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EFFECTS OF DIETARY PROTEIN LEVELS ON BODY WEIGHT, FOOD CONSUMPTION, AND NITROGEN BALANCE IN RUFFED GROUSE

PATRICK R. BECKERTON

AND

ALEX L. A. MIDDLETON

ABSTRACT.—The effects of five dietary protein levels on the body condition of captive female Ruffed Grouse (*Bonasa umbellus*) were studied throughout the breeding cycle at Guelph, Ontario. Isocaloric rations containing protein levels (% dry matter) of 7.6, 11.5, 13.6, 17.0 and 20.1 were supplied to five test groups in late February 1979. Before egg-laying, test groups had similar body weight and food consumption ($P > 0.05$). However, while birds grew heavier, the daily values for nitrogen balance increased linearly as the level of dietary protein (%) increased ($P < 0.01$). Over the laying period, an increase in dietary protein (%) was associated with greater food consumption and, for a two-day period at least, higher nitrogen balance values ($P < 0.01$). During egg-laying, test groups receiving higher protein (%) rations generally lost less weight than groups receiving lower protein rations. Nevertheless, after egg-laying, test groups had similar food consumption and began new primary feather growth at about the same date ($P > 0.05$). A significant positive quadratic trend in body weight, but no significant trend in nitrogen balance, was evident among test groups about four weeks after egg-laying.

In several species of grouse, the condition of the female before egg-laying may be important in determining subsequent reproductive success (Siivonen 1957, Jenkins 1963, Gullion 1967, 1970). Savory (1975) showed that the daily food consumption before egg-laying was correlated with the subsequent egg production of Red Grouse (*Lagopus lagopus scoticus*), presumably through its effects on body condition. Body weight, also, is usually accepted as a measure of condition of Ruffed Grouse (*Bonasa umbellus*), with unseasonally low weights indicating poor condition (Bump et al. 1947).

If body condition before breeding does affect annual reproduction, it would be valuable to know the factors that determine condition. Apparently, the utilization of green plants early in the spring may help restore the body weight of the female Capercaillie (*Tetrao urogallus*; Siivonen 1957). For female Red Grouse, dietary nitrogen may be particularly important in establishing the "nutritive condition" and subsequent breeding success (Moss 1967, Watson and Moss 1972, Moss et al. 1975). Likewise, level of protein intake may also have an important influence on body condition of Ruffed Grouse. Because the glycogen and lipid reserves of Ruffed Grouse are normally low (Thomas et al. 1975), the birds may not normally be heavily dependent upon them. However, under adverse winter conditions they may deplete these limited reserves and thus have to utilize body protein as an energy source. Thus, because of winter protein catabolism, birds may enter the breeding season with suboptimal protein reserves. Additionally, during winter, Ruffed Grouse may select those aspen (*Populus* sp.) buds with the highest protein content (Doerr et al. 1974) suggesting that the birds have a high protein requirement at this time. To further investigate the association between body condition and protein availability, we examined the effects of five levels of dietary protein on body weight, food consumption and nitrogen balance of Ruffed Grouse throughout the breeding cycle.

MATERIALS AND METHODS

EXPERIMENTAL ANIMALS

The study was conducted at the Department of Zoology aviary, University of Guelph, Guelph, Ontario, from 23 January to 9 July, 1979. Forty-eight captive female Ruffed Grouse were housed individually indoors in cages measuring 60 cm wide × 90 cm high × 180 cm long. All females were kept in the same room at a mean temperature of 18 ± 7°C ($\bar{x}$ ± SD) under natural photoperiod. Each female was given a commercial ration (Turkey Developer, United Co-operatives of Ontario, Guelph, Ontario) and unlimited water.

Thirty-five of the 48 females originated from eggs of wild grouse collected in southern Ontario, which were subsequently incubated,

TABLE 1. Schedule for nitrogen balance trials.

Trial	Time
NB1	Before vernal increase in body weight (28 February–4 March)
NB2	During vernal increase in body weight (18–24 March)
NB3	When vernal body weight approached maximum (1–7 April)
NB4	Following laying of first egg
NB5	Ten days after laying of last egg
NB6	At emergence of the new fourth primary feather

TABLE 2. Schedule for body weight measurement.

Measurement	Time
WT1	23 January
WT2–WT6	Every second week following WT1
WT7	At laying of fourth egg
WT8	Ten days after laying of the last egg
WT9	At emergence of the new fourth primary feather

hatched, and the young raised in captivity. Twelve females hatched from eggs of captive Ruffed Grouse that had been artificially inseminated. The captive stock itself originated from eggs collected from nests of wild grouse. One female was of unknown origin.

