

these studies. We thank D. Lemmon for comments on the manuscript. We thank Roland Wauer, Michael Fleming and the National Park Service for their help and permission to work in Big Bend National Park.

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METABOLIC, WATER AND THERMAL RELATIONS OF THE CHILEAN TINAMOU¹

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Key words: Tinamou; water loss; metabolism; temperature; phylogeny.

We present here some basic aspects of the thermal and metabolic physiology of the Chilean Tinamou (*Nothoprocta perdicaria*). Tinamous (Tinamidae) are quail-like ground birds widely distributed throughout the neotropics from Mexico to Patagonia. The taxonomic status of tinamou is controversial, but Cracraft (1981) includes Tinamidae in Palaeognathiformes. Hence, tinamous are suspected to be closely related to the ratites, although they are carinate and therefore may be more closely related to other birds than to ratites. The metabolic physiology of tinamou is thus of particular interest because ratites have been shown to have considerably lower basal metabolic rates than do carinates (Calder and Dawson 1978, Withers 1983).

Four Chilean Tinamous (mean mass $458 \pm SE 8$ g) were obtained from the Washington State Department of Fisheries and Wildlife in June 1980. They were maintained outdoors under natural photoperiod and ambient temperature throughout the year. The experiments reported here were conducted in late November and in December of 1980 and 1982. A standard flow-through respirometry system in a constant temperature cabinet was used for the measurement of oxygen consumption rate ($\dot{V}O_2$: ml $O_2 \cdot g^{-1} \cdot hr^{-1}$) and evaporative water loss (EWL: mg $H_2O \cdot g^{-1} \cdot hr^{-1}$) at ambient temperatures (T_a : °C) from -10 to +30. All experiments were conducted during the light portion of the ambient photoperiod (10:00 to 16:00). The flow rate of dry air (dew point < -5°C) was regulated with a Gilson mass flow controller and meter. Excurrent air was monitored for O_2 content to $\pm 0.01\%$ with a Servomax 570A paramagnetic O_2 analyzer calibrated with dry, CO_2 -free nitrogen (0% O_2) and room air (20.94% O_2). Incurrent and excurrent air was monitored for water vapor content to $\pm 0.05^\circ C$ dewpoint with an EG&G Dew-All hygrometer (NBS traceable hygrometer calibration). The percent O_2 and dewpoint were continuously recorded with a dual channel Honeywell stripchart recorder. Dewpoint was converted to absolute humidity (STP) using the equations of Parrish and Putnam (1977). The $\dot{V}O_2$ (STPD) and EWL were calculated using the equations of Withers (1977). EWL was not measured at

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$T_a < 5^\circ\text{C}$ since excurrent water condensed or froze in the air lines. Body temperature (T_b ; $^\circ\text{C}$) was measured with a Bailey Instruments Bat-4 thermocouple meter immediately after the bird was removed from the respirometry chamber, using a thermocouple inserted 4 cm into the cloaca. Values are presented as mean \pm standard error with the number of observations, or as least squares linear regression analysis with the correlation coefficient (Zar 1984).

