LIVER AND SPLEEN WEIGHT CYCLES IN NON-MIGRATORY WHITE-CROWNED SPARROWS

By BARBARA BLANCHARD OAKESON

Modern field studies on nutritional states of migrating birds, such as those of Irving and Paneak (1952), have cast doubt on the idea that migration is a period of stress. The facts in this paper bear indirectly on this question and support the suggestion (Oakeson, 1954) that it is not stress involved in the long flight north, but, rather, inherent endocrine changes that are responsible for the low body, liver and spleen weights of male White-crowned Sparrows (*Zonotrichia leucophrys gambelii*) arriving in May at Mountain Village, Alaska. The sharp decline in organ weights between April and May in *Z. l. gambelii* coincides not only with migration but with the period of most rapid testis development (Oakeson, 1953). To find out whether this decline is a concomitant of gonad recrudescence *per se,* I analyzed liver and spleen weights in the permanently resident form, *Z. l. nuttalli,* for the corresponding period. This race is ideal for such comparisons, since its gonad cycle is, except for timing, identical with that of *gambelii.*

ACKNOWLDGEMENTS

Research reported in this paper was aided by three grants from the Committee on Research at Santa Barbara College. Most of the material on *Z. l. gambelii* referred to here was collected under the Fellowship Crusade National Fellowship of the American Association of University Women, to whom my thanks are due.

MATERIAL AND METHODS

I was fortunate in finding at Guadalupe, Santa Barbara County, California, areas where White-crowned Sparrows of the race *nuttalli* were abundant and could be banded in early fall. Identification of this race in winter is complicated by the presence of the morphologically similar migratory race, *Z. l. pugetensis.* One hundred and forty-seven *nuttalli* were banded, before any *pugetensis* arrived, in the fall of two successive years. When the latter did come, they kept close to cultivated fields and shunned the more nearly natural vegetation of the trap-sites, where *nuttalli* abounded.

Between November and March of three seasons, eighty-seven specimens were collected. For the gonad cycle, this period corresponds in *nuttalli* to that between January and May in *gambelii.* These specimens comprised three groups of birds which could be assigned with certainty to the race *nuttalli*: birds banded in early fall (31 specimens); birds taken in January or later with gonads larger than those of any *pugetensis* taken in the month in question (46 specimens); and birds taken on ground where only individuals singing the local *nuttalli* song-pattern occurred (10 specimens). Trapping methods and analyses have been previously described (Oakeson, 1953). The birds taken in mid-March had to be shot, since they do not trap readily at this stage. The comparative figures given in this paper for *gambelii* are based on 200 specimens, collected at Santa Barbara, California, and Mountain Village, Alaska.

All calculations include adults and birds of the year. In neither race is there any significant difference between the two groups as to body dimensions, and in the large number of *gambelii* previously analyzed, no consistent difference between age groups as to liver and spleen weights was found.

In tables 1 and 2 and figure 1, the data are grouped by months. Then, to check whether a direct relation exists between testis volume and ratio of liver to body weight regardless of collection date, I grouped the males of each race in seven arbitrarily de-

Table 1

Monthly Means of Body, Liver and Spleen Weights in *Z. l. nuttalli*

Males

Month	Number	Body weight (gm.) Extremes	Body weight (gm.) Mean	Liver weight (mgm.) Extremes	Liver weight (mgm.) Mean
Nov.	14	25.1–30.6	27.59±0.37	739–1136	919.2±31.6
Dec.	11	26.8–29.5	28.35±0.90	918–1099	987.5±15.7
Jan.	8	27.0–31.6	28.94±0.43	928–1159	1047.9±24.3
Feb.	10	27.3–30.4	28.95±0.29	950–1330	1087.0±35.2
Mar.	12	25.4–31.0	28.30±0.48	772–1107	932.9±37.9

Month	Number	Ratio, liver to body weight (per cent)	Spleen weight (mgm.) Extremes	Spleen weight (mgm.) Mean	Ratio, spleen to body weight (per cent)
Nov.	14	3.33	25–65	36.2±3.1	0.13
Dec.	11	3.48	21–56	36.5±3.4	0.13
Jan.	8	3.62	36–89	52.4±5.6	0.18
Feb.	10	3.75	14–45	30.1±2.7	0.10
Mar.	12	3.30	17–51	27.5±2.7	0.10

Females

Month	Number	Body weight (gm.) Extremes	Body weight (gm.) Mean	Liver weight (mgm.) Extremes	Liver weight (mgm.) Mean
Nov.	6	24.4–25.3	24.97±0.25	739– 954	836.3±25.6
Dec.	2	25.9–26.9	26.40±0.35	880– 921	900.5±14.5
Jan.	5	25.2–27.1	26.10±0.33	848–1058	954.8±37.5
Feb.	5	24.2–28.8	26.54±0.67	913–1085	996.6±33.3
Mar.	7	24.5–26.7	25.71±0.29	849–1198	950.4±32.4

