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THE COMPARATIVE ABILITY OF THE BOB-WHITE AND THE RING-NECKED PHEASANT TO WITHSTAND COLD AND HUNGER[1]

BY PAUL L. ERRINGTON

THE native Bob-white (*Colinus virginianus*) and the introduced Ring-necked Pheasant (*Phasianus colchicus torquatus*) may both, on occasion, suffer severe winter mortality over much of their common range in north-central United States. Their habitats often overlap, although the Pheasant has a greater cruising radius and an ability to live in a more open type of country than the Bob-white. In given localities they also live upon much the same kinds of winter foods.

The scope of this paper is not intended to cover the ecological adjustments of Pheasants or of Bob-whites to their winter environment so much as the manifest effects of cold and malnutrition upon these birds under extreme conditions.

Data upon which this paper is based were, for the most part, obtained incidentally, in connection with a number of field study and experimental projects in Iowa and Wisconsin, chiefly between 1929 and 1934. Certain apparent hiatuses attributable to the incidental origin of the data would doubtless yield to specifically directed experimentation, but the latter I am not in a position to carry on and probably will not be, at least for some years to come. In the meantime, it may be of biological interest and possible value to wildlife management to summarize the data already available on the comparative hardiness of Bob-whites and Pheasants.

Experiments with 40 captive Bob-whites at Madison, Wisconsin, in 1930 and 1931, supported on the whole the conclusion arrived at from field studies that few of the foods commonly eaten are substantial enough to serve as winter staples (Errington, 1931*a*; 1933; 1936*b*; Errington and Hamerstrom, 1936, pp. 381–82). Bob-white populations thrived during cold weather only when they had access to corn, soybeans, achenes of lesser ragweed (*Ambrosia artemisiifolia*), and other high quality staples; when compelled by a shortage of these to feed heavily upon fleshy fruits, chaffy or woody material and similar foods of less sustentative types, the birds were able to maintain neither weight nor strength and were especially subject to mortality during periods of low temperatures.

Bob-white winter mortality from starvation and cold may be almost cataclysmic when acute food crises result through deep and persistent snows. Losses as high as 80 per cent of a wintering population in two weeks have been recorded (Errington, 1933), and there is historical evidence that great storms have practically depopulated wide

[1] Journal Paper No. J-262 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 329.

areas of this species in the past, though not necessarily through hunger and cold alone (Leopold, 1931; 1933; 1937).

The experiments with Pheasants were conducted at Lansing, Iowa, from January to April, 1933, through the coöperation of the Iowa Fish and Game Commission. The Commission made available 100 live Pheasants from the stock of the recently discontinued State Game Farm and contributed quarters and the services of W. E. Albert, Jr., for the care of the birds and the handling of the experimental routine. Experiments were planned not only to approximate emergency conditions but also to reduce the variables as much as possible to those of temperature and food (Errington, 1937).

U. S. Weather Bureau records were the source of the air temperature data for the Bob-white experiments at Madison, Wisconsin. Official records were not obtainable from Lansing, Iowa, so Weather Bureau records from Decorah were used for the Pheasant experiments. Unofficial readings made by Albert at Lansing, however, did not differ a great deal from the Decorah records.

Bob-whites and Pheasants alike were quartered in partly open, unheated pens in which the birds were exposed to natural temperature changes to about the same degree as free-living birds resorting to the cover types ordinarily used in their north-central states environment. Unquestionably, there were temperature differences in the shelter of the pens that were not reflected exactly by thermometers elsewhere, but probably not significantly greater than the differences to be expected between air temperatures and the temperatures of roosting places in marshy or grassy vegetation or in other retreats that the birds may happen to frequent in the wild.

Relation of Body Weight to Resistance to Cold

A. Bob-white.—Native northern Bob-whites, if well fed and in prime condition, usually withstand most low temperatures occurring within their range. Many of my field notes deal with populations surviving air temperatures lower than 15° below zero (F.). These notes show such extremes in temperature of 24°, 27°, and 30° below zero, with a minimum of 35° below.

It is true that Bob-white coveys reduce their activities or even cease moving for hours at a stretch during exceptionally cold weather but at these times they do not seem to prefer especially dense cover. Again and again, they have been observed bunched up for either night roosting or daylight resting in open cornfields or in cover more adapted to give them concealment than warmth.