On 3 February, each female was assigned randomly to a cage and to one of five test groups. Each test group had a similar proportion of yearlings (<12 months old) and adults (≥12 months old), mean age, mean body weight, and proportion of birds from captive versus wild origin.

TEST PROCEDURE

When egg-laying commenced, females were provided with nest boxes which were subsequently checked for eggs two to three times daily. Natural eggs were replaced with plaster analogues. Females were assumed to have completed a clutch of eggs (any complement of at least two normal-sized eggs produced by the same female for incubation at the same time) if they did not resume laying within 10 days of the last egg. Data from four females, classed as "non-layers," were not included in subsequent analyses (Beckerton 1980). As most females did not incubate their clutch of artificial eggs, the nest box, but not the eggs, was removed at this time and a nitrogen balance trial was begun. The artificial eggs were left with the female for the duration of the normal incubation period of 23.5 days (Bump et al. 1947) and then were removed from the cage.

The study was divided into three periods: pre-laying (24 January to onset of lay), laying (time between first and last eggs) and post-laying (time between last egg and emergence of new fourth primary feather) in order to facilitate analysis of the data. On 24 February, each female was allowed free access to a known quantity of test ration that was weighed one or two times weekly to the nearest 1.0 g. Plastic collars were attached to the feed trays to reduce spillage. Spilled food was weighed six times throughout the study for each female, and the food consumption data were adjusted accordingly. The quantity of food consumed by each female in a time period was also divided by the metabolic body weight ($W^{0.75}$, where W is the weight in grams; Savory 1975) to standardize food consumption by females of different body weights. Body weight at a particular time was found by interpolation between known weight measurements (see below). Analysis of food consumption started from 18 March because food consumption varied little before this date.

Six nitrogen balance (NB; nitrogen balance = difference between nitrogen ingested in the food and voided in the excreta) trials were conducted as shown in Table 1. Nitrogen balance trials lasted for six days except NB1 and NB4 which lasted for four and two days respectively, the shortened periods resulting from natural constraints of the experiment (e.g., addition of nest box so that eggs would not be laid on wire). At the end of the trials, the quantity of food consumed was recorded and the excreta, which had accumulated on the dropping trays, were collected and frozen for subsequent analysis.

Females were weighed to the nearest 5 g (Pesola spring scale, 1,000-g capacity) at biweekly intervals up to the onset of egg-laying (Table 2). Although carcass analysis of females from each group was contemplated, none was completed, for the sake of maintaining sample sizes. Likewise no eggs were taken for chemical analysis as they were required to complete a second aspect of the study (Beckerton and Middleton 1982).

TEST RATION FORMULATION

Five pelleted rations were prepared, using corn and soybean meal as the sources of protein (Table 3). The test ration for Group 1 was formulated to meet nutrient requirements of laying chickens (National Research Council 1977). Different quantities of corn and soybean meal (ratio 68:32) were replaced by corn starch and cellulose (ratio 84:16) of equal caloric value, to produce isocaloric (Atkinson, pers. comm.) rations representing a wide range of percent protein levels. By altering the pro-

TABLE 3. Percent ingredient composition of the test rations.

Ingredient	Test group 1	2	3	4	5
Ground corn	57.8	48.2	38.5	28.9	19.3
Soybean meal (49% protein)	27.2	22.7	18.1	13.6	9.1
Corn starch	1.5	13.5	25.4	37.4	49.3
Cellulose	0.0	2.2	4.4	6.6	8.9
Corn oil	4.0	4.0	4.0	4.0	4.0
Calcium phosphate	3.0	3.0	3.0	3.0	3.0
Limestone	5.7	5.7	5.7	5.7	5.7
Iodized salt	0.3	0.3	0.3	0.3	0.3
Vitamin-mineral mix[a]	0.5	0.5	0.5	0.5	0.5

[a] Supplies the following (mg/kg of ration): 2.3, vitamin A (retinol equivalents); 0.05, vitamin D (cholecalciferol equivalents); 5.5, vitamin E (dl-α-tocopheryl acetate); 1.1, vitamin K; 220.6, choline chloride; 6.6, pantothenic acid; 4.4, riboflavin; 0.4, folic acid; 17.6, niacin; 0.0088, vitamin B_{12}; 61.7, ethoxyquin; 2.2, calcium iodate; 7.7, copper oxide; 22.0, ferrous carbonate; 110.1, manganese oxide; 110.1, zinc oxide; 4.4, bacitracin; 125.0, methionine.

portion of protein in the test rations, the proportionate levels of other dietary compounds were unavoidably changed. However, the protein level exhibited the greatest change across test rations.

