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GROWTH AND DEVELOPMENT OF THERMOREGULATION IN NESTLING SAN MIGUEL ISLAND SONG SPARROWS¹

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Patterns of growth (reviewed by Ricklefs 1968, 1969; O'Connor 1984) and the development of endothermy (reviewed by Dawson and Hudson 1970, Dunn 1975, Hill and Beaver 1982) have been well-studied in altricial wild birds, especially passerines. But few studies compare growth and thermogenesis in separate populations of the same species. Results of such studies with emberizids varied among species. King and Hubbard (1981), for example, found that nestlings from subarctic, subalpine, and low-altitude montane populations of White-crowned Sparrows (*Zonotrichia leucophrys gambelii*) grew at similar rates. In contrast, Rogers (1985) reported that the growth rates of nestlings in different populations of Savannah Sparrows (*Passerculus sandwichensis*) varied in response to the different environmental constraints of the localities in which they were reared. Nice (1937) and Smith et al. (1982) documented patterns of nestling growth in mainland (Ohio) and insular (Mandarte Island, British Columbia, Canada) populations of Song Sparrows

(*Melospiza melodia*), respectively, and found that they were similar to those reported for most other passerines by Ricklefs (1968, 1969) and O'Connor (1984).

In 1985-1986, we had the opportunity to examine the growth of nestlings from a third race of Song Sparrows, *M. m. micronyx*, which is endemic to San Miguel Island near Santa Barbara, California. We also studied the development of endothermy in these young birds, a process not hitherto described for nestling Song Sparrows. We report both in this paper.

STUDY AREA AND METHODS

San Miguel Island (120°W, 34°N) is the northwesternmost of the California Channel Islands and lies 42 km from the southern California coastline, almost due south of Point Conception. It is 37 km² in area and has a maximum elevation of 253 m. It supports four major types of vegetation: coastal bluff, coastal sage scrub, foothill and valley grassland, and southern coastal dune (Philbrick and Haller 1977); and has large unstable sand dunes. Strong northwesterly winds are a dominant part of the island's Mediterranean climate, which features warm, dry summers and cool, wet winters.

Our study area was a 9.2-ha plot of grassland bisected by two large gullies on the north-central plateau of San Miguel Island. The gullies were more or less filled with

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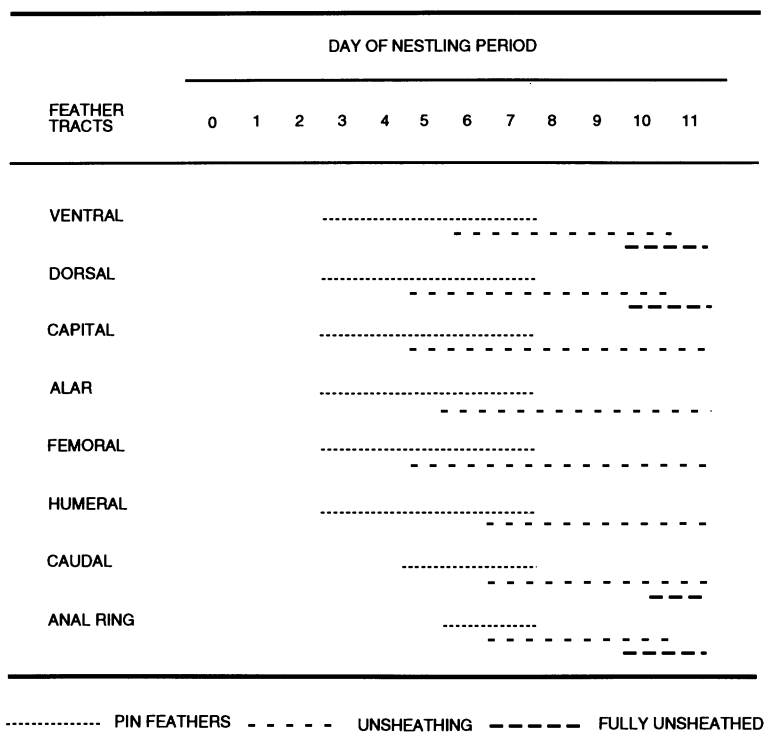


FIGURE 1. Appearance and changes in feather tracts of nestling San Miguel Island Song Sparrows.

shrubs, in particular bush lupine (*Lupinus albus*), coyote brush (*Baccharis pilularis*), and goldenbush (*Haplopappus venetus*).