Although nearly every unusually cold wave leaves an aftermath of Bob-whites dead on roosts, the intact carcasses that I have examined of birds thus killed were mostly those of individuals in subnormal physical condition from wounds, disease, or hunger. The sole record I, per-

sonally, have of well-conditioned Bob-whites freezing has to with a covey that roosted on a steaming manure pile and was flushed off into the sub-zero air. One bird of this covey was retrieved dead in fine flesh at 179 grams (practically full weight for this specimen), but the moisture from the steam had permeated its plumage and caused it to chill and die at a temperature it doubtless would have withstood had its plumage been dry (Errington, 1933).

On the other hand, the killing winter of 1935-36 demonstrated that Bob-whites may succumb to intense and continued cold even when in apparently good condition, fat and well fed. Exposure to blizzard winds and partial encasement of their heads in ice and snow evidently can reduce to a state of helpfulness otherwise normal birds (Scott, 1937). Leopold (1937) gives the results of examinations of a number of normal-weight Wisconsin birds found dead or helpless in the field and refers to 14 of a weather-killed covey found by Douglas Wade, one of his students. The members of this covey had a coating of ice under their wings, which, if suggesting wet plumage in cold weather, may have been responsible for their deaths through chilling as in the case of the birds roosting on the steaming manure pile. Perhaps most baffling of the questions raised by Leopold's paper are those pertaining to Bob-white individuals picked up dead or weak without anything perceptibly wrong with them. One of these weighed 250 grams (with a full crop of corn), the heaviest weight for this species that has come to my notice. Leopold recognized the possibility of undetected disease entering into the equation, a possibility supported by the fact that the 250-gram bird was caught by hand after a flight of 10 feet on December 28, 1935, before there had been any excessively cold weather.

Wade's 14 dead birds were included in the series of 40 weather-killed Bob-whites examined by Leopold and his students in 1935–36, but, exclusive of this covey, mention is made in the same publication of at least 7 of the birds either dying at weights exceeding 200 grams or "fat, with food in the crop." A total of 60 per cent of the 40 weather-killed birds exceeded 150 grams in weight, contrasted with a total of only 2 or 6.1 per cent of 33 dead birds previously examined by me in much the same area during the winters of 1929-30, 1930-31, and 1931-32. Of the 2 Bob-whites I recorded as dying in cold weather at exceptionally high weights, one was the steam-wet individual and the other was a large-frame bird reduced to 158 grams. The weights are those only of carcasses found intact before scavengers had eaten any part of them. Night-scattering of coveys during blizzards is sometimes attended by severe mortality (Errington, 1933, p. 14; Wade, 1938).

It may be seen that my Wisconsin data on Bob-white dying weights seemingly are less complicated by the unknowns and variables associated with the winter of 1935-36, a season of historically unprecedented severity and one perhaps atypical in other ways. We may then go on with a presentation of data in hand on relationship of temperature to

dying weights for less extraordinary winters and include pertinent data from Iowa and Missouri, as well.

Leopold (1931, p. 58) gives the weights of 6 Bob-whites picked up dead in southwestern Missouri in January, 1930, during a cold wave in which temperatures had dropped to about 20° below zero (F.), and I examined 7 more sent in by local game wardens. These 13 birds had died at an average of 124 grams or 67.8 per cent of the 183-gram average which Leopold (unpublished) found for normal Missouri Bob-whites in winter.

Five birds examined from south-central Wisconsin died during a March, 1932, cold snap with a minimum temperature of 4° below zero at an average of 129 grams or 65.2 per cent of the 196.5 grams average obtained from the weighing of 77 prime, early winter and mid-winter Bob-whites from the same general area. Four others died at an average of 110 grams or 55.6 per cent full average weight during a February, 1930 period when the minimum temperatures varied from 10° to 25°; at corresponding temperatures, 5 specimens alive but so weak as to be barely able to fly averaged 134 grams or 68 per cent full average weight.

Two Wisconsin birds, confined for experiments and reduced practically to the verge of death, were force-fed and brought back to recovery from 119 grams and 104 grams, or 58 per cent and 50 per cent of their known full weights. These withstood the air temperature of 5° on the first night after relief, but had more food in their stomachs than most starvation victims are likely to have when they are down to this stage. It is improbable that they would have survived without force-feeding.

Eighteen captive birds of a Wisconsin experimental lot died from January to April, 1931, on days for which the minimum air temperatures averaged 32° and at a weight average of 109 grams or 56.5 per cent of their original weight average of 193 grams. Twelve captive Bob-whites at Lansing, Iowa, died during the 1932-33 experiments at an average weight of 108 grams and at minimum temperatures averaging 21°. Weights of 287 southern Iowa Bob-whites taken by hunters in November and December, 1933, averaged 6¾ ounces or 191 grams (Schuenke, 1933), which would suggest that the Lansing captives died at 54.5 per cent to 56.5 per cent of their probable normal weights.

