

BODY TEMPERATURE OF SPECTACLED PARROTLET NESTLINGS IN RELATION TO BODY MASS AND BROOD SIZE¹

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Nestlings of altricial birds hatch as ectothermic poikilotherms and within a few days change to endothermic homeotherms. This ontogenetic development of physiological thermoregulation has been widely studied in passerines (e.g., Hill and Beaver 1982). Young nestlings isolated from the nest are unable to thermoregulate, and consequently their body temperature (T_b) drops close to ambient temperature (T_a). Gradually, nestlings develop a physiological capacity to maintain a high T_b . Young birds in the nest, however, experience a more benign thermal environment because of insulation provided by the nest itself and huddling with siblings. Thus, broods have a higher thermal inertia and can combine their thermogenic capabilities to maintain high body temperature (Hill and Beaver 1982). Passerines have high growth rates, and this has been related to thermoregulatory altriciality; it has been argued that because nestlings do not have to assume the costs of thermoregulation until late in nestling life, available energy can be devoted to growth (Case 1978).

The parrots (Psittaciformes) comprise a distinct and homogeneous order that exhibits some notable reproductive characteristics. They lay relatively small eggs that have prolonged incubation periods; hatchlings are extremely altricial and grow slowly (Bucher 1983). The ontogeny of homeothermy in psittaciforms has been studied in captive *Agapornis roseicollis* (Bucher and Bartholomew 1986). Body temperatures of brooded nestlings increase with age, while the lower critical temperature, i.e., the lower boundary of the thermal neutral zone, decreases with age. However, the effects that broods of different sizes may have on body temperature of nestlings have not been investigated. Parrots usually lay every two days and exhibit extreme hatching asynchrony (Forshaw 1973). Therefore, nestlings of widely differing ages are present in the nest. In this paper, we report field data on body temperature of nestling Spectacled Parrotlets (*Forpus conspicillatus*). In this species, hatching is asynchronous and brood size varies from one to six (Gómez 1991), thereby providing an op-

portunity to examine the effect that the presence of nestlings of different ages, and thus different thermoregulatory capacities, has on nestling body temperature.

SPECIES, STUDY AREA AND METHODS

The natural history of *Forpus conspicillatus* is described in detail by Gómez (1991). Briefly, these small parakeets lay 2–6 eggs ($\bar{x} = 3.7$) at two day-intervals. Incubation begins with the first or second egg, thereby producing a highly asynchronous brood. Modal brood size is three, with a range of 1–6. Females brood nestlings until the oldest is about 13 days. Therefore, in large broods the smaller nestlings may not be brooded at all by adults. Nestlings grow slowly and fledge asynchronously at an age of about 32 days. Fledging mass is about 27 g (adult mass $\bar{x} = 27.8$ g).

We studied Spectacled Parrotlets at a farm 15 km south of Cali, in the Cauca Valley (1,000 m elevation), Colombia. In this area, parrotlets nest mostly in cavities in bamboo (*Guadua angustifolia*) fence posts. For this study, we also used nest boxes (10 × 10 × 15 cm), which we hung from trees at heights of 1.8–2.2 m. Most data in this study are from nestlings growing in nest boxes.

During morning hours (07:00–10:30), we weighed nestlings with 20 g (0.5 g precision) and 50 g (1.0 g precision) Pesola spring balances and measured their cloacal temperature, using a digital thermometer with a 40-gauge copper-constantan thermocouple, or a Miller-Weber cloacal quick reading thermometer. Probes were inserted about 10 mm into the cloaca. Thermometers were checked against each other to ensure comparable readings. Cloacal temperature was measured within 30 sec after taking a nestling out of the nest. We also subjected nestlings to a mild cold challenge, by exposing them individually to ambient temperature in the shade for a 10 min period, after which cloacal temperature was measured. Ambient temperature was measured at a height of 1 m in the shade. Temperature in the nest cavity was measured by placing the thermocouple just above the nestlings, before opening the next box. We do not have a complete data set for nest temperatures, however, and we used ambient temperature for analyses. On average, nest temperature was 2.24°C higher than ambient temperature (SD = 1.15, $n = 22$).