We studied resident Song Sparrows here between February–June 1985 and 1986. For the part of the field study reported in this paper, we visited 15 nests containing marked nestlings on a daily basis. To determine the growth rates of chicks in these nests, we measured their mass (with a Pesola balance) and the length of the tarsus and wing chord (with calipers) at approxi-

mately 24-hr intervals throughout the 11-day nestling period. To determine the thermoregulatory capacity of nestlings, we daily measured the cloacal temperature of one or two chicks per nest with a flexible thermistor attached to a tele-thermometer (Yellow Springs Instrument, model 43 TD). This initial temperature reading was made within 1–3 min after arriving at the nest. We then put each chick in a small metal can with a styrofoam bottom (in such a way that the chick did not rest directly against the metal) and put the can

TABLE 1. The change in mass, tarsal length, wing chord length, and development of shivering in nestling Song Sparrows on San Miguel Island. Values given are the means, one standard deviation, and sample size (*n*).

Day of nestling period	Mass (in grams)			Tarsal length (in mm)			Wing chord length (in mm)			Chicks shivering	
	Mean	SD	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD	<i>n</i>	Percent	<i>n</i>
0	2.4	0.4	33	8.8	0.8	19	6.9	0.7	12	0	7
1	3.7	0.6	31	10.9	0.7	19	8.1	0.9	12	0	9
2	5.5	0.8	30	13.0	1.0	20	9.6	0.8	13	0	11
3	7.8	0.9	32	15.5	1.1	22	11.9	1.1	13	0	11
4	10.4	1.0	32	17.8	1.3	25	15.7	1.6	13	0	11
5	13.0	0.9	29	20.1	1.0	28	19.7	1.6	16	9	11
6	14.7	1.3	32	22.1	0.9	27	23.8	1.7	15	85	12
7	15.9	1.0	26	23.5	0.7	25	28.0	1.9	15	85	14
8	16.7	1.0	28	24.3	0.6	25	31.7	1.7	15	100	14
9	17.4	1.0	23	24.9	0.5	20	35.2	1.4	11	100	13
10	18.4	0.7	14	25.4	0.4	10	37.8	1.5	7	100	7
11	18.8	0.7	6	25.7	0.2	4	39.8	0.2	3	100	3

inside a larger styrofoam container, packed with ice, in which air temperature averaged 9°C (range = 2–15°C). After 5 min of cooling, we removed the chick, remeasured its internal temperature, and looked for shivering behavior. The difference between internal body temperature before and after cooling was used as an index of the chick's ability to thermoregulate.

RESULTS

Growth in body mass of nestling San Miguel Island Song Sparrows occurred rapidly (Table 1). Between days 0 and 9 posthatch, the overall growth rate was 1.8 g day⁻¹. Ricklefs' logistic growth constant $K = 0.52$. Nestlings fledged on day 11 posthatch at an average of 18.8 g, only 87% of adult weight. Changes in the length of the tarsus and wing chord averaged 1.9 and 3.4 mm day⁻¹, respectively (Table 1). Tarsus and wing chord were 97 and 66%, respectively, of adult length at fledging. Mean mass and length of the tarsus and wing chord were all strongly correlated with nestlings age (r^2 values all exceed 0.95; $P < 0.001$). There were no differences between the growth rate of nestlings from 2- ($n = 7$ nests) and 3- ($n = 8$ nests) chick nests (Student's t -test, $P > 0.05$), or between chicks which were cooled ($n = 13$) and others for which only mass was measured ($n = 13$; $P > 0.05$).

Nestlings hatched with only sparse down, but pin feathers were evident under the skin by day 2 and erupted through the skin on day 3. Feathers began unshedding rapidly starting on day 5 (Fig. 1) and covered most of the nestling's surface by day 8.

The internal temperature of the chicks before they were subjected to a cold challenge (T_{bc}) varied considerably during the first 6–7 days after hatch, but increased steadily through day 7 and then leveled off at approximately 37°C (Fig. 2A). Internal temperature after cooling (T_{ac}) behaved similarly. The change in body temperature during cold stress ($T_{bc} - T_{ac}$) was approximately 6°C on days 0–4 posthatch, then dropped sharply until day 8, after which it was only about 1.8°C (Fig. 2B). Some chicks, (9%) began to shiver as early as day 5 posthatch when exposed to cold stress. The number increased to 67% on day 6 and 100% by day 9 (Table 1).

Nestling temperature was never as high as adult body temperature, even on the day of fledging. Mean body temperature of five adults was 40.3 ± 1.1°C, while that of four 11-day-old nestlings was only 37.2 ± 1.8°C.