At the bottom of the scale of resistance were two Wisconsin birds still lively under experimental conditions at an average of 111 grams or 56.8 per cent full weight during mild weather but both dying from an abrupt autumn drop in temperature from 42° to 28°. Leopold (1937) makes some interesting statements bearing upon this point:

"After the return of mild weather in March, some birds of surprisingly low weight were found, 83, 90, 92, 102 grams. All these melted out of drifts, and hence had lost some weight by decomposition. The last three at least had been imprisoned alive in the snow, and thus

kept warm while starving; hence their weights are not representative of ordinary weather-killing. Another 95-gram bird, however, was picked up January 28 near a feeder. Death had apparently (but not surely) been recent. Survival of a free-ranging bird to such a low weight in cold weather is not explicable. It is usually believed that quail survive at very low weights only in warm weather."

I might observe parenthetically that my notes record one Wisconsin Bob-white weighing only 148 grams, collected on February 6, 1931, a fat and, to appearances, full weight bird but one that seemed naturally under-sized. Another bird taken on March 15, 1930, was in similarly good condition and weighed 161 grams. Either of these reduced to 60 per cent of their normal weights would go well below 100 grams.

A large number of starved birds were found in the field after they had been partially eaten by predators or scavengers, but the approximate dying weights of many could be ascertained from their breast profiles (see Errington, 1931a, or Leopold, 1933, p. 263); and these continue to support the concept of a progressive increase in susceptibility to cold with decrease in weight.

Expressed graphically, the data on dying weights and minimum air temperatures show two conspicuous cold resistance levels for winter Bob-whites. At minimum air temperatures of 10° to 32°, the birds seem to die at averages between 55 per cent and 57 per cent of their full weights; then, there is a lack of data on dying weights between 10° above zero and 4° below; finally, from 4° below to 20° below zero, the curve apparently levels off, and the birds die at averages between 65 per cent and 68 per cent of their full weights.

Kendeigh (1934, p. 339) concludes, on the basis of experiments with a migratory passerine bird, the House Wren (*Troglodytes aedon*), that "the critical aspect of low air temperature consists not in the absolute degree of low temperature itself, but low temperature combined with a period of time in which the bird must remain without food." He states further: "In the case of some of the larger birds of greater weight and correspondingly greater food reserves in the body, the critical role of night temperature and hours of darkness may become effective only if accumulative over a long period. If a bird is able during the daytime to assimilate only a part of the equivalent total energy that it loses at night, there will finally come a time when its temperature tolerance entirely breaks down, which results in death."

In general, it seems that healthy adult northern Bob-whites may be reduced to about 80 per cent of their full weights without danger of freezing to death under ordinary circumstances, although at this weight they have little reserve and must have regular access to substantial food. Reduction below 75 per cent begins to bring birds within the realm of danger, and birds down to 65 per cent are usually in a precarious way. At the latter stage, they may be expected to survive only if lucky, being unable to escape even clumsy enemies and dying

during moderate cold snaps. From 65 per cent on down to a known minimum of 45.2 per cent of full weight, the birds may be so delicately poised between life and death that they stand practically no chance of saving themselves or of being saved under natural winter conditions in north-central states.

Bob-whites of both sexes died from starvation at about the same weights in the course of the investigations: 27 cocks at an average of 113 grams and 24 hens at an average of 113.7 grams (Errington, 1936a). Forty-six of the birds in my series of 77 full winter weight individuals were cocks and averaged 196.8 grams, whereas the 31 hens averaged 196.1 grams.

B. Ring-necked Pheasant.—I have encountered scant evidence of Pheasants actually starving in communities where much land is under cultivation. Green and Beed (1936) found that, even during 1935-36 when the wintering loss on the principal area under observation in northern Iowa amounted to 250 or 62.5 per cent of a population of 400 birds, the death of only one of these was attributed to starvation. One hundred thirty-one birds, or 32.75 per cent of the population, were found dead, having died apparently as a result of choking from accumulation of ice about mouth and nostrils or from freezing or from choking and freezing combined. Exposed to very cold, snow-laden winds, Pheasants in unprotected places died with their feathers filled with ice and snow, and in some instances live birds were found "so heavily covered with ice and snow that they could not fly"; other birds with eyes covered with ice were taken in by farmers and were liberated, apparently unharmed, after the ice had melted off. The dead birds found were in good flesh, averaging 3 lbs. (1361 grams) per cock and 2 lbs. (907 grams) per hen.