CHEMICAL ANALYSES OF THE TEST RATIONS AND EXCRETA

Samples of each ration were freeze-dried for 48 h and moisture content was determined by loss in weight. The samples were ground in a Wiley mill using a #20 screen, allowed to equilibrate to atmospheric moisture for 48 h, and then stored in air-tight jars. For completeness and potential future value, subsamples were later analyzed for residual moisture (by oven-drying), ash, crude protein, crude fat, and crude fiber using standard analytical techniques (Horwitz 1975). Gross energy (used in determination of metabolizable energy, ME) was determined using a Parr oxygen bomb calorimeter. All determinations were made in triplicate except crude protein, for which six determinations were made.

Excreta samples were freeze-dried for 48 h and then ground in a Wiley mill using a #20 screen. The samples were allowed to equilibrate to atmospheric moisture for 48 h and then were stored in plastic bags. Duplicate subsamples were later analyzed for gross energy (during the NB2 period only), residual moisture and nitrogen content. The NB2 period was selected to determine the nitrogen corrected ME content of the rations. Our rationale was that the birds would be better adjusted to their rations than during the NB1 period, but would not yet be influenced by active reproduction.

In all cases, nutrient determinations are expressed on a dry matter (DM) basis. Where large ($\bar{x} \pm$ 95% C.L.) discrepancies appeared between the duplicates, a third determination was made and the three values were averaged.

STATISTICAL METHODS

One-way analysis of variance and analysis of covariance were used to determine if the overall differences among the test groups were statistically significant ($P < 0.025$). Age group (yearling, adult), actual female age (1–6 years) and body weight before the start of the experiment were examined for significance as covariates ($P < 0.05$). Four outliers (>4 SD) were encountered when analyzing the nitrogen balance data. As these observations were thought to originate from measurement errors, they were excluded from the analyses. Regression analysis was used to subdivide the treatment sum of squares into a sum of squares due to a linear trend, quadratic trend, cubic trend and lack of fit. These trends were then checked for statistical significance ($P = 0.025$). Because many measurements were analyzed for the same experimental birds, $\alpha = 0.025$ was chosen as a precaution against inflated α levels (Beckerton 1980).

RESULTS

Crude protein (% DM) ranged from 7.6 (Group 5) to 20.1 (Group 1). Although metabolizable energy decreased slightly as the protein level of the diet decreased, the rations were practi-

TABLE 4. Proximate analysis of the test rations.

Component	Test group 1	2	3	4	5
Dry matter (%)	89.7	89.9	91.6	91.6	91.3
Crude protein (% DM)	20.1	17.0	13.6	11.5	7.6
Ash (% DM)	10.3	9.0	8.9	8.8	8.6
Crude fat (% DM)	7.4	6.8	6.5	6.1	5.1
Crude fiber (% DM)	2.4	4.0	4.8	5.8	7.4
Nitrogen free extract (% DM)	59.8	63.2	66.2	67.8	71.3
Gross energy (kcal/g DM)	4.27	4.12	4.16	4.09	3.93
Classic metabolizable energy (kcal/g DM)	3.47	3.30	3.34	3.28	3.13
Nitrogen corrected metabolizable energy, ME (kcal/g DM)	3.45	3.27	3.33	3.26	3.12
Calorie : protein ratio (cal ME/% CP)	172	192	245	284	411

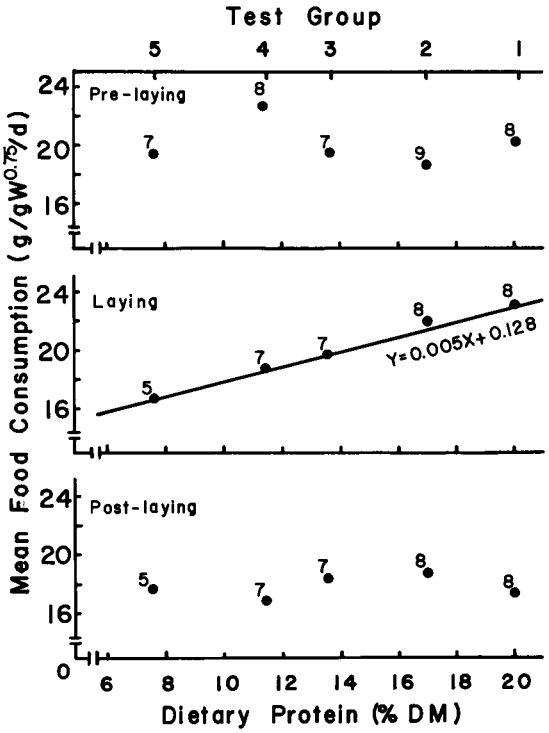

FIGURE 1. Mean food consumption for each of three time periods. Numbers indicate sample sizes. SE too small to register with plotted means.

