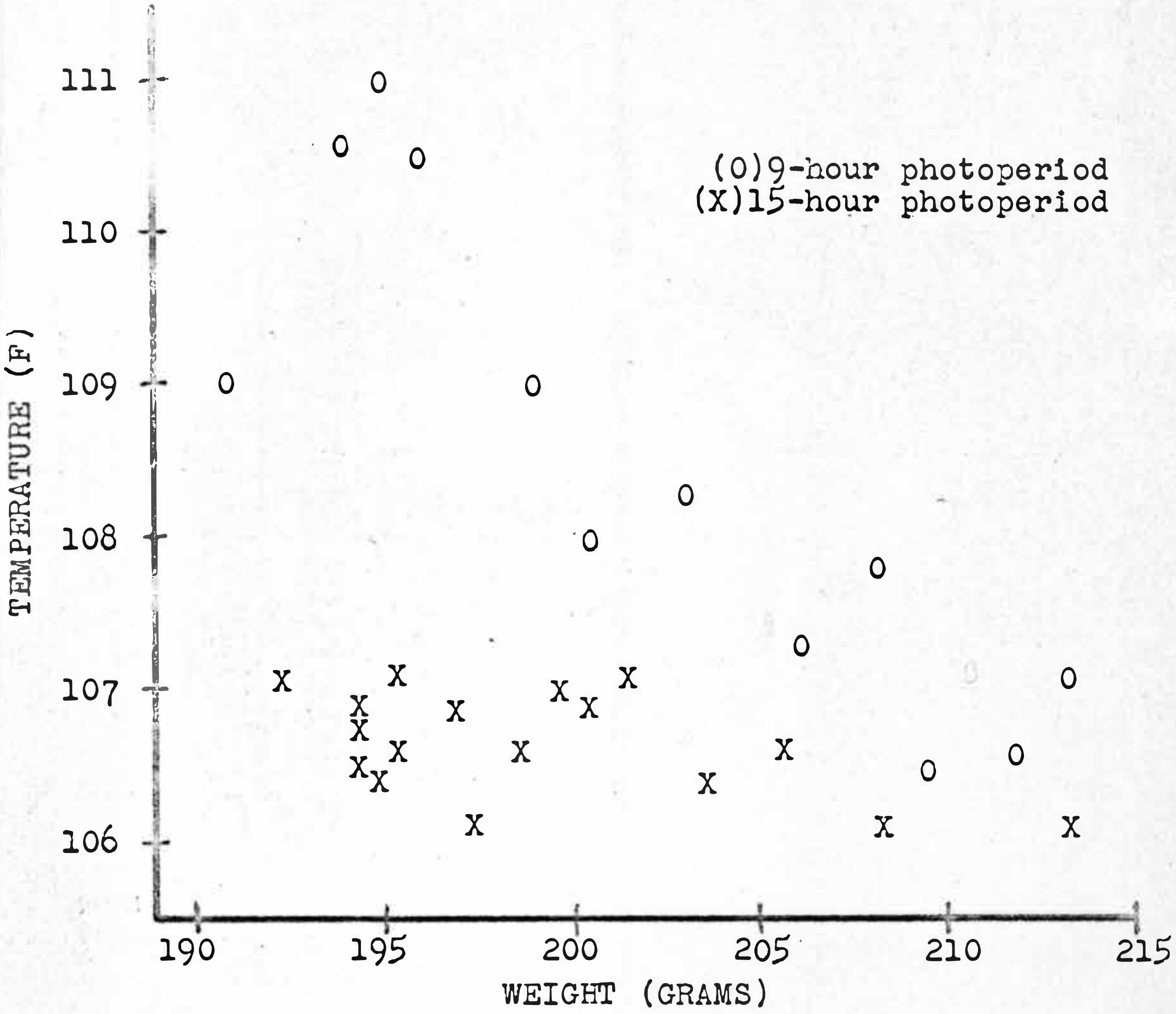

FIG. 1. Average temperature-weight relationships for four old, male bobwhites in breeding and non-breeding conditions.