Starvation of free-living Pheasants in north-central states seems more likely to occur in the northern-most parts of occupied range where acreages in cultivated crops are small and scattered. Most of the seemingly reliable second-hand information I have on Pheasants starving comes from northeastern and central Wisconsin and central and north-central Minnesota where not only is deep snow characteristic of winter environment but where there may be little suitable winter food for these birds when snow is light or absent. Beed (1938), however, reported an instance of severe Pheasant losses from starvation and exposure in northeastern South Dakota during the winter of 1936-37; of 126 Pheasants found dead and examined, the stomachs of 104 "contained no food whatever."

If corn or similarly high grade winter food exists in their habitats at all, the Pheasants show far more aptitude for getting it than do the Bob-whites, for the superior strength of the larger birds permits them to dig out food covered with snow or partially imbedded in ice or frozen ground. Moreover, if they do have to go hungry they can

withstand cold that underweight Bob-whites would find unendurable, as is illustrated by the following experimental data.

The initial weights of the game farm birds corresponded fairly well with the weights of Iowa Pheasants shot by hunters in Kossuth County (which has about the same latitude as Lansing) during open seasons. Forty-three wild cocks killed and weighed November 18, 1932, and 25 killed and weighed November 10, 1933, averaged 1252[2] grams and 1273 grams, respectively. Eighteen of the Lansing cocks, fully fleshed but of game farm origin, averaged 1132 grams in December, 1932. Thirteen wild hens killed November 18, 1932, averaged 932 grams, compared with the December average of 877 grams for 46 propagated hens.

The heavier cock Pheasants appeared to show somewhat more resistance to cold and hunger than the hens used in the experiments (Errington, 1936a), but the difference probably was not enough to introduce a significant variable into the data.

Initial and dying weights were secured for 32 Pheasants that died in the course of the experiments at Lansing. Of these 32 birds, 19 died in mild weather at an average minimum air temperature of 20.5° (F.). Minimum air temperatures for the two coldest nights were 4° above and 9° below zero. The average dying weight of the 19 birds was 504 grams or 55.1 per cent of their initial weight average of 914 grams.

The other 13 birds died during a cold wave when the minimum air temperatures varied from 9° above to 27° below zero, with an average minimum of 11.5° below. The average dying weight was 521 grams or 59.4 per cent of the initial average of 877 grams.

At the time of this cold wave—12 nights from February 4 to 15, 1933, of which but one showed a minimum air temperature above zero—39 Pheasants were in various stages of emaciation from drastic experiments. While some died, others were extremely emaciated yet survived even the 23° and 27° below zero nights of February 8 and 9, later to recover on full feed. There was no conspicuous mortality of underweight birds, the Pheasants apparently dying during ordinary winter weather when reduced to between 50 and 60 per cent normal weight. Extremely cold weather killed birds in but slightly better condition.

On the basis of the data presented, it would seem that Pheasants reduced to between 55 per cent and 60 per cent of their full weights may find themselves in a particularly critical zone in cold resistance, compared to a wider critical zone between about 55 per cent and 68 per cent of weight for Bob-whites. A correlation between size of Pheasants and Bob-whites and their respective tolerances as famished adults to sub-zero temperatures appears essentially what Kendeigh's findings would lead one to expect. Kendeigh, however, after reading a

[2] We did not have convenient access to metric scales large enough for the weighing of Pheasants; hence, weights of these birds were first taken in quarter ounces and later expressed in grams.

preliminary manuscript of this paper, doubted that the critical zone is wider in Bob-whites than in Pheasants but agreed that it comes at higher weight percentages (letter, March 22, 1935).

Acceleration of Loss Rates from Hunger

A. Bob-white.—The experiments with captive Bob-whites were intended to inquire into sustentative values of winter foods rather than into loss rates of the birds in detail. Moreover, the experiments of drastic nature (in which birds were starved or kept on very innutritious food) were of such short duration that it is virtually impossible to tabulate daily loss figures with any degree of completeness from individual bird records.

It may, nevertheless, be possible to improvise from these records a reasonably accurate and representative loss scale to express the day-by-day decline of typical Bob-whites during mid-winter starvation crises; in this way, the effect of food deprivation in the wild may conceivably be evaluated on the basis of how long it continues, provided that something is known of the initial and current weights of the wintering populations.

The average full weight of 17 captive Bob-whites yielding data on loss rates from acute starvation was 200.9 grams. Let us assume that a bird representing a composite of these weighs 190 grams or about 95 per cent of its full weight by February. Let us assume also that the mean air temperature is about 40° (F.), or a little lower, and that the supply of food suitable for Bob-whites is effectively cut off, as by very

TABLE 1

Composite of Maximum Loss Rates from Starvation Calculated from Records on 17 Captive Bob-whites at a Mean Air Temperature of 40° (F.)