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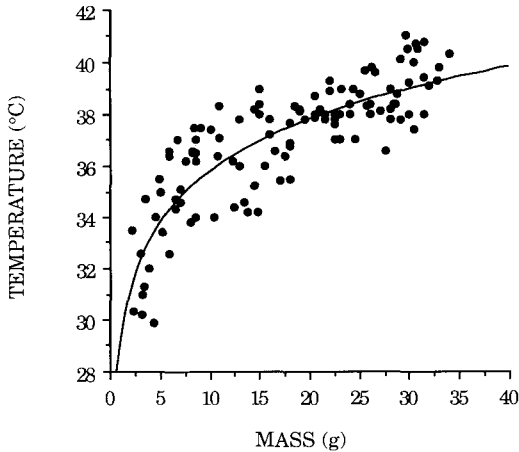


FIGURE 1. Cloacal temperature of nestling Spectacled Parrotlets as a function of body mass.

RESULTS

To determine the effects that nestling body mass, brood size, and ambient temperature had on cloacal temperature, we performed a multiple linear regression using log body temperature ($\log T_b$) as dependent variable, and log body mass ($\log W$), combined nestmate mass (NM), and ambient temperature (T_a) as independent variables. Presumably, the combined mass of nestmates would act to maintain thermal inertia and provide insulation for a nestling. Besides, larger nestmates are able to thermoregulate and brood smaller siblings. The multiple regression was significant ($P < 0.001$), with an R^2 of 0.56 ($n = 126$). Significance tests (t -test) on the beta coefficients indicated that $\log W$ is significant ($P < 0.001$), while NM and T_a do not significantly contribute to the model ($P > 0.4$ in both cases). Thus, in the range of ambient temperatures experienced by these parakeets (21–28°C), body temperature correlates with nestling mass, and is independent of the number and size of nestmates, and ambient temperature. A simple linear regression of $\log W$ on T_b yields the equation $T_b = 29.1 + 6.7 \log W$ ($r^2 = 0.71$, $n = 126$). Figure 1 shows the untransformed relationship between body temperature and nestling mass.

When nestlings were exposed to a mild cold challenge, their cloacal temperature dropped. Because we obtained these data in the field, we had no control of ambient temperature, which varied considerably (21–26°C). To control for T_a a posteriori we performed a multiple regression of the temperature drop (ΔT) as a function of nestling mass and ambient temperature. The regression was significant ($P = 0.008$), but only explained 25% of the variation ($n = 53$). The beta coefficient for W was significant ($P = 0.004$), but T_a did not significantly explain variation in ΔT ($P = 0.67$). The temperature drop as a function of body mass is shown in Figure 2.

DISCUSSION

Spectacled Parrotlet nestlings are brooded by the female parent until the oldest is about 13 days old (20 g). For broods of three, the modal brood size, parents

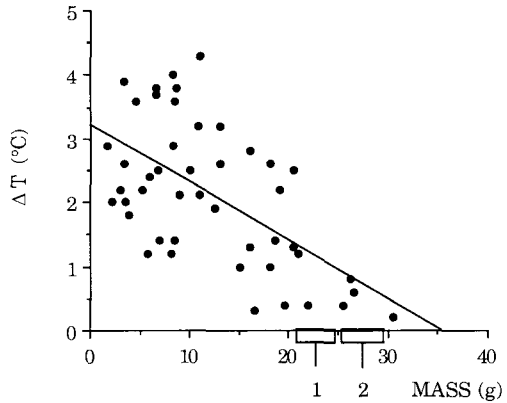


FIGURE 2. Drop in nestling cloacal temperature after a 10 min exposure to ambient temperature, as a function of body mass. Number 1 on the horizontal axis indicates the size at which sheathed feathers cover the body; number 2 indicates size at which feathers are unsheathing. The regression equation is $\Delta T = 3.22 - 0.09 W$ ($r^2 = 0.36$, $n = 53$).

