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Diurnal resting metabolic rates of accipiters.—One of the major sources of error in estimating avian daily energy expenditure with time budgets is the estimate of maintenance metabolism (Weathers et al. 1984, Goldstein 1988, Nagy 1989). Resting metabolic rate (RMR) of a species of interest is often calculated from an allometric equation derived from measurements on other species. For example, Aschoff and Pohl's (1970) allometric equations for non-passerine birds are typically used to estimate active phase and resting phase RMR's of falconiforms (Tarboton 1978, Wakeley 1978, Koplín et al. 1980), but they do not include data from falconiforms. Wasser (1986) demonstrated that the relationship of RMR to body mass during the resting phase of falconiforms does not conform well to the predictions of Aschoff and Pohl (1970).

The RMR during the active phase of the daily cycle is approximately 24% higher than during the resting phase in some non-passerine species (Aschoff and Pohl 1970). Our ob-

jectives were to: (1) measure active phase RMR in accipiters, a group of falconiforms for which few metabolism measurements are available; and (2) compare our empirical results with the predictions from allometric equations in the literature.

Methods.—Metabolism was measured using Sharp-shinned Hawks (*Accipiter striatus*), two females and one male; Cooper's Hawks (*A. cooperii*), three females and two males; Northern Goshawks (*A. gentilis*), one female and one male; and a Black-and-White Goshawk (*A. melanoleucus*), one female. All birds were adults, thus minimizing potential variation in metabolic rates resulting from age class differences.

Five of the accipiters (the Black-and White Goshawk, the two Northern Goshawks, and two of the Cooper's Hawks) were long-term captives from a private breeding and falconry facility in San Diego, California. These birds were maintained in outdoor aviaries under natural conditions of temperature and photoperiod. The metabolism measurements of these birds were taken at the San Diego facility during September 1988.

The six additional birds (the three Sharp-shinned Hawks, and three of the Cooper's Hawks) were migrants that were trapped in bow nets or mist nets at the southern end of the Goshute Mountains in Elko County, Nevada, during September 1985. The measurements were taken near the trapping site soon after capture and the birds were released after the measurements were completed.

To collect the metabolism measurements, we confined each bird in a metabolism chamber of 4–30 L depending upon the size of the bird. We measured the temperature within the chambers with a copper-constantan thermocouple. The chamber temperatures ranged from 19°C–31°C, within the thermoneutral zone of most raptors (Wasser 1986).

We measured the rate of oxygen consumption ($\dot{V}O_2$ in L O₂ min⁻¹) of each bird in an open-flow system using a portable Ametek S-3A oxygen analyzer that had been calibrated with atmospheric air. We removed carbon dioxide and water from the air stream by circulating the air through Ascarite and Drierite after it exited the metabolism chamber. Air then passed through a rotameter that was calibrated with a Vol-u-meter (Brooks Instrument Division, Emerson Electric Co.) before and after $\dot{V}O_2$ was measured. For each experiment we selected a flow rate between 1.5 and 1.8 L min⁻¹ (STPD) depending on the bird's size and the size of the metabolism chamber.

The $\dot{V}O_2$ of a bird was measured for 60–90 min. At the end of a measurement the bird was calm, and its $\dot{V}O_2$ was judged to be in a steady-state. We calculated the rate of oxygen consumption with Equation 4b of Withers (1977) and calculated the rate of metabolic heat production ($\dot{H}_{m\alpha}$ in mW) from $\dot{V}O_2$ by assuming 19.6 kJ of heat is produced per liter of O₂ consumed. This was based on an assumed respiratory quotient (RQ) of 0.7. Gessaman and Nagy (1988) found that errors in converting gas exchange measurements to energy metabolism for uricotelic carnivores were minimized when an RQ of 0.72 was used as compared with higher RQ values.

The San Diego birds were not fed 12–24 hours before the experiment and consequently were in a post-absorptive condition. The absorptive status of the Nevada birds could not be determined with certainty. We assumed these birds were post-absorptive because their crops were empty (determined by palpation). If the migrants were actively digesting and assimilating prey their metabolic rates should have been significantly higher than the captive birds' metabolic rates because of the produced heat increment of feeding.

To test this prediction, we used an analysis of covariance to examine whether or not the migrant metabolic rates were significantly different from the captive birds. Biomass was treated as a covariate in this analysis. The metabolic rates of the wild birds were not significantly different from the captive birds ($F = 1.59$, $P = 0.24$) which supports our assumption that the migrants were fasting when measured.

All experimental measurements were made between dawn and dusk, the active phase of

TABLE 1
METABOLIC HEAT PRODUCTION OF ACCIPITERS DURING THE ACTIVE PHASE OF THE DAILY CYCLE

Species	Sex	Mass (g)	\dot{H}_{ma} (mW)	Aschoff and Pohl (1970) ^a	Wasser (1986) ^b
<i>Accipiter striatus</i>	M	101.0	850.60	827.02	663.88
	F	170.0	1178.63	1208.82	926.43
	F	172.7	1097.47	1222.79	935.82
Avg. females		171.4	1138.05		
<i>A. cooperii</i>	M	286.9	2598.17	1770.32	1295.01
	M	384.0	2434.33	2189.49	1560.63
Avg. males		335.5	2516.25		
	F	436.2	2556.13	2402.69	1693.27
	F	427.8	3079.86	2368.87	1672.33
	F	536.5	2330.50	2793.97	1933.09
	F	466.8	2655.50		
Avg. females		466.8	2655.50		
<i>A. gentilis</i>	M	751.0	4281.60	3570.32	2397.38
	F	958.2	3620.94	4264.30	2801.94
<i>A. melanoleucus</i>	F	919.0	3023.14	4136.40	2728.03
Mean deviation from measurements (%)				-0.17	-28.82

^a Active phase RMR for non-passerine birds calculated from the relation $mW = 28.6M^{0.729}$.