Weight at start of hunger crisis	Loss[1] Day 1	Loss Day 2	Loss Day 3	Loss Day 4	Loss Day 5	Loss Day 6	Loss Day 7	Dying Weight
190 g. (94.5% full weight)	7 g. (3.5% full wt.)	8 g. (3.9% full wt.)	8 g. (3.9% full wt.)	10 g. (4.9% full wt.)	15 g. (7.5% full wt.)	17 g. (8.5% full wt.)	10 g. (4.9% full wt.)	115 g. (57.2% full wt.)

[1] Mainly contents of alimentary tract.

heavy snows or a thick glaze of ice. By piecing together the fragments of data at hand, we may then deduce that a strong Bob-white may starve in a minimum of about one week during fairly mild weather, losing weight at approximately the rates calculated for Table 1.

Deprivation of food the first day apparently may mean little real loss of weight to a prime Bob-white, as much of the 4 to 8 grams difference usually noted may be attributed to the emptying of the alimentary tract of food, although such losses have greater significance to small passerine birds without crops (Baldwin and Kendeigh, 1938).

Wild Bob-whites frequently "lay up" a whole day without feeding, especially after an early snow; and they sometimes hide one day or even two in succession when persistently harassed by shooters or by Cooper's Hawks (*Accipiter cooperi*) (Errington, 1931b).

The second day of a fast is commonly attended by a more distinct drop in weight than the first. This may amount to 8 or 10 grams, bringing the total loss for the first two days up to about 16 grams, inclusive of the unreplenished food used in metabolism and the material passed as feces. Birds down to 175 grams appear to lose at about the same rate for the next two days also, or sufficient to reduce them to the vicinity of 155 to 160 grams.

After the fourth or fifth day, the loss rate tends to be greatly accelerated. This accelerated rate usually varies between 14 and 18 grams per day and continues for about two days before decreasing to perhaps 10 grams on the day of death.

When Bob-whites are in poorer condition to begin with, they starve with greater rapidity, as they also do in cold weather, though not without some apparent exceptions. It may be suspected that some of the birds killed by cold waves early in the season may be hypersensitive individuals in comparatively good flesh.

Loss rates for undernourished birds in the course of more benign experiments show much the same tendency toward acceleration as body weight goes down, though reckoned more aptly in terms of weeks instead of days. In the wild, starving birds are often able to retard their loss rates by eating winter-available fruits and inferior foods (Errington, 1931a; 1936b), but, even so, a great many may weaken and die between the first and second weeks of a winter food crisis (Errington, 1933; 1936c). W. H. Long (quoted by Baldwin and Kendeigh, 1938) demonstrated distinctly greater food consumption of both Pheasants and Bob-whites in very cold weather.

B. Ring-necked Pheasant.—I know of no field data on weight loss rates of Pheasants from hunger, but two lots of experimentally starved

TABLE 2

AVERAGE DAILY LOSSES OF EIGHT PHEASANTS OF STARVATION LOT NO. 1 FROM JANUARY 20 TO FEBRUARY 2, 1933

Date	Jan. 20	Jan. 21	Jan. 22	Jan. 23	Jan. 24	Jan. 25	Jan. 26	Jan. 27	Jan. 28	Jan. 29	Jan. 30	Jan. 31	Feb. 1	Feb. 2
Min. temp. (F.)	9°	20°	34°	23°	27°	33°	24°	22°	14°	18°	27°	19°	20°	8°
Mean temp. (F.)	21°	33°	39°	34°	36°	37°	30°	56°	18°	24°	31°	28°	30°	16°
Average loss (g.)		18	34	16	21	18	28	30	50	28	38	36	38	62

[1]Four birds died, one on each of the following nights: January 28, 30, 31, and February 1.

Pheasants were productive of some data that may be of value. Each lot consisted of eight birds, the first lot starving from January 20 to February 2, 1933, at a mean temperature of 29.2° (F.), and the second from February 3 to 14 at a mean temperature of 1.6°. The birds of lot No. 1 averaged 1012 grams before starving and their maximum recorded average weight was 1065 grams; corresponding average weights

TABLE 3

AVERAGE[1] DAILY LOSSES OF EIGHT PHEASANTS OF STARVATION LOT NO. 2 FROM FEBRUARY 3 TO 14, 1933

Date	Feb. 3	Feb. 4	Feb. 5	Feb. 6	Feb. 7	Feb. 8	Feb. 9	Feb. 10	Feb. 11	Feb. 12	Feb. 13	Feb. 14
Min. temp. (F.)	-10°	-10°	-17°	0°	-14°	-23°	-27°	-9°	-12°	-7°	6°	-1°
Mean temp. (F.)	13°	1°	-3°	10°	-7°	-16°	-15°	3°	0°	13°	12°	6°
Average loss (g.)		46	25	12	30	46	48	40	28	54	28	54

[1] Four birds died, one on each of the following nights: February 8, 10, 11, and 13.

