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Further observations on skull pneumatization

Robert P. Yunick

When I wrote "Variations in skull pneumatization patterns of various passerines" (Yunick 1980), I unsuccessfully sought an explanation of why certain passerines showed either peripheral or median line pneumatization of their crania. Attempts to ascribe a species' grouping based on taxonomic relations, feeding habits, etc. failed to give adequate reasons for the groupings observed.

In the meantime, a review of that paper by R.J. Clark (1980) sparked an idea which I have since investigated and which appears to explain why certain species exhibit one or the other of these patterns. Skull size and structural requirements of the bone tissue undergoing pneumatization appear to be responsible for the observed patterns. This paper reports on these findings and on the classification of pneumatization patterns of 20 more species.

The clue that size might be a factor in determining the group into which a species fits was provided by further consideration of the then-disturbing difference in the groupings of two closely-related species, the Red-breasted Nuthatch and the White-breasted Nuthatch. In addition, other cases of closely-related species (certain parids, parulids, and fringillids) occurring in both groups were found, lending support to the possibility that size was a factor.

In reviewing the species within the two classifications, it seemed to me that the peripheral group was dominated by small species, the median line group by larger ones. However, certain conflicts based on similarities in external size appeared to exist. For instance, why should some warblers such as Yellow-rumped and Blackpoll be in the peripheral group while the similarly-sized Northern Waterthrush and Ovenbird were in the median line group? Or, why should the Chipping Sparrow be in the peripheral group and the Song and Swamp Sparrow be in the median line group?

Nevertheless, accepting for the moment the general principle that a species' grouping was somehow size-related, it seemed to follow that a skull below a certain size and of a certain configuration possessed a small enough area and sufficient curvature to provide adequate structural support to the unpneumatized bone to

allow peripheral pneumatization to occur. Above a certain size, the skull either lacked sufficient curvature or had a sufficiently large, unsupported surface not rigid enough to protect the underlying delicate tissue. To overcome this structural deficiency, these larger species apparently evolved the process of pneumatization along the median line as a means of structural support. Past observations of species such as Purple Finch, Dark-eyed Junco, White-throated Sparrow and others undergoing median-line pneumatization showed that this suture usually undergoes pneumatization in the first 60-80 days. Once formed, further outward growth from the suture slows in some species, and the pneumatization process is completed mostly by growth of pneumatized tissue toward the suture rather than away from it.

To test the hypothesis that the occurrence of pneumatization of the median suture was size related, I made measurements on available species for which pneumatization patterns had been ascertained. As skull volume and surface area are difficult to determine, measurements of width and length, as depicted in Figure 1, were made using a vernier caliper capable of measuring to the nearest 0.001 in. These data, converted to mm, are summarized in Table 1 and are plotted in Figure 2.

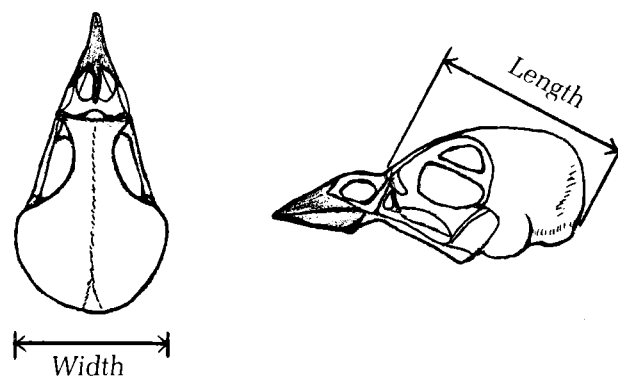


Figure 1. Dorsal and lateral views of a Swamp Sparrow skull; depicting the measurements shown in Table 1.