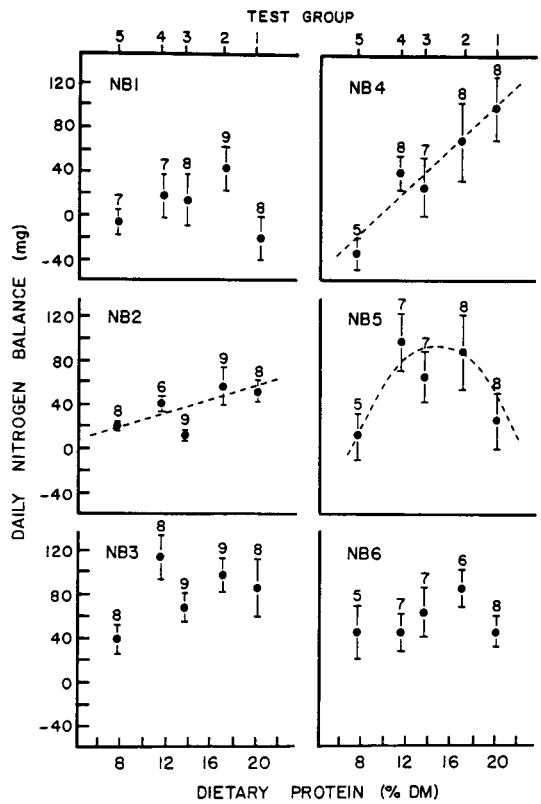

FIGURE 2. Daily nitrogen balance of the test groups for each nitrogen balance trial. Bars represent 1 SE. Numbers indicate sample sizes. Dashed lines indicate curves fitted by regression. (NB means nitrogen balance, e.g., NB2).

cally isocaloric. However, a decrease in protein level resulted in a curvilinear increase in calorie/protein ratio (C/P ratio). The largest increment in the C/P ratio was between Groups 4 and 5 (Table 4).

About four weeks before egg-laying, food consumption generally began to increase for all test groups. However, the test groups did not differ in the mean food consumption before egg-laying ($P > 0.05$), the overall mean and SE being 0.200 ± 0.007 g/g$^{0.75}$/d ($n = 37$ females). The mean food consumption for the laying period increased linearly ($P < 0.01$) as the protein level (%) of the ration increased (Fig. 1). In the post-laying period, the test groups did not differ regarding mean food consumption (0.178 ± 0.005 g/g$^{0.75}$/d, $n = 35$, $P > 0.05$).

For each of the nitrogen balance trials, the mean nitrogen balance (mg N/d) of each test group was plotted against the protein level (% DM) of the respective ration (Fig. 2). In each trial, test groups that received a higher dietary percent protein level also had a greater mean daily protein intake (g/d). Nitrogen balance was not significantly different among the test groups for the first (NB1) and third (NB3) nitrogen balance trials ($P > 0.05$). Increases in dietary protein level (%) were accompanied by linear increases in nitrogen balance during the second (NB2) and fourth (NB4) nitrogen balance trials ($P < 0.01$). Ten days after the last egg was laid, nitrogen balance (NB5) was related to dietary protein level in a positive quadratic manner. Although this was not statistically significant ($0.025 < P < 0.05$), there was at least an indication of a quadratic trend. Nitrogen balance was similar among test groups during feather molt ($P > 0.05$).

The late winter weight (WT4) and the subsequent spring weight (WT6) did not differ among the test groups ($P > 0.05$) (Fig. 3). After the fourth egg was laid, body weight (WT7) was related in a positive quadratic manner to the dietary protein levels received by the test groups ($P < 0.01$). Ten days after the laying period, body weights increased linearly as the protein level of the ration increased ($P < 0.01$). A quadratic relationship between body weight and dietary protein level was again evident during feather molt (WT9) ($P < 0.01$).

The weight of each female before the experiment started (WT2) was related to all subsequent measurements of body weight ($P < 0.01$). Yearling females weighed less during