TABLE 4

ACCELERATION OF DAILY LOSS RATES OF UNDERNOURISHED PHEASANT EXPERIMENTAL LOTS

Birds in lot	Av. wt. start expt.	FIRST WK. EXPT.			SECOND WK. EXPT.		
		Av. daily loss		Mean temp. (F.)	Av. daily loss		Mean temp. (F.)
		Grams	Pct. wt.		Grams	Pct. wt.	
8	1006	34	3.4	—5°	93[1]	9.2	14°
6	990	12	1.2	33°	30	3.0	25°
6	1010	17	1.7	33°	28	2.8	25°
4	906	16	1.8	24°	28	3.1	32°
6	914	25	2.7	24°	35	3.8	32°
3	906	17	1.9	24°	30	3.3	32°
6	821	17	2.1	24°	19	2.3	32°
4	940	13	1.4	24°	6[2]	0.5	32°
8	1012	23	2.3	33°	57	5.6	25°
4	849	16	1.9	29°	12[3]	1.4	39°
4	863	15	1.8	32°	26	3.0	34°
4	884	8	0.9	32°	11[4]	1.3	34°
8	891	9	1.0	34°	9[5]	1.0	32°
4	955	15	1.6	29°	19	2.0	39°
4	792	5	0.6	34°	14	1.8	39°
6	821	19	2.3	39°	26	3.2	40°

[1] Experiment was concluded on fifth day of second week.

[2] Unaccustomed though comparatively adequate diet; decrease of loss rate was probably due to increased experience on the part of the birds.

[3] The six days following the first two weeks brought about a loss rate increased to 19 grams per day at a mean temperature of 23°.

[4] A pronounced acceleration of loss came the third week, when the birds lost an average of 27 grams per day at a mean temperature of 27°.

[5] Unaccustomed though comparatively adequate diet.

for lot No. 2 were 1006 grams and 1100 grams. We do not have exact temperature readings, hour by hour, but the average daily losses of the two lots may be tabulated along with the minimum and mean air temperatures (Tables 2 and 3).

The records of individual birds show a rather slow decrease of weight during the early stages of starvation with an evident acceleration of loss commonly beginning three or four days before death. Aside from this lethal decline, nearly all of the Pheasant lots used in more or less drastic food experiments suffered increasingly higher loss rates after the first week (Table 4).

TABLE 5

COMPOSITE OF MAXIMUM LOSS RATES FROM STARVATION CALCULATED FROM RECORDS ON 16 CAPTIVE PHEASANTS AT MEAN AIR TEMPERATURE OF 16.5° (F.)

Weight at start of hunger crisis	Loss[1] Day 1	Loss Day 2	Loss Day 3	Loss Day 4	Loss Day 5	Loss Day 6	Loss Day 7
1045 g. (95% full weight)	40 g. (3.6% full wt.)	15 g. (1.4% full wt.)	15 g. (1.4% full wt.)	15 g. (1.4% full wt.)	15 g. (1.4% full wt.)	20 g. (1.8% full wt.)	25 g. (2.3% full wt.)

Loss Day 8	Loss Day 9	Loss Day 10	Loss Day 11	Loss Day 12	Loss Day 13	Loss Day 14	Dying Weight
25 g. (2.3% full wt.)	30 g. (2.7% full wt.)	40 g. (3.6% full wt.)	55 g. (5.0% full wt.)	55 g. (5.0% full wt.)	65 g. (5.9% full wt.)	25 g. (2.3% full wt.)	605 g. (55% full wt.)

[1] Mainly contents of alimentary tract.

Temporary accelerations of loss rates also seemed to accompany the more decided drops in air temperature. There are too many variables incorporated in Tables 2 and 3 to present a clear picture of loss rates through hunger alone, but maximum loss rates of a typical bird in moderately cold weather may perhaps be calculated as for the Bob-white in Table 1. Let us say that our typical Pheasant before starving weighs 1045 grams or 95 per cent of its full weight of 1100 grams and that it dies at 605 grams or 55 per cent full weight (Table 5).

