Basal Metabolism of the Apapane: Comparison of Freshly Caught Birds with Long-term Captives

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Although the overwhelming majority of researchers studying avian metabolism have used captive birds, scant information is available concerning the metabolic consequences of captivity. This is particularly unfortunate, because avian physiological ecologists have been concerned with extrapolating laboratory determinations of basal metabolic rate ($\dot{H}_b$) to the field and with assessing adaptations in $\dot{H}_b$ by comparing measured values with rates predicted allometrically (e.g. Weathers 1979, MacMillen 1981). If the duration of captivity had a systematic influence on $\dot{H}_b$, evaluating metabolic adaptations would be difficult, and field extrapolations might be inaccurate. To investigate whether or not captivity *per se* affects metabolism, we compared the $\dot{H}_b$ of Apapanes (*Himatione sanguinea*, Fringillidae) that had been held for 1 yr in an outdoor aviary with that of freshly caught individuals. Our data indicate that the length of time aviary birds are held in captivity has little effect on $\dot{H}_b$, but that the length of time they are fasted before their $\dot{H}_b$ is measured has a pronounced effect.

The birds used in this study were collected near the Hawaii Field Research Center (elev. 1,220 m), Hawaii Volcanoes National Park (19°30′N). One group (old captives) was maintained for a year in a small aviary (2.2 × 1.5 × 1.2 m) on a diet of 20% sugar solution plus vitamins, Gerbers high protein baby cereal, and various fruits and greens *ad libitum*. The old captives were protected from the region's frequent rains by the aviary roof, but they were exposed to prevailing temperatures and photoperiods. The other group (freshly caught birds) was captured near the research center with mist nets and held in cages in the laboratory until nightfall; $\dot{H}_b$ then was determined. These birds were released the following morning. All measurements were made during December 1980. Rates of oxygen consumption and evaporative water loss were determined at night between 1800 and 0200 on postabsorptive birds that had been resting in darkened 4-l metabolism chambers for at least 2 h. We maintained air temperature at 32–34°C during the determinations by submerging the metabolism chambers in a controlled temperature water bath. Body temperature (intestinal) was determined immediately after the metabolic run with a YSI telethermometer (Series 511 probe). Details of the apparatus and calibration procedures are presented elsewhere (Weathers and van Riper 1982).

Although old captives tended to be heavier than freshly caught birds (Table 1), their weight ranges overlapped, and the difference was not statistically significant ($P > 0.10$; Mann-Whitney U-test). Indeed, none of the two groups' measured parameters differed significantly (Mann-Whitney U-test). Apparently, the conditions under which we housed the Apapane sufficiently mimicked their wild counterparts' environment so that the birds maintained normal metabolic function despite their spending a year in captivity. We suspect that the similarity of the old captives' responses to those of new captives partly resulted from subjecting old captives to the same temperature and photoperiod as those of their wild counterparts. Additionally, aviary housing permitted the birds a nearly normal range of physical activity, and this could be a critical factor. In many avian ecophysiological studies, birds are maintained in small cages rather than aviaries for several weeks before measurement. The flight muscles of cage-housed birds atrophy, and their powers of flight become impaired (pers. obs.). Whether or not this affects $\dot{H}_b$ is uncertain, but studies of cage-housed birds are clearly needed.

Combining data for both old and new captives, we determined that our Apapanes' nighttime $\dot{H}_b$ averaged 27.5 kJ/day ($n = 8$). This value is 18% higher than that predicted for a 14.5-g passerine bird (Aschoff and Pohl 1970) and lies above the 95% confidence interval (20.2–24.5 kJ/day) for the predicted value. A substantially lower value (21.5 kJ/day, $n = 7$) was obtained by MacMillen (1981), who measured the $\dot{H}_b$ of freshly caught Apapane (from the same locality) during the day. His value is 23% lower than that predicted for a 12.9-g passerine bird (mean weight of his birds) and lies below the 95% confidence interval (25.0–30.4 kJ/day; Aschoff and Pohl 1970). Thus, two groups of researchers studying the same population obtained quite different values for $\dot{H}_b$, despite using the same measurement techniques. Because differing conclusions about the metabolic adaptation of Apapanes are possible depending upon which of the two $\dot{H}_b$ valves is chosen, identifying the reason for the observed variation is important.

There were two major differences between our study and MacMillen's that could have contributed to our dissimilar results. First, our measurements were made during December, whereas MacMillen's were made during July and August. In small, temperate-zone birds $\dot{H}_b$ is typically higher in winter than in summer—a response to the seasonal change in temperature and photoperiod (Weathers and Caccamise

TABLE 1. Oxygen consumption ($\dot{V}_{O_2}$), evaporative water loss ($\dot{m}_{we}$), and body temperature (T_b) of *Himatione sanguinea*.[a]

Status	n	Mass (g)	$\dot{V}_{O_2}$ [cm³O₂ (g·h)⁻¹]	$\dot{m}_{we}$ [mg H₂O (g·h)⁻¹]	T_b (°C)
Old captives	4	15.5 ± 2.3	3.91 ± 0.32	7.00 ± 3.32	40.7 ± 0.5
Freshly caught	4	13.5 ± 1.7	3.97 ± 0.39	6.61 ± 1.65[b]	41.2 ± 0.9[b]

[a] Values are mean ± SD.
[b] Value based on three individuals.

1978). Tropical regions exhibit little seasonality with respect to temperature, but seasonal changes in photoperiod (albeit small) and rainfall can serve to entrain annual cycles (see King 1976, Murton and Westwood 1977). Whether or not tropical birds possess seasonal cycles in $\dot{H}_b$ is uncertain, however, and their role in the current situation is problematical.

The second major difference between the two studies was that MacMillen's birds were subjected to a longer period without food before measurement than were our birds. He captured birds one day, held them overnight, and measured $\dot{H}_b$ the ensuing day. Thus, his birds were fasted for a full 24 h, whereas ours were fasted only 6–12 h. Small birds achieve a postabsorptive state in as little as 2–3 h (Cade et al. 1965) and exhibit decreases in body temperature (T_b) and $\dot{H}_b$ below the initial postabsorptive level if fasting is prolonged (see Shapiro and Weathers 1981). The time required for $\dot{H}_b$ to fall below the initial postabsorptive level apparently varies inversely with body size. In the tropical manakins *Pipra mentalis* and *Manacus vitellinus* (14–18 g), fasts as brief as 12 h elicited substantial reductions in both T_b and $\dot{H}_b$ (Bucher and Worthington 1982), whereas in the 29-g White-crowned Sparrow (*Zonotrichia leucophrys*) $\dot{H}_b$ decreased only during the second night of fasting (Ketterson and King 1977). Although MacMillen did not report T_b for his honeycreepers, it seems likely that the longer period of fasting he employed contributed to their lower $\dot{H}_b$. The T_bs we measured are within normal limits for small birds, which indicates that our $\dot{H}_b$ values correspond to normal postabsorptive conditions.

Our findings have two major implications for students of physiological adaptation. First, they indicate that the $\dot{H}_b$ of birds held in aviaries for up to a year may be comparable to that of wild individuals exposed to the same temperature and photoperiod. Second, they emphasize the need for simultaneous measurements of T_b and $\dot{H}_b$, and the necessity of chosing appropriate fasting intervals.

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