Table 1. Pneumatization patterns

Species	Width, mm			Length, mm			Sample Size	Pattern ¹
	Avg.	Min.	Max.	Avg.	Min.	Max.		
Ruby-crowned Kinglet	11.68	11.22	12.06	14.42	13.56	15.06	21	P1
Brown Creeper	11.74	11.12	12.24	14.77	13.66	15.31	18	P2
Golden-crowned Kinglet	11.76	11.37	12.26	13.92	13.46	14.37	17	P3
American Redstart	11.82	11.37	12.21	15.18	14.73	15.74	14	P4*
Blackpoll Warbler	12.57	11.93	13.10	16.61	15.94	17.24	12	P5*
Pine Siskin	12.67	12.26	13.03	15.23	14.85	15.94	9	P6*
Black-throated Green Warbler	12.69	12.49	13.00	16.07	15.92	16.38	7	P7*
Yellow-rumped Warbler	12.84	12.44	13.10	16.42	15.72	17.01	18	P8
Red-breasted Nuthatch	13.07	12.70	13.33	16.82	16.30	17.29	7	P9
Common Yellowthroat	13.12	12.39	13.56	16.35	15.61	17.01	18	P10*
Chipping Sparrow	13.29	13.03	13.61	16.34	15.59	16.83	8	P11*
Northern Waterthrush	13.33	12.75	14.34	17.97	17.34	19.68	18	M1*
Common Redpoll	13.43	12.97	13.94	15.72	14.93	16.66	10	P12
Black-capped Chickadee	14.12	13.46	14.93	16.82	16.30	17.47	26	P13
Ovenbird	14.45	14.02	14.73	19.12	18.18	19.80	17	M2*
Swamp Sparrow	14.46	14.22	14.90	18.47	17.93	19.04	8	M3
Purple Finch	14.52	14.02	14.90	18.63	17.24	19.30	21	M4
Dark-eyed Junco	15.17	14.70	16.00	18.16	17.09	18.89	21	M5
Gray-cheeked Thrush	15.45	14.47	16.42	21.10	20.36	22.22	16	M6*
Song Sparrow	15.53	13.63	16.88	19.29	17.67	20.31	20	M7*
Swainson's Thrush	15.58	14.60	16.43	21.07	19.96	21.71	18	M8*
White-breasted Nuthatch	15.60	15.16	16.12	18.92	17.65	19.91	20	M9
Veery	15.71	15.01	16.38	21.32	20.49	22.47	18	M10*
Hermit Thrush	16.00	15.54	16.81	21.64	20.82	23.33	22	M11*
White-throated Sparrow	16.08	15.03	16.81	19.64	19.04	20.57	21	M12
Fox Sparrow	16.12	15.61	17.01	21.32	20.85	22.34	13	M13
Tufted Titmouse	16.29	15.89	16.71	19.13	18.51	19.47	10	M14*
Gray Catbird	16.50	15.44	17.42	22.37	21.20	23.31	17	M15*
White-crowned Sparrow	16.59	16.05	17.54	20.14	19.65	20.67	13	M16*
Rufous-sided Towhee	16.69	16.05	17.14	22.43	20.67	23.36	24	M17*
Wood Thrush	16.95	15.84	17.54	23.67	23.56	24.88	19	M18*
Rose-breasted Grosbeak	17.17	16.33	17.67	22.20	20.95	23.18	25	M19*
Evening Grosbeak	17.69	16.50	18.48	21.87	20.82	22.34	7	M20
American Robin	18.99	17.98	20.31	25.80	23.74	27.17	15	M21*

¹ P = Peripheral, M = Median Line. The number following the letter refers to the data point in Figure 1.

* Species marked with an asterisk are among the 20 whose patterns are reported here for the first time.

Species cited in Table 1

Ruby-crowned Kinglet, *Regulus calendula*; Brown Creeper, *Certhia familiaris*; Golden-crowned Kinglet, *Regulus satrapa*; American Redstart, *Setophaga ruticilla*; Blackpoll Warbler, *Dendroica striata*; Pine Siskin, *Carduelis pinus*; Black-throated Green Warbler, *Dendroica virens*; Yellow-rumped Warbler, *Dendroica coronata*; Red-breasted Nuthatch, *Sitta canadensis*; Common Yellowthroat, *Geothlypis trichas*; Chipping Sparrow, *Spizella passerina*; Northern Waterthrush, *Sieurus noveboracensis*; Common Redpoll, *Carduelis flammea*; Black-capped Chickadee, *Parus atricapillus*; Ovenbird, *Sieurus aurocapillus*; Swamp Sparrow, *Melospiza georgiana*; Purple Finch, *Carpodacus purpureus*; Dark-eyed