There seems to be no essential difference in the way that Pheasants and Bob-whites manifest the effect of undernourishment, except that the Pheasants lose weight more gradually than do Bob-whites and that they are better able to endure vicissitudes when in poor flesh. Experimental evidence suggests that Pheasants may retard starvation for brief periods far more effectively than Bob-whites by feeding upon low quality herbaceous foods (Errington, 1937).

Minimum Living Weights and Rates of Recovery from Malnutrition

A. Bob-white.—During the Wisconsin experiments, 7 Bob-whites were given access to or force-fed substantial food after being reduced almost to the point of death. Of these, all but two died. These two, as indicated elsewhere in this paper, barely survived after one had been reduced to 50 per cent of its full weight and the other to 58 per cent. I think this represents very nearly the minimum level from which recovery is possible under the best of circumstances. Recovery from such a desperate condition was very slow, and virtually no gain in weight was noted during the first week; during the second week, each bird gained about 10 grams; thereafter, at variable weekly rates.

TABLE 6

Rate and Degree of Recovery of Undernourished Bob-whites from Different Stages of Emaciation, January to April 1931; Mean Temp. about 40° (F.)

Per cent full weight to which reduced	No. of birds	Av. gain 1st week	Av. gain 2nd week	Av. gain 3rd week	Av. gain 4th week	Av. gain 5th week	Average per cent of full weight reached during recorded period of recovery
90%	4	8 g.	4 g.	3 g.			96% in 3 weeks[1]
80%	2	8 g.	3 g.	3 g.			89% in 3 weeks[2]
75%	4	9 g.	6 g.	2 g.			81% in 3 weeks[3]
70%	2	12 g.	6 g.				82% in 2 weeks
60%	6	8 g.	10 g.	6 g.	7 g.	2 g.	77% in 5 weeks
50%	1	1 g.	10 g.	1 g.	4 g.	17 g.	66% in 5 weeks

[1, 2, and 3] Weights not recorded weekly after the third week, but additional gains were plainly slight.

Table 6 gives the average rate and degree of recovery of undernourished captive Bob-whites for which data seem most reliable. The recovery rates were computed for experimental lots collectively to reduce variations due to contents of alimentary tracts of individuals. Except for birds in exceedingly poor flesh, the rate of recovery was most rapid in the first week after being placed on full feed; during the next two weeks as a rule the birds recovered about as much as they would with facility; subsequently, they gained a few grams per month until they reached the weight normal to them for the season of the year.

The degree to which the captive Bob-whites were run down had an evident influence on their rate of recovery. The first four birds of Table 6, which were reduced only to 90 per cent of their full weight, easily regained in two or three weeks nearly all that they had lost, whereas the 6 birds reduced to 60 per cent of their full weight had difficulty recovering past the 75 per cent level, even in five weeks. The distinction should be made plain that while the rate of recovery for the first three weeks on full feed was greater for the birds reduced to 60 per cent of their weight, these were months behind the recovery stage shown by the birds reduced only to 90 per cent full weight.

In the wild, a great deal of the Bob-white mortality attending late winter starvation crises may be charged to imperfect recovery from previous emergencies. During the winter of 1935-36, the Bob-white population on one of my observational areas near Ames, Iowa, declined from 21 birds on December 16 to 4 by February 21. The heavy decline came during the cold weather and blizzards of February, and seemed due to the wearing effect of the cold plus intermittent feeding. The birds would find good picking for a few days by following squirrels (*Sciurus niger rufiventer*) in a snow-filled cornfield; then more snow would cover all suitable food for another day or two until the wind subsided, and squirrels again exposed deep-buried corn ears. It seemed simply beyond the recuperative powers of the Bob-whites to cope with recurring, if relatively brief, periods of famine at this time, and their physical trend seemed to be steadily downward as long as the crisis lasted.

Weight data from Bob-whites at the southern and northern extremes of their geographic range suggest that winter loss of weight may be cumulative even during mild seasons. Ten Wisconsin specimens collected at random from ordinarily well fed (but occasionally hungry) coveys in March, 1931, averaged 178 grams or 90.6 per cent of the 196.5 gram average for early winter and mid-winter. Stoddard (1931, p. 76) found the average weight of a series of 43 mature cock Bob-whites trapped in Georgia and Florida during the last week in April and the first week in May to be 154.7 grams, which is 93.6 per cent of the 165.11 gram average obtained from 475 winter cocks. He did not have a large enough series of spring hen weights for comparison but states that hens gain weight as the breeding season approaches—which would make the average seasonal decline of the southern birds still less in proportion. It seems probable that only part of the late winter decline indicated by the Wisconsin specimens represents a normal seasonal rhythm, the rest presumably being the consequence of temporary deprivation of food during snow or sleet storms.