Month	Number	Ratio, liver to body weight (per cent)	Spleen weight (mgm.) Extremes	Spleen weight (mgm.) Mean	Ratio, spleen to body weight (per cent)
Nov.	6	3.35	23–48	31.7±3.2	0.13
Dec.	2	3.41	37–49	43.0±4.3	0.16
Jan.	5	3.67	26–79	50.0±7.6	0.19
Feb.	5	3.76	13–75	41.8±9.5	0.16
Mar.	7	3.70	22–37	28.7±2.5	0.11

limited categories of testis volume and calculated the means of testis volume and ratio of liver to body weight (table 3). Since for testes below 3.00 mm.^{3}, size is not a reliable criterion of histologic stage, not all specimens in the second category are necessarily further advanced histologically than those in the first. From category III on, however, the higher the category, the more advanced the histologic stage. This method is especially valuable for *nuttalli*, which shows high individual variability. For example, testis volumes of six adult *nuttalli* collected at Guadalupe on the same day in February, 1953, ranged from 4.41 mm.^{3} to 75.94 mm.^{3}. Those of three birds of the year collected on March 14, 1953, ranged from 8.62 mm.^{3} to 130.97 mm.^{3}

RESULTS

The outstanding fact revealed in table 1 is that both sexes of *nuttalli* show cyclic changes in monthly means of liver and spleen weights comparable to those in *gambelii* as to direction, magnitude, and timing with respect to the gonad cycle. In males (table 2 and figure 1), the similarity extends to the detail that in spring the highest value for mean spleen weight is reached a month ahead of that for mean liver weight. The curves for monthly means of body weight are also comparable as to direction and timing but not as to magnitude, since *nuttalli* does not show the cycle of fat accumulation that migratory White-crowned Sparrows do. For the males of *nuttalli,* the standard errors indicate the chances to be about 95 to 5 that the increases in body weight and in liver weight between November and February are statistically significant. The decrease in liver weight between February and March, and in spleen weight between January and February have the same high probability of significance, and the increase in spleen weights between December and January falls only slightly short of this. The smaller numbers of females collected do not warrant comparable statistical analyses.

Table 2

Monthly Means of Body, Liver and Spleen Weights in Males of *gambelii* and *nuttalli* for Comparable Segments of the Gonad Cycle

Race	Month	Number	Total body wt. (gm.)	Liver weight (mgm.)	Ratio, liver to body wt. (per cent)	Spleen weight (mgm.)	Ratio, spleen to body wt. (per cent)	Testis volume (mm.^{3})
gambelii	Jan.	29	26.67	990.0	3.71	46.3	0.17	0.49
nuttalli	Nov.	14	27.59	919.2	3.33	36.2	0.13	0.59
gambelii	Feb.	17	26.40	949.9	3.60	42.5	0.16	0.50
nuttalli	Dec.	11	28.35	987.5	3.48	36.5	0.13	0.42
gambelii	Mar.	33	27.29	1025.5	3.76	46.8	0.17	1.01
nuttalli	Jan.	8	28.94	1047.9	3.62	52.4	0.18	3.85
gambelii	Apr.	35	28.31	1084.3	3.83	40.1	0.14	1.48
nuttalli	Feb.	10	28.95	1087.0	3.75	30.1	0.10	15.00
gambelii	May	8	25.94	775.4	2.99	19.6	0.08	148.99
nuttalli	Mar.	7*	28.59	873.7	3.06	26.4	0.09	155.45

= maximum.

= minimum.

* Only those specimens comparable in mean testis volume with *gambelii* of Mountain Village are included in the March averages.

Table 3 shows the same tendency in both races for a rise in ratio of liver to body weight through the first three or four categories of testis volume followed by a decline. In both races, the lowest mean value for ratio of liver to body weight falls in category VII. The highest mean values coincide almost as closely: in *nuttalli* the high point falls in category IV. In *gambelii,* where no material for category IV is available, it falls in category III.

One other variable not directly connected with testis volume changes must be considered. The birds of both races in category VII and the *gambelii* in category VI were shot, whereas almost all those in other categories were trapped. To assess the effect, if any, of differences in methods of collection would necessitate trapping large numbers of birds in category VII. This is not feasible. The available evidence does not suggest, however, that differences in collection methods affect the liver weights to any appreciable degree. First, since all *gambelii* included in the averages for categories I through III were trapped, the rise in mean liver weights cannot be due to differences in collection.