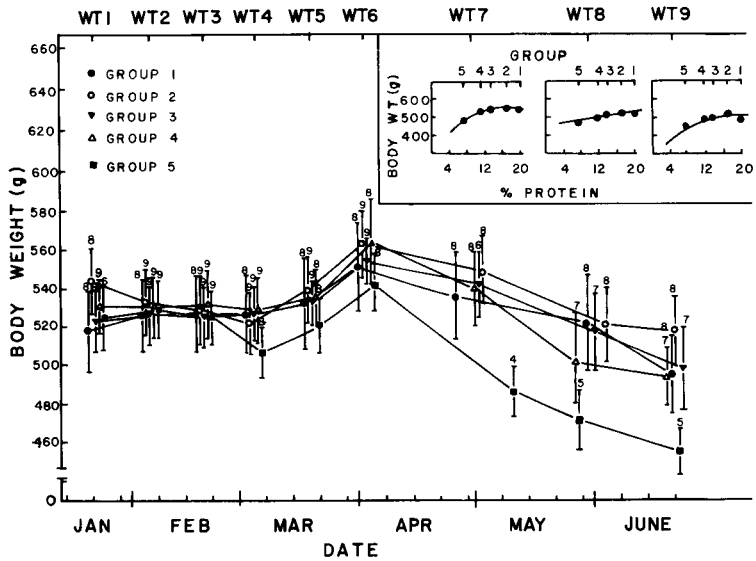

FIGURE 3. Mean body weights of the test groups. Bars represent 1 SE. Numbers indicate sample sizes. All test groups were weighed on the same day for measurements WT1–WT6 but the mean values are staggered to simplify the plot. Insets show quadratic (WT7 and WT9) versus linear (WT8) trends between body weight measurements.

molt (WT9) (455 ± 8 g, $n = 13$) than adult females (517 ± 9 g, $n = 24$, $P < 0.01$).

The weight change during laying that was attributed to the utilization of pre-breeding nutrient reserves during laying was found by comparing the body weight in late winter (WT4), before ovarian recrudescence, to the body weight after egg-laying (WT8), and following atrophy of the gonads (Fig. 3). All test groups lost weight during laying but females receiving higher protein rations tended to lose less weight than females receiving lower protein rations. Relative weight loss ranged from 0 g (Group 2) to 34 g (Group 5).

The mean date for the initial emergence of the fourth primary feather was 16 June ± 1 day ($n = 35$) with no differences found among the test groups ($P > 0.05$).

DISCUSSION

The observed pattern of body weight changes was similar to that reported previously for wild birds (Bump et al. 1947, Thomas et al. 1975), but the late winter decline was not as distinct. As the captive females in this experiment were held indoors, their energy requirements for thermoregulation were reasonably constant and presumably less than those for birds exposed to natural conditions; thus, weight loss may have been minimized.

In late winter (28 February–4 March), nitrogen balance (NB1) was not significantly different among test groups (Fig. 3). Body weights and food consumption had not begun to increase, suggesting that gonadal recrudescence had not started at this time (Breitenbach et al. 1963). Therefore, the only requirements for protein would likely be for body maintenance and this should be similar for all test groups.

By mid-March, all test groups showed similar increases in food consumption and body weight, suggesting that gonadal recrudescence had begun (Breitenbach et al. 1963). If birds feed to satisfy their requirements for energy (Hill and Dansky 1954, Barrett 1969, Price 1975), this equality of food consumption indicates that test groups had equal energy requirements during the pre-laying period, irrespective of the protein level of the ration. Presumably the increase in food consumption represented an increased energy requirement for development of all organs associated with reproduction.

The weights of the ovary, oviduct, body muscles and gastro-intestinal tract account for part of the vernal increase in body weight for several galliform species (Breitenbach et al. 1963, Pendergast and Boag 1973, Modafferi 1975). Consequently, the linear relationship between dietary protein level and nitrogen balance during this time (NB2) may have resulted in differential development of body components among the test groups of Ruffed Grouse, as has been found for Wild Turkey (*Meleagris gallopavo*; Pattee 1977). The development of some or all of these body components may represent a differential development of a labile reserve or protein (Kendall et al. 1973, Modafferi 1975) that can be utilized during egg production (Leveille et al. 1961, Fisher 1967).

Furthermore, the differences in nitrogen balance among test groups probably prevailed throughout gonadal recrudescence as indicated by differences in the weight of the first egg and dry weight of the first ovum (Beckerton 1980). That no significant differences in nitrogen balance were detected in early April (NB3) may be related to the observation that some females, being at a relatively advanced physiological stage, began egg-laying soon afterwards.

Despite the differences in nitrogen balance during the pre-laying period, test groups had similar body weights. However, body weight changes may also be associated with changes in the weights of fat deposits and/or body water content (Breitenbach et al. 1963, West and Meng 1968). Fluctuations in these latter components may have counteracted weight changes in other body components so that the carcass composition changed but the overall body weight was similar among test groups.