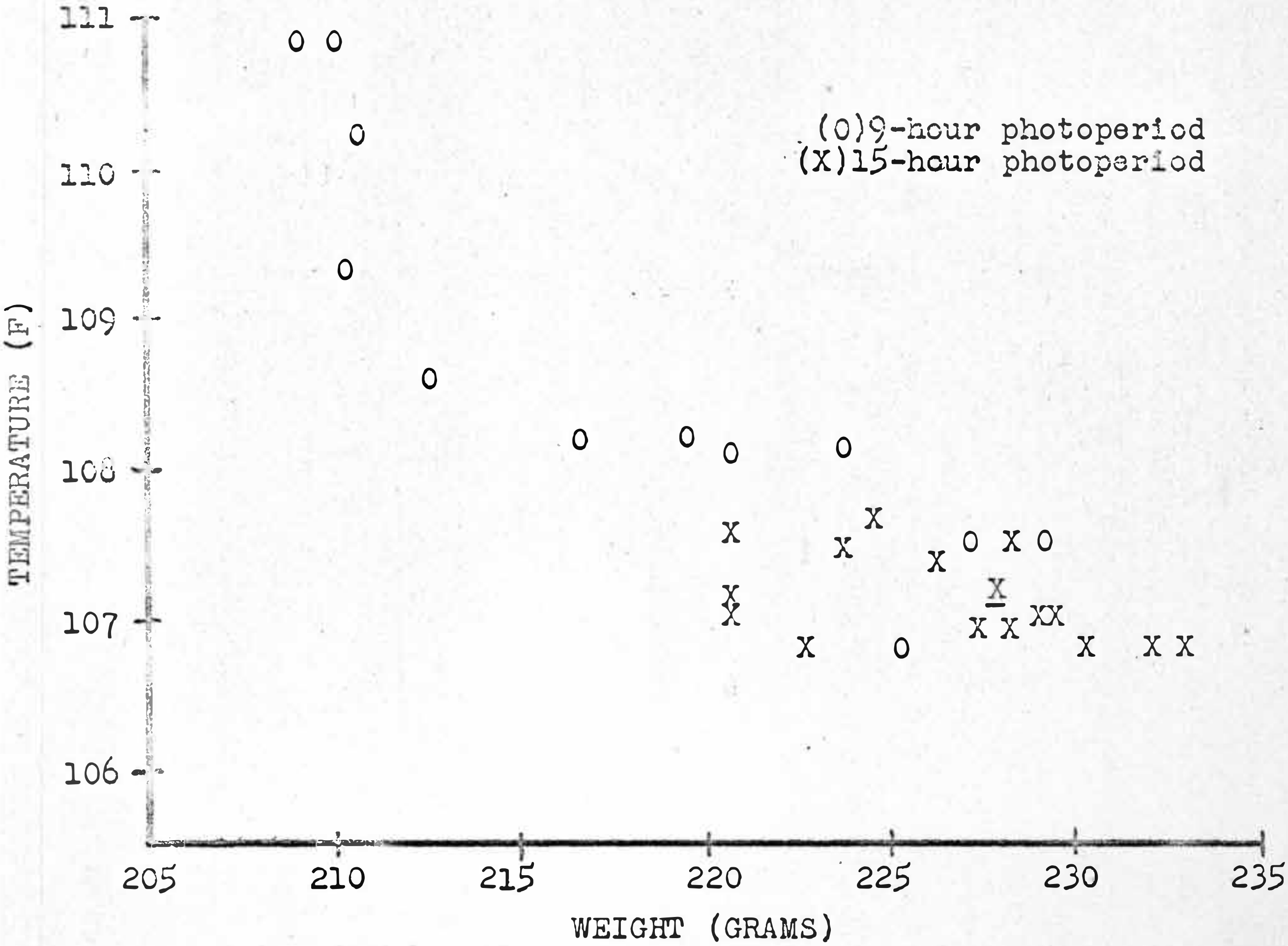

FIG. 2. Average temperature-weight relationships for four old, female bobwhites in breeding and non-breeding conditions.