stop brooding when the smallest nestling is about nine days old, or 14 g (Gómez 1991). In larger broods, small nestlings are not brooded by their parents, but by older siblings, which should already have some capacity to thermoregulate. Thus, we expected that in the relevant nest conditions (several nestmates huddled in a cavity protected from wind), nestlings would maintain a relatively high body temperature most of the time. In contrast, we found that nestlings maintained a body temperature that increased in correlation with body mass (which in turn correlates with age; Gómez 1991), independently of brood mass. Cloacal temperature of nestling *Forpus conspicillatus* increased from about 31–32°C in hatchlings, to 39–40°C in nestlings ready to fledge (Fig. 1). Cloacal temperature of isolated nestlings exposed to ambient temperature decreased at a rate that depended on mass of the nestling. Small nestlings cooled rapidly, but as they increased in mass, grew feathers and developed endothermy, their body temperature only dropped slightly.

A similar increase of T_b with age is reported for *Agapornis roseicollis* (Bucher and Bartholomew 1986), an African psittacid slightly larger than *F. conspicillatus*. The pattern of increase of T_b with age in parrots contrasts with that reported for passerines. Broods of passerine nestlings maintain relatively high body temperatures, even at low ambient temperatures (Hill and Beaver 1982, Olson 1991). Thermoregulatory atriality and high body temperature in passerines are traits related to rapid growth, and it has been shown that large broods promote maintenance of high T_b (Case 1978, Hill and Beaver 1982).

Parrot nestlings apparently maintain a body temperature in accordance with body mass, independently of brood size; small nestlings do not have a high body temperature, even when brooded. Whether this phenomenon is due to a constraint or a specific adaptation is unclear. Possibly a granivorous diet, such as that of *F. conspicillatus* (Gómez 1991), constitutes a physio-

logically limiting factor. In contrast, the observed correlation between body mass and temperature may be determined by a pattern of slow growth, which is part of a suite of life history parameters (delayed maturity, long life span) that are coupled with their complex social behavior (Bucher 1983).

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DENSITY OF LOONS IN CENTRAL ALASKA¹

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Loons breed across North America from the high arctic south to about 43° north latitude (AOU 1983). Populations, particularly of Common Loons (*Gavia immer*), have recently declined in the continental U.S. and southern Canada (Sutcliffe 1979, Titus and VanDruff 1981, McIntyre 1988). As a result, state and private natural resource organizations began more intensive monitoring of loon populations (in McIntyre 1986, Strong 1988). These surveys, however, are restricted to areas accessible by road, although recently aircraft were used for more remote areas (Lee and Arbuckle 1988, Strong 1990).

Previous studies of loons in remote areas of Canada

and Alaska were primarily about reproductive behavior and nesting ecology, and have focused on small geographic areas (Munro 1945; Davis 1972; Petersen 1976, 1979; Sjölander and Ågren 1976; Bergman and Derksen 1977; Fox et al. 1980; Smith 1981; Yonge 1981; North 1986). Few studies specifically addressed abundance over large, remote portions of Canada and Alaska. Available data for these regions come primarily from studies which focused on other species or species-groups of waterbirds (e.g., U.S. Fish and Wildlife Service annual pairs counts of waterfowl). Errors in accuracy and precision are common in such multi-species surveys (Smit et al. 1981; Butler, U.S. Fish and Wildlife Service, pers. comm.). Annual Breeding Bird Surveys throughout Canada are another source of information, but again, are of limited value because only road surveys are conducted (McNicholl 1988). We know of only one unpublished study conducted specifically to assess the abundance of loons in Alaska (McIntyre, Utica College, in prep.).

Our goal was to design and conduct an aerial survey to estimate loon density over a large and remote area of central Alaska. Previously, we reported the aerial

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