The relationship between \dot{V}_{O_2} and ambient air for tinamous is typical of endothermic vertebrates (Fig. 1). There was a significant relationship between \dot{V}_{O_2} and $T_a \leq 10.0^\circ\text{C}$ ($\dot{V}_{\text{O}_2} = 1.05 - 0.037T_a$; $n = 24$; $r = 0.73$) but not at $T_a \geq 10.0^\circ\text{C}$. The basal \dot{V}_{O_2} at $T_a \geq 10.0$ was $0.69 \pm 0.03 \text{ ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$ (1.76 W, assuming 1 ml $\text{O}_2 = 20.1 \text{ J}$). The predicted basal metabolic rate for a 458-g ratite bird is $0.48 \text{ ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$ (Withers 1983) and for a carinate nonpasserine is 0.79 (resting phase) to 0.98 (activity phase) $\text{ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$ (Aschoff and Pohl 1970). The lower critical temperature of the thermo-neutral zone, determined from the point of intersection of the $\dot{V}_{\text{O}_2} - T_a$ regression at $T_a \leq 10.0^\circ\text{C}$ and the mean \dot{V}_{O_2} at $T_a \geq 10.0^\circ\text{C}$, was 9.8°C . The EWL ($\text{mg}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$) was significantly related to T_a ($\text{EWL} = 0.133 + 0.055T_a$; $n = 19$; $r = 0.80$). There was a significant relationship between $\text{EWL}/\dot{V}_{\text{O}_2}$ ($\text{mg H}_2\text{O}/\text{ml O}_2$) and $T_a < 20^\circ\text{C}$ ($\text{EWL}/\dot{V}_{\text{O}_2} = 0.08 + 0.09T_a$; $n = 13$; $r = 0.87$). The mean $\text{EWL}/\dot{V}_{\text{O}_2}$ of $2.07 \pm 0.07 \text{ mg/ml O}_2$ at $T_a > 18^\circ\text{C}$ for tinamous is similar to the value expected for ratites (2.1) and greater than the value for carinate birds (1.4) because the \dot{V}_{O_2} is lower (Table 1). T_b was independent of T_a ; the mean value was $39.6 \pm 0.2^\circ\text{C}$ ($n = 32$). This is similar to T_b values for some ratites, but it is within the lower range for carinate nonpasserine birds (Table 1).

Thermal conductance (C : $\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$), estimated as the slope of the regression between \dot{V}_{O_2} and $T_a \leq 10^\circ\text{C}$, was 0.035 ± 0.009 ($n = 21$). However, this regression between \dot{V}_{O_2} and T_a extrapolated to $T_b = 28.4 \pm 7.43^\circ\text{C}$ at $\dot{V}_{\text{O}_2} = 0$, which is significantly lower than the observed T_b of 39.6°C . Consequently, 0.035 is only an approximate overestimate of C . An alternative estimate of conductance, the slope of the $\dot{V}_{\text{O}_2} - T_a$ relationship for all data, forced through $\dot{V}_{\text{O}_2} = 0$ at

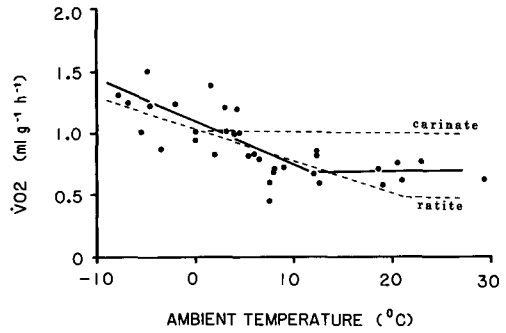


FIGURE 1. Relationship between metabolic rate (\dot{V}_{O_2} ; $\text{ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$) and ambient temperature (T_a ; $^\circ\text{C}$) for the Chilean Tinamou. Solid line is the best-fit least squares linear regression analysis. Upper broken line indicates the predicted \dot{V}_{O_2} values for a 458-g nonpasserine carinate during the active phase (Aschoff and Pohl 1970, Aschoff 1981) and the lower broken line indicates the predicted \dot{V}_{O_2} values for a 458-g ratite (Withers 1983) with a thermal conductance of $0.026 \text{ ml O}_2\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$. Predicted relationships are forced to extrapolate through T_b (39.6°C) from below the lower critical temperature.

$T_b = 39.6$, was 0.027 ± 0.006 . This value is statistically identical to that calculated as $\dot{V}_{\text{O}_2}/(T_b - T_a)$ for $T_a < 20^\circ\text{C}$ of $0.026 \pm 0.001 \text{ ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$ ($n = 27$). The conductance of the tinamou (at $T_a > 20^\circ\text{C}$) was 0.039 ± 0.006 , ranging from 0.027 to 0.063; the higher values were similar to that predicted (0.049). The corresponding dry conductance, calculated as $C_d = C - \text{EHL}/(T_b - T_a)$ for all T_a , was $0.025 \pm 0.002 \text{ ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$ ($n = 21$); EHL is the evaporative heat loss calculated from EWL assuming $540 \text{ cal}\cdot\text{g}^{-1}$ latent heat of fusion and $4.8 \text{ cal}\cdot\text{ml O}_2^{-1}$. The predicted dry conductance for a 458-g bird is 0.025 (Aschoff 1981).

