LEAN DRY WEIGHT AND WATER BALANCE IN SLATE-COLORED JUNCOS

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ALTHOUGH a number of recent studies have analyzed the components of bird carcasses (Connell, Odum, and Kale, 1960; Rogers and Odum, 1964), there is still little information on several of the species widely used in the study of bioenergetics. One of these species, the Slate-colored Junco, *Junco hyemalis*, was the subject of the present study. Lean dry weight and water content were analyzed in wild birds and in birds held captive for varying lengths of time. Some previously unreported trends were noted which are important to work on the bioenergetics of wintering juncos.

METHODS

All specimens were netted between 24 February and 13 April 1965 at Kalamazoo, Kalamazoo County, Michigan. Of the birds captured on various days before 22 March, 31 were held in individual wire mesh cages (11.5 × 8.5 × 7.5 inches) sheltered from wind and rain but exposed to normal outdoor temperatures and light fluctuations. They were provided with a constant supply of water, millet, and chick starter feed. (Two of these birds died within two days of capture and were not included in later calculations.) After allowing for overnight removal of most material from the alimentary tract, the birds were sacrificed on 24 March. The empty gut is desirable; by dissection I have found that at maximum the digestive tract of juncos may contain about 2.0 g of undigested food and residue. This could represent a variation of about 10 per cent in calculated total wet weight and introduce error into fat and nonfat determinations. Most previous studies of carcass components have used birds which had collided with television towers during nocturnal migration. The guts of such birds are presumably empty.

An additional 30 birds, captured throughout the period, were held for three hours after capture and then sacrificed. Like the 29 caged birds, these wild, non-captive birds were from the local wintering population and showed no evidence of premigratory obesity. The three-hour holding period assured that the digestive tracts would be empty as verified by later dissection.

At death, wing length (chord) and total weight were taken on all of the 59 birds, which were then frozen and stored at −15°C until the first part of June, 1965. Immediately upon removal from the freezer, measurements were taken again. Of these birds, 5 showed a mean weight gain during storage of 0.26 g, representing 1.5 per cent of their average wet weight. The other 54 juncos showed a mean weight loss of 0.17 g, or 0.9 per cent of their average wet weight, with a maximum of 3.0 per cent loss in one individual. The weight changes probably are due to water loss or absorption during storage. Banks (1965) recorded variable weight changes in frozen specimens of small mammals, but thought that the small changes involved did not warrant the inconvenience of weighing specimens in the field prior to freezing. In this study, however, the changes would have significantly affected subsequent calculations. For this reason, the weights taken before freezing were used as the wet weights.

Specimens taken from the freezer were dissected quickly to determine sex and general condition, then macerated and returned immediately to storage before ex-

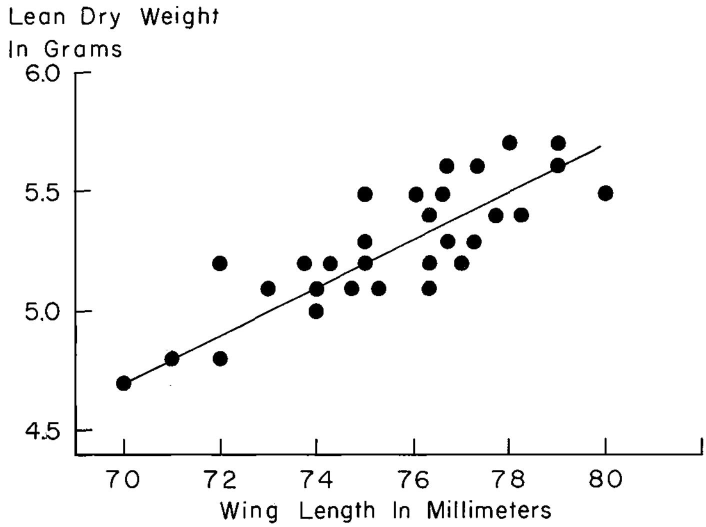

Figure 1. Relationship between lean dry weights and wing length in 30 freshly netted *Junco hyemalis*. The line was fitted by eye to means of each wing length class (nearest even millimeter below actual measurement).

tensive thawing. After 24 hours they were removed and placed in a vacuum desiccator. Water was drawn off at < 1.0 mm Hg pressure and caught in a cold trap, with the use of trichloroethylene and "dry ice." Complete dehydration was completed in 48 hours. In this process, the cooling by sublimation keeps the specimens at 0°C until they are dry. Odum and his co-workers have used a vacuum oven at 40°C for preliminary drying of the birds (Rogers and Odum, 1964). Freeze-drying may prevent the small volitilization losses which occur at the temperatures of the vacuum oven. Although Odum has experimented with freeze-drying techniques (L. D. Caldwell, pers. comm.), no comparison of results from the two processes has been published.