Table 3

Mean Liver Weight in Relation to Testis Volume in *gambelii* and *nuttalli*

Category of testis volume	Volume range ($mm.^3$)	Number *gamb.*	Number *nutt.*	Mean testis vol. ($mm.^3$) *gamb.*	Mean testis vol. ($mm.^3$) *nutt.*	Mean liver wt. (mgm.) *gamb.*	Mean liver wt. (mgm.) *nutt.*	Ratio, liver to body wt. *gamb.*	Ratio, liver to body wt. *nutt.*	Histologic stages included
I	0.90– 0.50	56	12	0.34	0.36	922.7	969.8	3.65	3.48	1, 2,
II	0.51– 1.83	74	15	1.00	0.79	1028.1	941.1	3.73	3.35	and 3
III	1.84– 5.00	11	6	2.31	3.56	1091.1	1052.5	3.79	3.70	4
IV	5.01– 20.00	....	12		7.26		1083.5		3.74	5
V	21.00– 56.00	(1)	3	(55.8)	41.59	(752)	1065.7	(2.91)	3.68	6
VI	75.00–131.00	3	2	120.25	103.46	846.3	995.5	3.26	3.51	7
VII	132.00–251.00	4	5	194.10	180.79	728.0	801.4	2.79	2.76	7

——— = maximum.

═══ = minimum.

Second, the mean ratio of liver to body weight for four *gambelii* shot between April 3 and April 10, 1954 (3.24), is too close to that for nine *gambelii* trapped during the same period (3.30) to suggest any wide discrepancy attributable to collection methods. Furthermore, no consistent difference in ratio of liver to body weight was found between shot birds and trapped birds with closely similar testis volumes.

To summarize, the results reveal a cycle of liver and spleen weights in *nuttalli* closely similar to that for the corresponding period of gonad development in *gambelii*. This casts further doubt on the concept of migration as a strenuous journey taxing the energy reserves of the bird. On the basis of the admittedly incomplete picture which weights alone reveal, we can say that if the energy reserves of *gambelii* are taxed by flying to Alaska, those of *nuttalli* appear to be taxed about as much by staying home. Actually, the seasonal changes in means of organ weights shown here probably do not reflect stress but rather an endocrine rhythm common to migrants and permanent residents alike.

DISCUSSION

With what events in the annual cycle of *nuttalli* do the declines in spleen weight and in body and liver weights coincide? Assuming that stages of behavior at Guadalupe are identical with those of the same race at Berkeley, California (Blanchard, 1941) and that timing in years of average weather conditions is about the same, then the decline in spleen weights between mid-January and mid-February would coincide with a time of intense competition. Young males would be establishing territories and seeking mates; adults would be defending territories and mates acquired in previous years. Such observations of behavior as I made at Guadalupe in January and February confirms these suppositions. The decline in body and liver weights between mid-February and mid-March should, in contrast, coincide with a period of orderliness and relative calm. Most birds should be mated, the patrol of boundaries should be temporarily in abeyance, the females should be building nests, and there would of course be no young. That the pairs at Guadalupe collected in mid-March had achieved this stage was shown by the lack of loud singing, the absence of disputes, and the frequent utterance of the "seep" call note. This is given by males whose mates are engaged in nest building. It is probable that copulation was also taking place.

The low point in body and liver weights falls, therefore, within a period of reduced activity, when the energy demands imposed by membership in the average sparrow community should be less than they had been a month before and less than they were to be a month later, when there would be young to feed. Studies such as Pearson (1954)