The thermal, metabolic, and EWL values measured here for tinamous are generally more typical of ratite birds than carinate birds (Table 1). The basal \dot{V}_{O_2} of tinamous measured during the daytime (active phase

TABLE 1. Thermal, metabolic, and evaporative water loss values for the Chilean Tinamou compared with predicted values for a 458-g ratite and a nonpasserine carinate. Values for tinamous are mean \pm standard error.

	Tinamou	Ratite	Carinate
Body temperature ($^\circ\text{C}$)	39.6 ± 0.2	38–40 ^{a,b,c}	39–42 ^d
Basal \dot{V}_{O_2} ($\text{ml}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$)	0.69 ± 0.03	0.48 ^{a,c}	0.98 (α) ^f
Wet conductance ($\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$)	0.026–0.039	—	0.049 ^g
Dry conductance ($\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{hr}^{-1}\cdot^\circ\text{C}^{-1}$)	0.025	—	0.027 ^g
Lower critical temperature ($^\circ\text{C}$)	9.8	—	20 ^h
Evaporative water loss ($\text{mg}\cdot\text{g}^{-1}\cdot\text{hr}^{-1}$) (20–30 $^\circ\text{C}$)	1.49 ± 0.14	—	1.37 ^b
EWL/ \dot{V}_{O_2} (18–30 $^\circ\text{C}$)	2.07 ± 0.07	2.1 ^a	1.40 ^b

^a Withers (1983).

^b Crawford and Lasiewski (1968).

^c Farner et al. (1956), King and Farner (1961), Crawford and Schmidt-Nielsen (1967).

^d King and Farner (1961).

^e Calder and Dawson (1978).

^f (α) Daytime, Aschoff and Pohl (1970).

^g Aschoff (1981).

^h Calculated from Aschoff and Pohl (1970) and Aschoff (1981) as $39.6 - (\text{basal } \dot{V}_{\text{O}_2}/\text{conductance})$.

of their circadian cycle) was intermediate between the predicted values for ratites and nonpasserine carinate birds. It is important to recognize that many factors other than phylogeny (e.g., phase of circadian cycle, season, latitude—see Weathers 1979) can influence basal metabolic rate, so the intermediate basal $\dot{V}O_2$ of tinamous should not be interpreted as conclusive evidence for their being phylogenetically intermediate between ratites and carinate nonpasserines. Nevertheless, the intermediate basal $\dot{V}O_2$ of tinamous is consistent with the phyletically-correlated differences in basal $\dot{V}O_2$ of ratites and carinate nonpasserines (Calder and Dawson 1978, Withers 1983) and the phylogenetic position of tinamous as nonratite but palaeognathous carinates (Cracraft 1981).

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WINTER DIETS OF COMMON MURRES AND MARBLED MURRELETS IN KACHEMAK BAY, ALASKA¹

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Key words: Common Murre; Marbled Murrelet; foraging habitat; mysids; euphausiids; pandalid shrimp; capelin; Pacific sand lance.

Knowledge of the winter diets of seabirds in high latitudes like Alaskan waters has been an elusive aspect of their biology. Scanty information on winter diets of Common Murres (*Uria aalge*) are available from the Pribilof Islands (Preble and McAtee 1923), California (Baltz and Morejohn 1977), Kodiak Island (Krasnow and Sanger 1986), Newfoundland (Tuck 1960) and the

North Sea (Blake 1984), and for Marbled Murrelets (*Brachyramphus marmoratus*) from British Columbia (Munro and Clemens 1931, Carter 1984) and Kodiak (Krasnow and Sanger 1986). This paper summarizes the diets of these two species, as observed during the winter season of 1977–1978 in Kachemak Bay, Alaska, as a part of the Alaskan Outer Continental Shelf Environmental Assessment Program, OCSEAP (Sanger and Jones 1982; Krasnow and Sanger 1986; Fukuyama, Sanger, and Hironaka, unpubl.) and provides further interpretation of the data.

STUDY AREA

Kachemak Bay (Fig. 1) is a highly productive embayment located near the mouth of Cook Inlet in the ex-

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