DISCUSSION

The pattern of growth in nestling San Miguel Island Song Sparrows is similar to those of most passerines that have been studied (for example, see Ricklefs 1968, King and Hubbard 1981, O'Connor 1984, Rogers 1985). The pattern and rate of nestling growth is similar between the two insular populations of Song Sparrows that have now been studied: for days 0–6 posthatch (for which comparable data are available), 2.1 g day⁻¹ on San Miguel Island, and ca. 2.2 g day⁻¹ on Mandarte Island (Smith et al. 1982). Both insular populations had slightly faster growth rates than Song Sparrows in Ohio (1.8 g day⁻¹; Nice 1937). Statistical comparisons between populations were not possible due to avail-

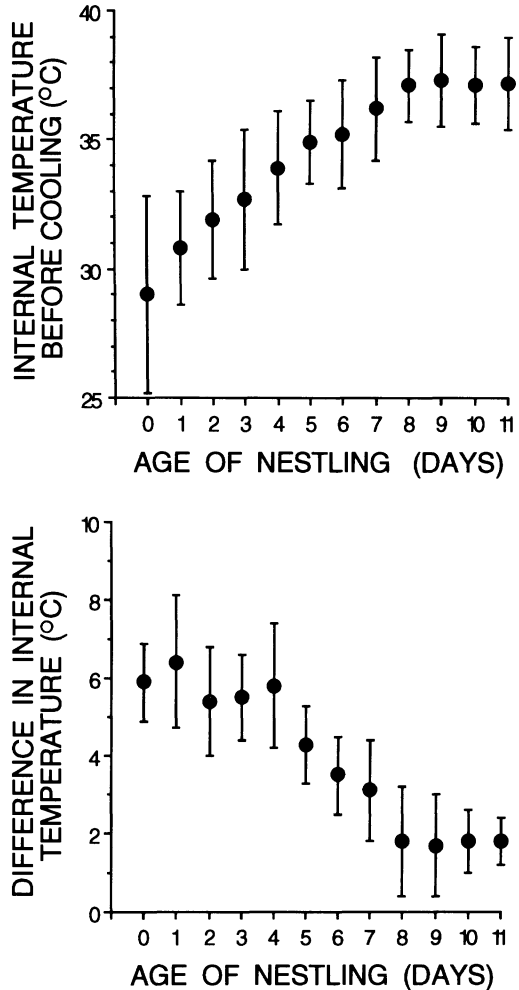


FIGURE 2. A—Average cloacal temperature (°C) of 15 nestling Song Sparrows as a function of age. B—Average difference between the cloacal temperature of these 15 nestlings before (T_{bc}) and after (T_{ac}) they were cooled as a function of age. In both A and B, closed circles are means and vertical lines ± 1 SD.

ability of only summary data for Mandarte Island and Ohio.

The endothermic capacity of individual nestling Song Sparrows developed gradually and in three successive phases, similar to that described for several other emberizids (for example, see Dawson and Evans 1957, 1960; Morton and Carey 1971). During phase 1 (days 0–4 posthatch), the chicks were small, naked, did not shiver, and apparently neither produced nor conserved heat effectively (Figs. 1, 2). They responded to thermal challenges like poikilotherms: as ambient temperature decreased, so did their body temperature.

During phase 2 (days 5–7 posthatch), endothermy began to develop. Brushies appeared in all major feather

tracts (Fig. 1). Chicks were larger and better filled the nest cup, shivered, and huddled together, all of which aid in thermoregulation (Hill and Beaver 1982). Based on data from other species (Hill and Beaver 1982), Song Sparrow broods probably maintained higher body temperatures than individual nestlings at this stage of development.

During phase 3 (days 8–11 posthatch), the chick's internal temperature was high and stable before and after cold stress test; in fact it only declined about 2°C during the cold-stress period (Fig. 2). The nestlings were now large and crowded together in the nest. Song Sparrow nestlings were virtually covered with feathers (Fig. 1) and all of them shivered in the cold (Table 1). This combination of increased mass coupled with internal metabolic processes and shivering apparently enabled the young birds to regulate their body temperatures near adult levels (Marsh 1979, Hill and Beaver 1982).

As occurs in many ground-foraging emberizids (Dawson and Evans 1960, Morton and Carey 1971, O'Connor 1984, Rogers 1985), nestling Song Sparrows fledged before they reached adult mass, before they could fly (Sogge and van Riper 1988), and before their ability to thermoregulate was as well developed as that of adult birds.

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