During egg-laying, females that received a high protein ration consumed more food than those that received a low protein ration. These differences may be explained on the basis of the caloric-protein ratio of the rations. Differences in the quantity of protein consumed and retained among test groups before egg-laying, may have induced initial variations in egg production (Beckerton 1980), and so established a requirement for different amounts of energy (food) during egg-laying. Variations in energy intake would lead to further differences in protein intake and the associated differences in nitrogen balance (NB4). Consequently, increases in dietary protein level (%) were associated with linear increases for: duration of laying, rate of laying, clutch size, weight of the first egg, mean egg weight, clutch weight, hatching success, chick weight at hatching, and chick survival (Beckerton 1980).

Nitrogen retention by Ruffed Grouse was apparently lower than that measured for Red Grouse (Moss 1977). For several reasons, however, the two results may not be comparable. First, the comparison is being made between forest- as opposed to tundra-adapted species that have strikingly different food habits (Johnsgard 1973). Second, the birds in the two studies were maintained under different environmental conditions. Third, nitrogen balance is affected by the energy content of the diet, level of food intake, quality (amino acid balance) and quantity of protein, and the previous nutritional status of the birds. Fourth, Moss (1977) measured nitrogen retention over the entire laying period while NB4 of this study was based on a two-day measurement following laying of the first egg.

High body weights during egg-laying (WT7) were associated with high dietary protein levels with the exception of Group 1 (20.1% protein), which also had a relatively, but not significantly, low weight before egg-laying (WT6). In the pre-laying period, the ration with 17.0% protein resulted in the highest nitrogen balance (NB2) and the highest level of protein (20.1%) actually produced a lower nitrogen balance. In the chicken, excess dietary protein caused a decrease in growth and produced stress (Scott et al. 1976). Possibly the high level of dietary protein (20.1%) during the pre-laying period was excessive and resulted in a low body weight that was detectable early in the laying period (WT7).

Nevertheless, body weights immediately after egg-laying (WT8) indicate that females receiving high protein rations used less nutrient reserve during egg-laying, than females receiving low protein rations. Also, nitrogen balance after egg-laying (NB5) indicates that a differential utilization of protein reserves may have occurred during laying. If an increase in dietary protein intake were coupled with a decrease in protein required for repletion of reserves, the net effect would be, as was observed, a positive quadratic trend in nitrogen balance.

Regardless of different reproductive performance (Beckerton 1980) and physical condition after egg-laying, all test groups consumed similar quantities of the isocaloric rations during the post-laying period, which may suggest they had similar energy requirements. However during molt (about four weeks after egg-laying), females that received high protein rations were still generally heavier than females that received low protein rations (WT9), with the exception of Group 1. During laying, Group 1 used the abundant dietary protein for egg production but during molt, relatively less protein was apparently required. As has been suggested for the pre-laying period, Group 1 may have been consuming excessive quantities of protein which could have resulted in reduced body weight. Despite the positive quadratic trend in body weight during molt, nitrogen balance was similar among test groups (NB6). Much of the protein reserve used during egg-laying may have been replaced by this time for Groups 1 to 4, and the trend in body weight may be related to some reserve, other than protein, that had not been fully repleted. However, although Group 5 had a nitrogen balance similar to that of the other test groups, the mean body weight was substantially lower. Thus Group 5 may still have had partially-depleted protein reserves and the recorded nitrogen balance may have been the maximum that was possible on the low protein ration.

Birds in test groups shed the fourth primary

feather about the same date. As Ruffed Grouse shed the first five primary feathers rapidly (Garbutt and Middleton 1974), the test groups likely began molting the first primary at about the same date. Thus, some factor(s) other than dietary protein must determine the onset of primary molt.

Our results showed that during egg-laying, females consuming foods with high protein levels maintained better physiological condition than those with low dietary protein levels. Presumably, an optimum level of protein intake exists which will result in peak female condition. This level was not identified in this study and few quantitative predictions can be made for wild Ruffed Grouse because of the uncontrollable differences in diet and environment. However, wild Ruffed Grouse are known to show dietary selection in winter (Doer et al. 1974), which may be related to a need to increase nitrogen retention as ovarian recrudescence occurs. Our data suggest that the degree of nitrogen retention, related to dietary protein level, varies in relation to the timing of egg-laying. This is understandable because the protein demand before egg-laying should be less than during egg-laying. However, for wild Ruffed Grouse, high dietary protein levels would be expected to result in better physiological condition even though the birds probably do not lack food protein outside the breeding season.

In captive situations where dietary and environmental conditions can be controlled, a ration with ME of 3.45 kcal/g DM and a protein level $\geq 20\%$ during egg-laying will result in the greatest food consumption, nitrogen balance, and least weight loss. By contrast, during the non-breeding period a ration with similar ME content but 11.5% protein should be adequate for maintenance. However, during ovarian recrudescence a level of approximately 17% protein should be provided for greatest nitrogen retention. These data have potential value for anyone considering the captive maintenance and propagation of Ruffed Grouse.