Junco, *Junco hyemalis*; Gray-cheeked Thrush, *Catharus minimus*; Song Sparrow, *Melospiza melodia*; Swainson's Thrush, *Catharus ustulatus*; White-breasted Nuthatch, *Sitta carolinensis*; Veery, *Catharus fuscescens*; Hermit Thrush, *Catharus guttatus*; White-throated Sparrow, *Zonotrichia albicollis*; Fox Sparrow, *Passerella iliaca*; Tufted Titmouse, *Parus bicolor*; Gray Catbird, *Dumetella carolinensis*; White-crowned Sparrow, *Zonotrichia leucophrys*; Rufous-sided Towhee, *Pipilo erythrophthalmus*; Wood Thrush, *Hylocichla mustelina*; Rose-breasted Grosbeak, *Pheucticus ludovicianus*; Evening Grosbeak, *Hesperiphona vespertina*; American Robin, *Turdus migratorius*.

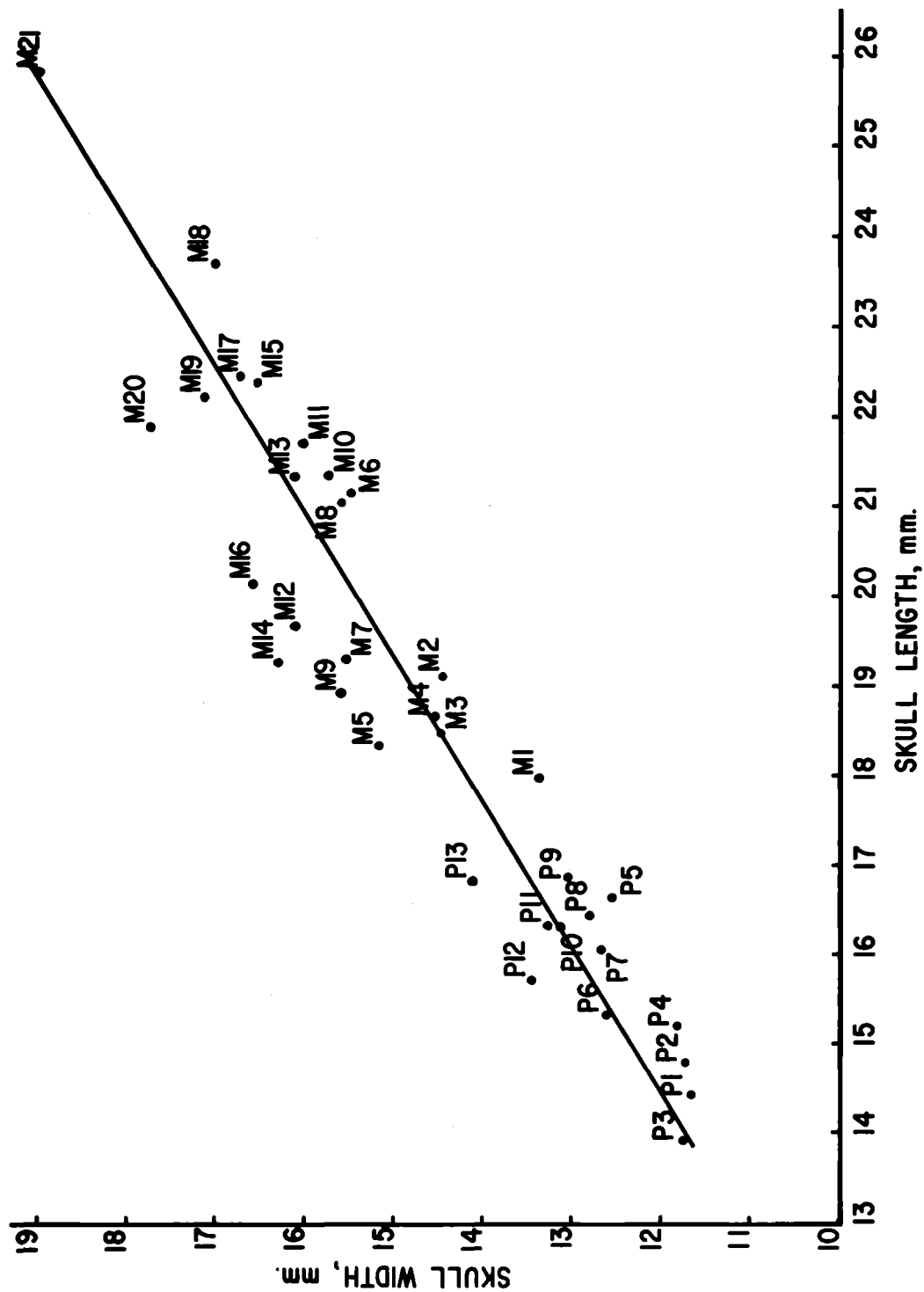


Figure 2. A comparison of skull width and length data from Table 1. Each point represents a single species whose identity is keyed to the alpha-numeric designation in Table 1. The group with peripheral pneumatization patterns is labelled P1 through 13, and the group with mean line pneumatization patterns is labelled M1 through 21. The line drawn through the data points was determined by regression analysis of the 34 points: $Width = 2.99 \pm 0.623(Length)$. Its index of fit was 0.8994.

Figure 2 shows that the two pneumatization patterns are grouped by skull size, to the mutual exclusion of each other, regardless of other apparent size parameters. The peripheral group occurs at a skull length of up to about 17 mm, and the median line group at lengths above some value in the 17-18 mm range. Skull width does not appear to be as discriminating a parameter between the groups as is length.

Among the 20 additional species reported in Table 1, all except some of the turdids showed typical patterns for their respective groups. Based on a sufficient series of November skulls among the turdids in the American Museum of Natural History (AMNH) collection, I found some interesting variations of the median line pattern. The principally represented specimens, based on collection in the New York area at that time of year, were Hermit Thrush and American Robin. Some of these variations are illustrated in Figure 3.