B. Ring-necked Pheasant.—Twenty-four Pheasants of the experimental lots were still alive after having been reduced to an average of 57 per cent of their full weights. These birds may be subdivided into (1) those killed for examination while obviously in critical conditon and before they had proved their ability to recover and (2) those placed on full feed after emaciation but not necessarily after having been irrecoverably run down.

The nine birds of the first group were killed for examination at an average of 477 grams or 52 per cent of their full average weight of 918 grams; one was down to 42 per cent, another to 43 per cent, and another to 48 per cent. The majority of these birds probably would have recovered with feeding.

The average minimum weight of 14 Pheasants that recovered was

621 grams or 61.2 per cent of their full average of 1015 grams, with two birds down to 46 per cent. One other individual was down to 41.2 per cent but became entangled in the wire of its pen and died; this bird seemed weakened beyond recovery, however, as it had continued to lose weight after having been given access to adequate food.

Table 7 summarizes the data on rate of recovery of undernourished Pheasants after having been returned to full feed.

The Pheasants worked with, in contrast with the Bob-whites, seemed to have little difficulty recovering completely from any non-lethal degree of emaciation. Recovery was quickly completed for birds down to 90 per cent of their full weights and was also complete for birds reduced

TABLE 7

RATE AND DEGREE OF RECOVERY OF UNDERNOURISHED PHEASANTS FROM DIFFERENT STAGES OF EMACIATION, JANUARY TO MARCH, 1933; MEAN TEMP. 25.4° (F.)

Per cent full weight to which reduced	Number of birds	Average gain first week	Average gain second week	Average gain third week	Average per cent full weight reached during recorded period of recovery
90%	3	65 g.	45 g.		100% in 2 weeks
85%	11	57 g.	37 g.	14 g.	97% in 3 weeks
80%	11	85 g.	28 g.	23 g.	95% in 3 weeks
75%	11	85 g.	71 g.	14 g.	94% in 3 weeks
70%	11	57 g.	57 g.	37 g.	89% in 3 weeks
65%	5	57 g.	57 g.	40 g.	81% in 3 weeks
60%	7	85 g.	57 g.	34 g.	77% in 3 weeks
55%	2	113 g.	85 g.		60% in 2 weeks[1]
45–50%	3	113 g.			54% in 1 week[2]

[1 and 2] Weights not recorded weekly thereafter, but evidence points to continued gains at rates corresponding to percentages of full weight.

much more, although, as expected, the more an individual had to gain back the more time was required.

Greatly emaciated birds regained approximately their full normal weight in about seven weeks under experimental conditions. Such birds would commonly recover over 60 per cent of their lost weight within the first three weeks, thereafter to gain at progressively diminishing rates.

Discussion

It is apparent from the existing experimental and observational data that winter food crises do not have the malignant significance to wintering Pheasants that they may have to Bob-whites in north-central states. Not only does the Ring-necked Pheasant have superior ability to withstand cold when in poor flesh, but it is much less likely to become emaciated from hunger in the first place. Its loss rates are less rapid in proportion to its weight even while starving, and there is evidence that it can retard starvation during crises by feeding upon buds and other herbaceous foods that are not of comparable nutritive value

to Bob-white (Errington, 1937). Dalke (1937) writes on the basis of his Pheasant work in Michigan, "In winter, the birds . . . may be observed feeding upon grass. If no grain or seeds are easily available, they may feed exclusively on grass for short periods." The Pheasant's greater strength is of distinct advantage to it if the food is covered by snow or ice; and its greater mobility and comparative independence of brushy cover takes much of the pinch out of many local food shortages. Furthermore, the facility with which it regains lost weight when opportunity permits is probably a major reason for the fewness of authentic records of Pheasant starvation in the field.

I am by no means advocating the replacement of the native northern Bob-white by the exotic Ring-necked Pheasant. There are biological, economic, and esthetic angles to questions pertaining to the desirability of encouraging Pheasants and Bob-whites that are not here considered; but, whatever may be the ramifications or controversial aspects of these, it should be useful to conservation workers merely to have a clearer idea of how much better the Pheasant is adapted to forage for a living when the ground is covered with snow and to appreciate more the significance of a uniformly reliable food supply to wintering Bob-white populations.

Summary

Field and experimental data from Iowa and Wisconsin, chiefly obtained between 1929 and 1934, indicate that susceptibility to cold attending decrease in weight was usually much more pronounced in Bob-whites than in Ring-necked Pheasants and that the latter were also better able to retard and to endure starvation as well as to recover after temporary food crises.

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