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LITERATURE CITED

BARRETT, M. W. 1969. Response of Ring-necked Pheasants to ecological factors and reduced metabolizable energy levels. Unpubl. M.Sc. thesis, University of Guelph, Guelph, Ontario.

BECKERTON, P. R. 1980. Effects of five dietary protein levels on reproduction of Ruffed Grouse. Unpubl. M.Sc. thesis, University of Guelph, Guelph, Ontario.

BECKERTON, P. R., AND A. L. A. MIDDLETON. 1982. Effects of dietary protein levels on Ruffed Grouse reproduction. J. Wildl. Manage. 46:569–579.

BREITENBACH, R. P., C. L. NAGRA, AND R. K. MEYER. 1963. Effects of limited food intake on cyclic annual changes in Ring-necked Pheasant hens. J. Wildl. Manage. 27:24–36.

BUMP, G., R. W. DARROW, F. C. EDMINSTER, AND W. F. CRISSEY. 1947. The Ruffed Grouse: Life History—propagation—management. New York State Conservation Department. Reprinted by Telegraph Press, Harrisburg, PA.

DOERR, P. D., L. B. KEITH, D. H. RUSCH, AND C. A. FISCHER. 1974. Characteristics of winter feeding aggregations of Ruffed Grouse in Alberta. J. Wildl. Manage. 38:601–615.

FISHER, H. 1967. Nutritional aspects of protein reserves, p. 101–124. *In* A. A. Albanese [ed.], Newer methods of nutritional biochemistry: with applications and interpretations. Vol. 3. Academic Press, New York.

GARBUTT, A., AND A. L. A. MIDDLETON. 1974. Molt sequence of captive Ruffed Grouse. Auk 91:421–423.

GULLION, G. W. 1967. Ruffed Grouse research and the road ahead. Conservation Volunteer, Sept.–Oct.:23–30.

GULLION, G. W. 1970. Factors affecting Ruffed Grouse populations in the boreal forests of northern Minnesota, U.S.A. Finn. Game Res. 30:103–117.

HILL, F. W., AND L. M. DANSKY. 1954. Studies of the energy requirements of chickens. I. The effect of dietary energy level on growth and feed consumption. Poult. Sci. 33:112–119.

HORWITZ, W. [ED.]. 1975. Methods of analysis. 12th ed. Association of Official Analytical Chemists, Washington, DC.

JENKINS, D. 1963. Population control in Red Grouse (*Lagopus lagopus scoticus*). Proc. XIII Int. Ornithol. Congr. (1962):690–700.

JOHNSGARD, P. A. 1973. Grouse and quails of North America. Univ. Nebraska Press, Lincoln.

KENDALL, M. D., P. WARD, AND S. BACCHUS. 1973. A protein reserve in the pectoralis major flight muscle of *Quelea quelea*. Ibis 115:600–601.

LEVEILLE, G. A., H. FISHER, AND A. S. FEIGENBAUM. 1961. Dietary protein and its effects on the serum proteins of the chicken. Ann. N.Y. Acad. Sci. 94:265–271.

MODAFERRI, R. D. 1975. Aspects of morphology in female Rock Ptarmigan (*Lagopus mutus*) during ovarian recrudescence. Unpubl. Ph.D. thesis, University of Alaska, Fairbanks.

MOSS, R. 1967. Probable limiting nutrients in the main food of Red Grouse (*Lagopus lagopus scoticus*), p. 369–379. *In* K. Petrusewicz [ed.], Secondary productivity of terrestrial Ecosystems. Vol. 1. Panstwowe Wydawnictwo Nuakowe, Warszawa.

MOSS, R. 1977. The digestion of heather by Red Grouse during the spring. Condor 79:471–477.

MOSS, R., A. WATSON, AND R. PARR. 1975. Maternal nutrition and breeding success in Red Grouse (*Lagopus lagopus scoticus*). J. Anim. Ecol. 44:233–244.

NATIONAL RESEARCH COUNCIL. 1977. Nutrient requirements of domestic animals, number 1. Nutrient requirements of poultry. 7th ed. National Academy of Sciences, Washington, DC.

PATTEE, O. H. 1977. Effects of nutrition on wild turkey reproduction in south Texas. Diss. Abstr. Int. B. Sci. Eng. 38(8):3489B.

PENDERGAST, B. A., AND D. A. BOAG. 1973. Seasonal changes in the internal anatomy of Spruce Grouse in Alberta. Auk 90:307–317.

PRICE, D. H. 1975. Some factors affecting the growth, development, reproduction, and energy metabolism of captive Ruffed Grouse, *Bonasa umbellus* (Linnaeus). Unpubl. M.Sc. thesis, University of Guelph, Guelph, Ontario.