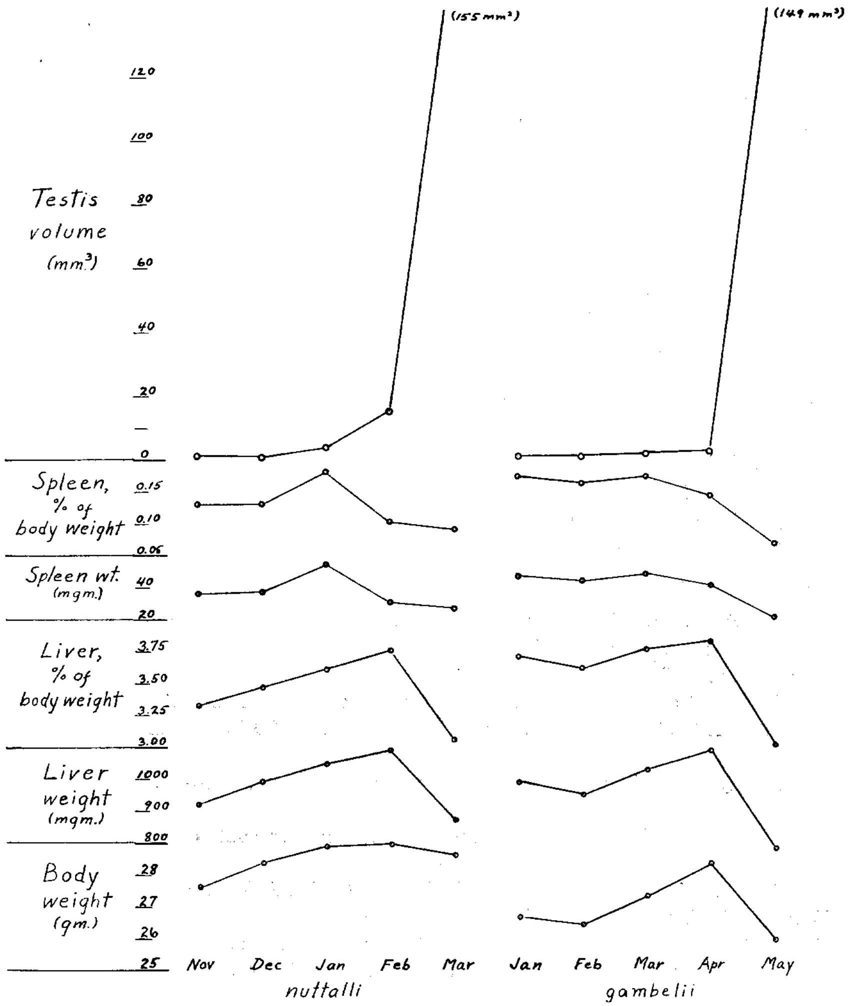

Fig. 1. Cyclic changes in organ weights of resident and migratory White-crowned Sparrows.

is conducting on the metabolism of native species should ultimately permit more accurate assessment of the energy requirements for specific phases of the breeding cycle.

Knowledge of the chemical basis for the liver weight changes is also needed. Odum and Perkinson (1951) analyzed the total body lipids of White-throated Sparrows (*Zonotrichia albicollis*) and the lipid content of eight body parts, including the liver. They found that subcutaneous lipids are an accurate index to total lipids, and that, except for the heart, all body parts varied seasonally in the same manner, but not necessarily in the same proportion, as did the total body lipids. Values for total lipids in livers of White-throated Sparrows for the four seasons, expressed as percentage of fresh weight of the organ, were as follows: postmigration, 6.4 per cent; midwinter, 10.4 per cent; molting period, 7.9 per cent; and premigration period, 10.6 per cent. Indirect measurements indicate that the water content of the fatty tissues was greater in spring than in winter. Thus weight changes do not completely reflect lipid changes.

If weights of subcutaneous fat and of total fat show a straight-line relationship in *Zonotrichia leucophrys* as they do in *Zonotrichia albicollis*, then we have one hint of the chemical basis for the increase in liver weights in *gambelii* during the premigration period. Another indirect indication is provided by Musacchia (1953), who found that in the premigration period of late summer there was a high level of fat turnover in four species of arctic migrants. Similar analyses of tissue lipids should be made for permanently resident forms. Since the rise in liver weight in *nuttalli* is not accompanied by increase in subcutaneous fat, substances other than lipids may be involved. It would be highly desirable to analyze the liver for total nitrogen and for glycogen.

For the present, in so far as White-crowned Sparrows are concerned, we can say that, whatever may be the energy demands on the organism during the period of most rapid gonad development, the pattern of liver and spleen weight changes is basically the same, whether the bird flies three thousand miles north or stays on the same spot. The low values for body weight and liver and spleen weights in *Zonotrichia leucophrys gambelii* newly-arrived at Mountain Village, Alaska, were therefore not necessarily signs of stress imposed by the flight north. From the indirect evidence presented here, migration appears to play a relatively minor part in determining the nutritional state of *gambelii* as it arrives on its breeding grounds.

LITERATURE CITED

Blanchard, B. D.

1941. The white-crowned sparrows (*Zonotrichcia leucophrys*) of the Pacific seaboard: environment and annual cycle. Univ. Calif. Publ. Zool., 46:1–178.

Irving, L., and Paneak, S.

1952. The weight and nutritional state of birds at the arctic terminus of migration. Report presented at the Third Alaska Science Conference, Mt. McKinley National Park, Alaska.

Musacchia, X. J.

1953. A study of the lipids in arctic migratory birds. Condor, 55:305–312.

Oakeson, B. B.

1953. Cyclic changes in liver and spleen weights in migratory white-crowned sparrows. Condor, 55:3–16.

1954. The Gambel's Sparrow at Mountain Village, Alaska. Auk, 71:351–365.

Odum, E. P., and Perkinson, J. D., Jr.

1951. Relation of lipid metabolism to migration in birds; seasonal variation in body lipids of the migratory white-throated sparrow. Physiol. Zool., 24:216–230.

Pearson, O. P.

1954. The daily energy requirements of a wild Anna hummingbird. Condor, 56:317–322.

Department of Biological Sciences, Santa Barbara College, University of California, Goleta, California, July 4, 1955.