Specimens were again weighed immediately after removal from the freeze-drying apparatus, and the amount of water lost was recorded. Each specimen was then mixed with 95 per cent ethanol in an electric blender, the dissolved fat was strained through a cloth filter, and the residue boiled twice with petroleum ether over a hot water bath with intervening filtration. After a final filtration, the residue was dried and weighed. The resulting lean dry weight and lost fat content were recorded.

LEAN DRY WEIGHT

Lean dry weight was found to increase directly with body size as measured by wing length (Figure 1). The captives are not shown on the graph, but both the freshly netted juncos and the birds held in captivity showed this positive correlation. In general a 1.0 mm increase in wing length seemed to reflect a 0.1 g increase in lean dry weight. This observed trend is similar to that described for other species (Connell *et al.*, 1960; Rogers and Odum, 1964). Although it might be expected that body volume

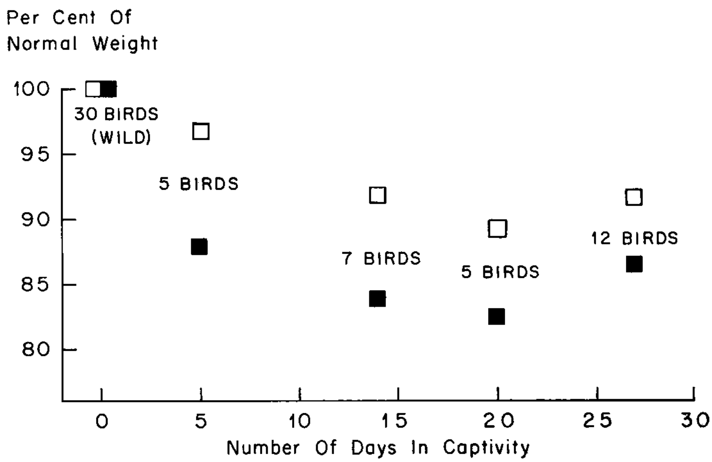

Figure 2. Weight loss of nonfat components in captive *Junco hyemalis*. Dark squares indicate lean dry weight as per cent of normal weight for wild juncos of the same mean wing length. Open squares represent the same per cent of water weight.

(weight) should show an exponential relationship to wing length, this is not always demonstrated by measurements from small birds (e.g., Rogers and Odum, 1964: figures 1 and 2).

Sex, age, and fat levels were found to have essentially no relationship to the lean dry weight when birds of the same wing length were compared. This conclusion is also in accord with previous studies of other species.

Loss of Nonfat Weight in Captive Birds

Lean dry weight and water content determinations on the 29 captive birds indicate that both of these nonfat components decreased with increased length of captivity, to a minimum on about day 20 (Figure 2). There seemed to be an increase after this time. Analysis of variance indicated that the differences among the means for the different lengths of captivity were significant at the 5 per cent level. King and Farner (1959) reported an average difference of about 1.0 g between the nonfat weights of wild White-crowned Sparrows (*Zonotrichia leucophrys*) and outdoor captives which had been held for four to nine months. Thus their captive birds showed a 4.1 per cent loss of lean dry weight; juncos in the present study showed a loss of 12.7 per cent from normal nonfat weight after 20 days of captivity, but only 10.1 per cent after 27 days (Table 1). It seems reasonable to suggest that at least Slate-colored Juncos captured in late winter and held outdoors should show an immediate decrease in nonfat components, followed by an increase to some stabilized position below normal weight. The rate of change, maximum loss, timing, and final

TABLE 1

WEIGHT LOSS OF NONFAT COMPONENTS IN CAPTIVE SLATE-COLORED JUNCOS

Period (days of captivity)	*N*	*Average loss at end of period (per cent of normal)*[1]			*Rate of change/day for the period (per cent)*[2]		
		Lean dry weight	*Water*	*Total nonfat wet weight*	*Lean dry weight*	*Water*	*Total nonfat wet weight*
1–5	5	11.8	3.5	6.0	2.36	0.70	1.20
6–14	7	15.7	8.7	11.0	0.43	0.58	0.56
15–20	5	17.3	10.5	12.7	0.27	0.30	0.29
21–27	12	13.2	8.6	10.1	0.59	0.27	0.37

[1] Normal refers to the respective mean weights of the nonfat components of wild juncos netted and sacrificed in the same season as the captive birds, and of the same average wing length.

[2] Percentages are based on the respective average weights found for the end of the preceding period.

stabilization point may or may not be dependent upon environmental conditions. The decrease may be a result of some psychological effect, a change in diet, or most probably inactivity (resulting in muscle atrophy accompanied by a shift in water content to restore normal water balance).

WATER BALANCE

There is an apparent lag in the adjustment of water balance at the time of initial loss of lean dry weight in captive birds (Figure 2). If water balance involves a constant relationship between water and nonfat dry material, the per cent loss per day of the two components should be the same. However, lean dry weight is lost at a faster rate than water for at least the first 5 days, and there is no return to the initial ratio within 27 days (Table 1).