The advance of typical median line pneumatization is illustrated in Figure 3a (taken from Figure 1, 1980). Patterns exhibited by two November Hermit Thrushes are given in Figure 3b. The three skulls shown here

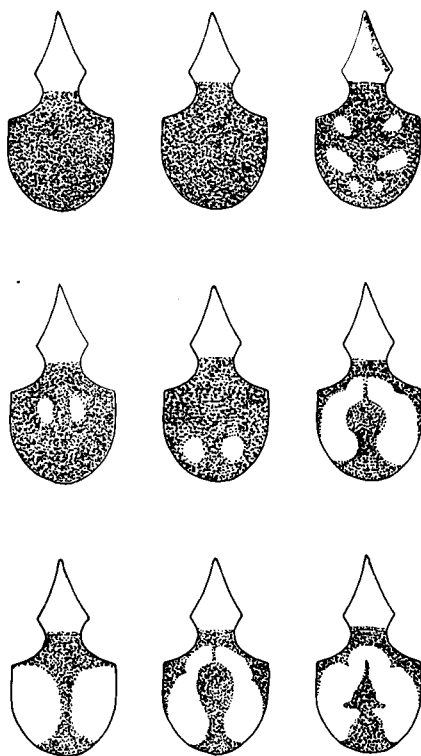


Figure 3a, top; 3b, middle; and 3c, bottom. Pneumatization patterns illustrating normal median line pneumatization (3a); and two turdid variations of this pattern (3b and c). Figure 3b represents Hermit Thrush specimens AMNH 10502 and 10561, left to right. Figure 3c represents American Robin specimens AMNH 10548, 10568, and 10530 — left to right.

illustrate the successive advance of the pneumatization process. Part of the median line is relatively narrow, the remainder irregularly shaped, and — at final stage — the process shows a pattern of symmetrically-placed windows toward the back of the rear quadrants.

The three American Robin patterns shown in Figure 3c are from three individuals not necessarily in succession. The first to the left shows not only the narrow anterior portion and irregularly-shaped posterior portion to the median suture, but also shows a discontinuous suture unlike that seen in any other species at this advanced stage of pneumatization which I have yet examined. The middle skull shows a pattern similar to that of the Hermit Thrush in Figure 3b, and the skull to the right shows how the irregularity in direction of growth can cause formation of multiple windows at the nearly final stage of pneumatization.

Summary

Examination of certain skull dimensions of 34 passerine species shows a relationship between skull length and the type of pneumatization process observed. Those species which undergo pneumatization from the periphery (as viewed dorsally), without involvement of pneumatization along the median line, are the smaller species with a skull length of less than 17 mm. At some value above the 17-18 mm range, all of the species examined undergo pneumatization by a process involving a median line. Median line pneumatization thus appears to offer the structural support needed in skulls of greater length.

Pneumatization patterns of 20 additional species are described, and certain pattern variations found among some turdids are illustrated.

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