^b Resting phase RMR for falconiforms calculated from the relation $mW = 34.62M^{0.64}$.

these diurnal raptors. Each bird was weighed to the nearest 0.1 g immediately after each experiment.

Metabolism-body weight relationships are generally presented as allometric equations generated by standard regression techniques (Lasiewski and Dawson 1967, Zar 1969, Aschoff and Pohl 1970). We did not generate an allometric equation because our data were from a small number of species (4) and a narrow range of body sizes (100–958 g). The validity of the relationship of such a narrowly defined allometric equation is questionable (Zar 1969). Differences in metabolic rates between species were evaluated using the analysis of variance. Paired *t*-tests were used to compare the measurements with the predictions of Aschoff and Pohl (1970) and Wasser (1986) for non-passerines and falconiforms, respectively, of equivalent body size.

Results and discussion.—Larger accipiter species had significantly higher rates of metabolic heat production than smaller species (Table 1, $F = 30.26$, $P < 0.01$). Sample sizes were too small for all species to test for significant differences between sexes but mean values for male Sharp-shinned Hawks and Cooper's Hawks were smaller than the mean values for the larger-bodied females.

From regression analysis, Aschoff and Pohl's (1970) relationship between the body mass (M in g) of non-passerine birds and (1) their active phase RMR (\dot{H}_{ma} in mW) can be expressed as:

$$\dot{H}_{ma} = 28.6 M^{0.729} \quad (1)$$

and (2) their resting phase RMR can be expressed as

$$\dot{H}_{mr} = 22.4 M^{0.734}. \quad (2)$$

The mean active phase RMR of accipiters in our study was not significantly different than Aschoff and Pohl's (1970) predictions (Eq. 1) for non-passerine birds of similar mass (Table 1; $t = 1.41$, $P = 0.19$).

Wasser (1986) derived an allometric equation for predicting falconiform RMR during the resting phase of the daily cycle. This relationship expressed in the units of Equation 1 is

$$\dot{H}_{mr} = 34.62 M^{0.64}. \quad (3)$$

In general, Aschoff and Pohl's equation for non-passerines of similar mass (100–1000 g) predicts a resting phase RMR that is higher than the RMR predicted by Wasser suggesting that most falconiforms, but not accipiters, have a lower resting phase RMR than other non-passerines.

The mean active phase RMR of accipiters was significantly higher (28.8%) than Wasser's (1986) predictions for falconiforms during the resting phase of their diurnal cycle (Table 1; $t = 76.9$, $P < 0.01$). Wasser measured only two accipiters in his study of 22 species of falconiforms; consistent with our results, both of Wasser's measurements were approximately 20% higher than what was predicted by his regression equation.

Although commonly cited as examples of "sit-and-wait" predators (Pianka 1974), recent telemetry studies (Widén 1984, Fischer 1986, Kennedy, 1991 indicate accipiters are very active and do not perch for long periods of time. As a result of these high activity levels, the metabolic rates of accipiters appear to be higher than other falconiforms of similar size throughout the daily cycle.

Since the values of active phase RMR computed from Aschoff and Pohl's equation (Eq. 1) for non-passerines were similar to the RMRs that we measured, it is reasonable to use their equation to predict the RMR of accipiters during the active phase of the daily cycle. Furthermore, Aschoff and Pohl's equation for non-passerines during the resting phase (Eq. 2) may be more appropriate for estimating accipiter resting phase RMR than Wasser's equation for falconiforms (Eq. 3).

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Feeding ecology of Chesapeake Bay Ospreys and growth and behavior of their young.—

As the Chesapeake Bay's fish population has declined, food may have become more limiting to the bay's Ospreys (*Pandion haliaetus*) (Rothschild et al. 1981, Thompson 1984, Bird 1985). In 1985, we studied Ospreys in southwestern Chesapeake Bay. During this study, it appeared that there was increased sibling aggression, brood reduction, and decreased growth of the young compared with 1975 (Stinson 1976, 1977). This paper examines those differences and their apparent cause.

Methods.—Seven Osprey nests in Mathews and Lancaster counties, Virginia, were studied 21 May-25 July 1985. All nests were approximately 25-125 m from shore and accessible by boat. At most study locations, the Ospreys experienced various amounts of human activity (including our own), but they appeared to habituate to disturbance. Ospreys were observed four days per week. Each day included two, 7.5 h observation periods (0530-1300; 1300-2030 h DST) which were arranged systematically such that we spent 15 h/wk at each nest. We used 20 × 60, 40 × 60 and 40 × 80 scopes for observation. We estimated the size of the fish brought to each nest by comparing them with 48-cm wooden rods graduated at 12-cm intervals affixed to each nest; we used the adult Osprey's tarsus for reference as well.