In fact, the lag in adjustment is not nearly as great as it might seem since equilibrium does not involve a constant ratio of water to nonfat material (Table 2). Freshly netted juncos in good condition show a negative correlation of water index (water content/lean dry weight, as used by Odum *et al.*, 1964) to lean dry weight, meaning that birds of lower lean dry weight apparently require a proportionately higher water content. Captive birds, then, can be losing nonfat dry weight at a faster rate than they are losing water, and still be in water balance. Of the captive birds in this study, only that group in captivity for the shortest time (five days) showed any statistically significant deviation (at the five per cent level) from normal water balance at their new lean dry weight. These birds were 0.11 over their normal water index. Since all other captives held for longer than five days had water indices similar to wild birds of the same lean dry weights, it seems reasonable to suggest that the trend of higher water indices for birds of lower lean dry weights holds true for individual birds as they lose weight in captivity.

TABLE 2
WATER CONTENT OF FRESHLY NETTED SLATE-COLORED JUNCOS RELATIVE TO LEAN DRY WEIGHT

Lean dry weight (g)	*N*	*Water content mean and range (g)*	*Water index*[1] *Mean ± S.E.*
5.7–5.8	2	12.1 (11.2–13.0)	2.10
5.5–5.6	7	11.8 (11.0–12.5)	2.14 ± .04
5.3–5.4	6	11.7 (11.2–12.4)	2.17 ± .04
5.1–5.2	11	11.3 (10.7–11.9)	2.21 ± .02
4.9–5.0			2.24[2]
4.7–4.8	3	11.0 (10.9–11.2)	2.28 ± .03
4.5–4.6			2.31[2]
4.3–4.4			2.35[2]
4.1–4.2			2.38[2]

[1] Grams H_2O/gram lean dry weight.

[2] Estimated from extension of other water indices. Although wild birds in good condition do not generally have lean dry weights as low as 4.5 g, the extension is probably valid for captive birds. The 29 captives with lean dry weights of 4.1–5.0 g exhibited water indices of the same linear relationship.

The trend of decreasing water index with increasing lean dry weight within a species has not previously been reported and should prove to be of special interest if it is generally applicable. For instance, Odum *et al.* (1964) noted that migrant Parula Warblers (*Parula americana*) killed at a television tower in Florida showed a higher water index in spring than in autumn. Their suggested explanation of this was that the spring birds had lost weight due to catabolism of protein during the long trans-gulf migration; water had been kept at high levels through replacement by fat metabolism, but a negative nitrogen balance prevented replacement of protein (the major constituent of lean dry weight). This suggestion seems inconsistent with their further statement that nonfat components (presumably including protein) are homeostatic in Parula Warblers having fat indices over 0.3, since their birds in spring had an average fat index of 0.49. It seems entirely possible, on the basis of conclusions drawn in the present study, that the higher water indices noted by Odum and his co-workers in their spring migrant Parula Warblers were from a population with normally lower lean dry weights than fall migrants. If this were the case, there would be no need to postulate detrimental protein metabolism in the trans-gulf flight.

Variation of fat in the captive birds in this study had no effect on the indicated trends in water balance, nor on water levels in general. This finding is consistent with those of Rogers and Odum (1964) for several species of warblers.

The only other published values for nonfat components of wild Slate-colored Juncos (Johnston, 1962) indicate mean water and nonfat dry weights somewhat above those of this study. In that report 12 freshly netted juncos had a mean nonfat dry weight of 6.2 g and a mean water content of 12.4 g. The resulting mean water index of 2.00, however, compares favorably with the figure predicted by an extension of Table 2 in the present study (2.03). The heavier weights found by Johnston may have been normal for the geographical population with which he was working (wintering birds of the area around Winston-Salem, North Carolina).

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Summary

In all, 59 Slate-colored Juncos, *Junco hyemalis*, captured in late winter in Michigan, were analyzed for nonfat body components. Loss of these components in 29 captive birds was investigated. The other 30 birds were sacrificed three hours after capture. These latter individuals showed a positive correlation between wing length and lean dry weight that was unaffected by sex, age, or fat levels. A 1.0 mm increase in wing length reflected a 0.1 g increase in lean dry weight. The average junco of this study had a 76 mm wing length and a nonfat dry weight of 5.3 g.

Although birds of lower lean dry weight have a lower water content, the ratio of water to nonfat dry weight (water index) is higher. This seems to hold true for individual birds as they lose weight, as well as for comparison of two birds of different weights. The average junco had a water index of 2.17.

Captive birds lose nonfat dry weight and water rapidly for the first several days of captivity, probably as the result of inactivity, with only a slight lag in water balance adjustment (adjustment takes two weeks or less). The nonfat components seem to reach a minimum after about three weeks of captivity, and then return to a point slightly below normal.

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