SAVORY, C. J. 1975. Seasonal variations in the food intake of captive Red Grouse. Br. Poult. Sci. 16:471–479.

SCOTT, M. L., M. C. NESHEIM, AND R. J. YOUNG. 1976. Nutrition of the chicken. M. L. Scott and Associates, Ithaca, New York.

SIIVONEN, L. 1957. The problem of the short-term fluctuations in numbers of tetraonids in Europe. Finn. Game Res. 19:1–44.

THOMAS, V. G., H. G. LUMSDEN, AND D. H. PRICE. 1975. Aspects of the winter metabolism of Ruffed Grouse (*Bonasa umbellus*) with special reference to energy reserves. Can. J. Zool. 53:434–440.

WATSON, A., AND R. MOSS. 1972. A current model of population dynamics in Red Grouse. Proc. XV Int. Ornithol. Congr. (1970):134–149.

WEST, G. C., AND M. S. MENG. 1968. Seasonal changes in body weight and fat and the relation of fatty acid composition to diet in the Willow Ptarmigan. Wilson Bull. 80:426–441.

Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1, Canada. Present address of first author: Ontario Ministry of Natural Resources, Bracebridge, Ontario P0B 1C0, Canada. Received 22 July 1981. Final acceptance 30 June 1982.

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RECENT PUBLICATIONS

The Life of Birds. Third edition.—Joel Carl Welty. 1982. Saunders College Publishing, Philadelphia. 754 p. $27.50. The revision of this familiar textbook of ornithology just seven years after the last edition (noticed in Condor 77: 522) is a tribute to the progress of the science, the author's industriousness, and the market for such books. The character, organization, and bulk of the material are unchanged. Details have been extensively revised, however, especially in the chapters on reproduction, numbers of birds, ecology, and migration. That this edition is 130 pages longer than its predecessor is due to a change of format more than the addition of material. Certainly, one can find topics whose treatment is less up-to-date than one would like (e.g., vocalizations, community structure, and the early evolution of birds). Nevertheless, this remains the most readable, modern, comprehensive, and well-balanced introductory text currently available. Furthermore, advanced students and teachers, should they deign to consult it, will find the book often a good source for elusive facts and references.

The Living Bird. Nineteenth Annual of the Cornell Laboratory of Ornithology 1980-81.—Edited by Mary Heimerdinger Clench. 1982. Laboratory of Ornithology, Cornell University, Ithaca, NY. 164 p. Paper cover. $21.25 postpaid. The nine articles in this volume span a variety of New World birds: from the Boreal Owl to the Hooded Grebe of Patagonia, and from Hawaiian thrushes to the Pearl Kite in Trinidad. The major piece is a survey of the tyrant flycatchers by Melvin A. Traylor, Jr. and John W. Fitzpatrick. In addition, the volume is generously illustrated in color and black-and-white, mostly paintings and drawings. These specimens of bird art maintain *TLB's* reputation as far-and-away the most handsome ornithological periodical. Altogether, the package of scientific content, careful editing, and outstanding illustrations that Clench has produced is equal in quality, if not size, to those prepared by her forerunners, Olin Sewall Pettingill, Jr. and Douglas A. Lancaster.

Regrettably, the Cornell Laboratory has announced that it will suspend publication of the series with this issue, in order to use its resources for a new magazine, *The Living Bird Quarterly* (see below). It is hoped that *TLB* in its traditional format will resume publication in the future, probably as an occasional journal rather than as an annual. Not for nothing does the tailpiece of the present volume carry a drawing of a Phoenix.

The Living Bird Quarterly.—In the summer of 1982 the Cornell Laboratory of Ornithology started publication of this new magazine for its members. It is intended to have a wider appeal than *TLB*, yet occupy a niche not presently filled by any other American publication, a sort of *Natural History Magazine* about birds. As Sewall Pettingill originally conceived its predecessor, the Quarterly "will present varied articles, each significant and stimulating. The journal writes neither down to the amateur ornithologist, bird watcher or bird hobbyist, nor writes up to the professional ornithologist or biologist." The two issues thus far bear that out. Limited to 24 pages (and a format close to that of *Audubon*), each contains a few articles up to four pages in length, a non-technical résumé of an interesting piece of recent research, and news and notes about people and happenings at the Laboratory. Color photographs and paintings, many of them first-rate, are used abundantly, on the covers and inside, giving the magazine instant eye-appeal. In order to join the Laboratory and receive the magazine (basic membership $25.00) write to: Laboratory of Ornithology, Cornell University, P.O. Box 223, Etna, NY 13062.