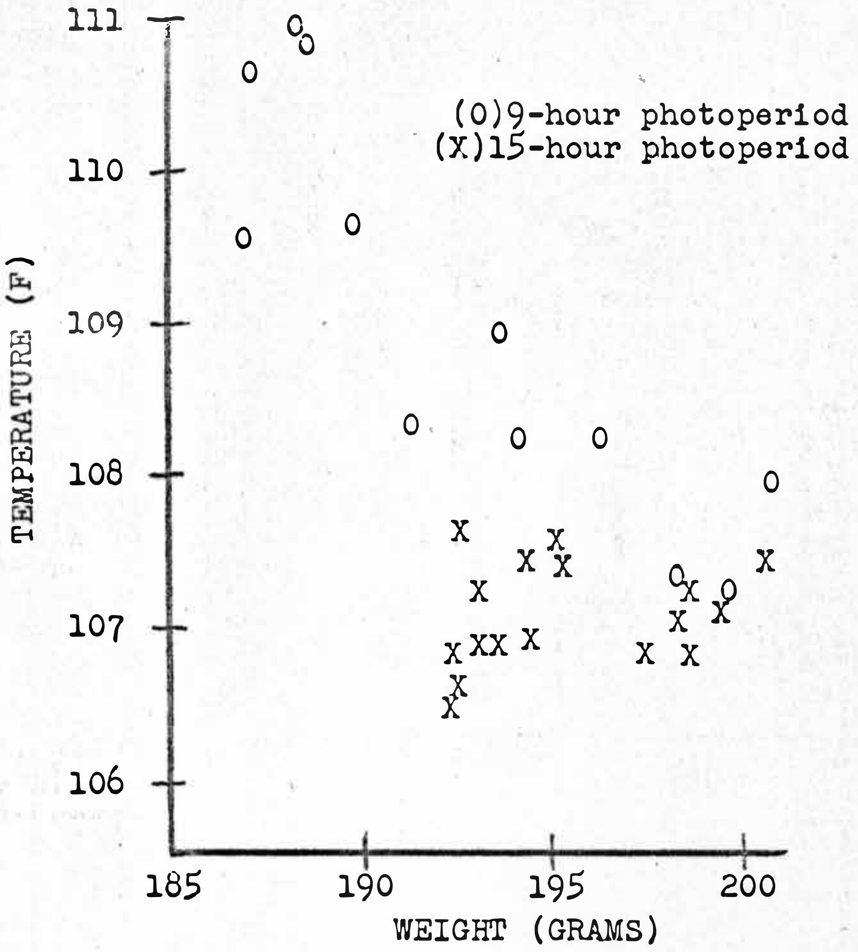

FIG. 3. Average temperature-weight relationships for six young, male bobwhites in breeding and non-breeding conditions.

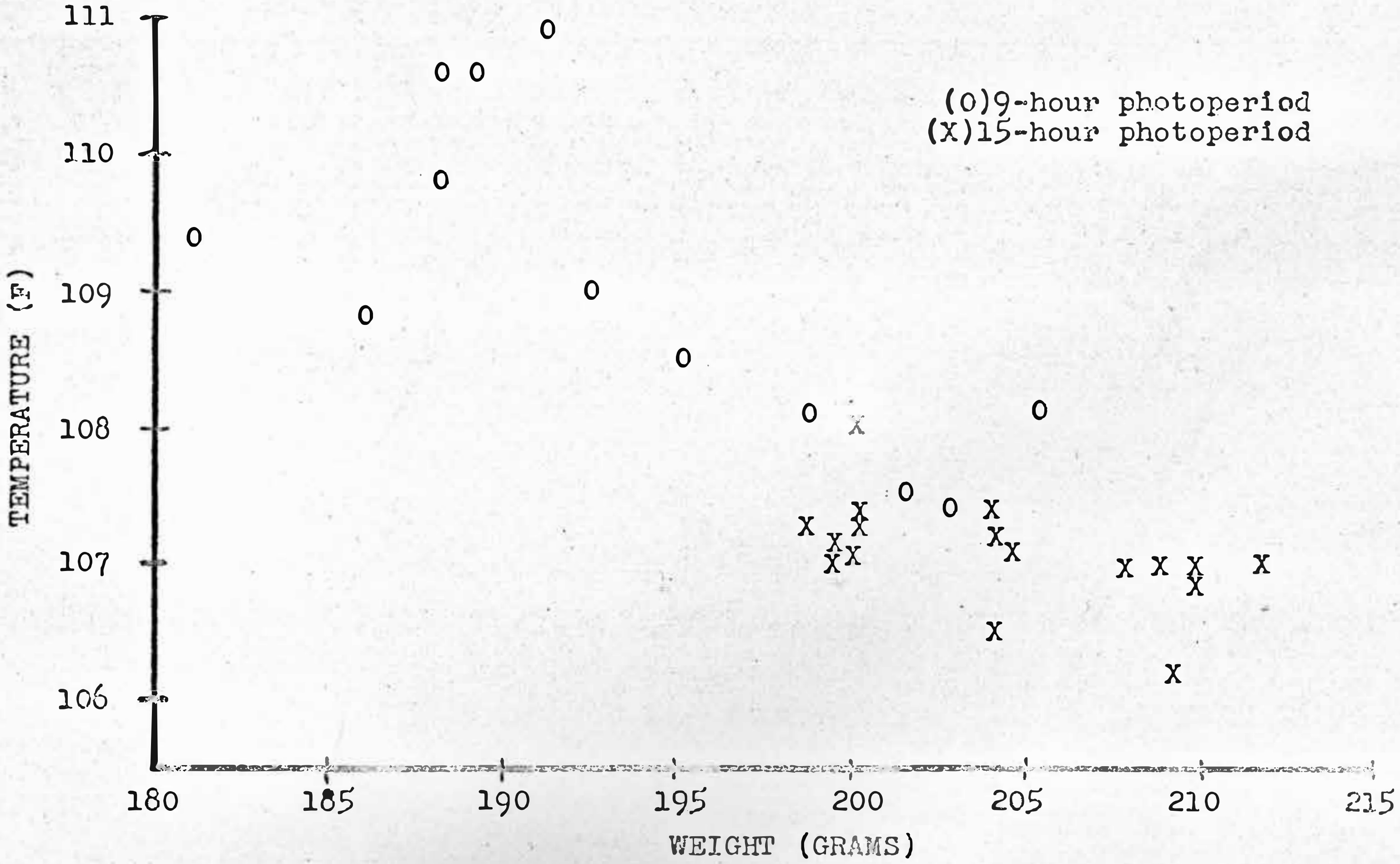

FIG. 4. Average temperature-weight relationships for four young, female bobwhites in breeding and non-breeding conditions.