Variation in skull pneumatization patterns of certain passerines

Robert P. Yunick

While examining the skulls of some passerine species to establish timing schedules of the completion of the pneumatization process, it became apparent to me that two basically different pneumatization patterns existed in these species. One involved pneumatization which eminated from the median line as well as from the periphery of the skull, as illustrated in Figure 1. This process will be referred to as median line pneumatization. The other process began at the periphery and grew inwardly without involving growth from the median line. This is illustrated in Figure 2. This process will be referred to as peripheral pneumatization. Each process led to a characteristic pattern generally typified in the latter stages by a twin-circle or twin-ellipse pattern in the median line process, and a heart- or V-shaped pattern in the peripheral process.

Among different species, and even among individuals of a species, there was substantial variation in shape and positioning of the unpneumatized windows in both of these two basic patterns. Most individuals that completed the peripheral process did so as shown in Figure 2. In this case, the V-shaped window finally closed without ever being bisected by pneumatization from the median line. One variant of the peripheral process, shown in Figure 3, gives the appearance of median line pneumatization only in its very last stages. This variant pattern is simply the result of more rapid growth of the inner wedge of the V to, in effect, cleave the V to give two small windows. Another variant of the peripheral process is shown in Figure 5. In this case, a crescent-shaped window formed, always well forward in the skull, and it finally developed into two laterally dispersed windows which eventually closed.

Most median line pneumatization followed the pattern of Figure 1 wherein the semi-elliptical windows closed approximately uniformly on both axes of the semi-ellipses. Figure 4 illustrates a variant of this process. In this variant form, the windows closed preferentially at first on the shorter, lateral axis to form windows in the shape of long, thin slits measuring one-two mm wide and five-ten mm long, depending on the species involved. Finally these windows closed completely.

Most of the species examined exhibited principally one or the other of these patterns. A few species showed sufficient ambiguity to defy firm classification into one or the other group. Among the species found to exhibit median line pneumatization were the following:

Dark-eyed Junco *(Junco hyemalis)*
Evening Grosbeak *(Hesperiphona vespertina)*
Purple Finch *(Carpodacus purpureus)*
White-throated Sparrow *(Zonotrichia albicollis)*
Fox Sparrow *(Passerella iliaca)*
Swamp Sparrow *(Melospiza georgiana)*
White-breasted Nuthatch *(Sitta carolinensis)*

Most of them followed the pattern illustrated in Figure 1. However, the White-breasted Nuthatch commonly showed the variant in Figure 4. Only rarely did the Dark-eyed Junco show this tendency. The final stages of pneumatization in the Evening Grosbeak could not be followed fully to the end because fleshy tissue obscured that part of the skull where the process was finishing. It was evident from the early stages, however, that the median line process was occurring.

Those which exhibited peripheral pneumatization were the following:

Black-capped Chickadee *(Parus atricapillus)*
Red-breasted Nuthatch *(Sitta canadensis)*
Brown Creeper *(Certhia familiaris)*
Golden-crowned Kinglet *(Regulus satrapa)*
Ruby-crowned Kinglet *(Regulus calendula)*
Yellow-rumped Warbler *(Dendroica coronata)*
American Goldfinch *(Spinus tristus)*
Common Redpoll *(Carduelis flammea)*

All, except the American Goldfinch, showed patterns similar to those in Figure 2; or to a lesser extent similar to the variant in Figure 3. One other minor variation that was seen, but which was not illustrated, involved completion of the process beyond the point illustrated in the far right pattern in Figure 2. Some individuals maintained the V-shaped pattern to the very end, whereas others compressed the V-shaped window to form a single elliptical shape, and finally closed it. Again, individual variation led to irregularities in these patterns, and Figures 1-5 represent the patterns in a somewhat idealized state. However, despite the

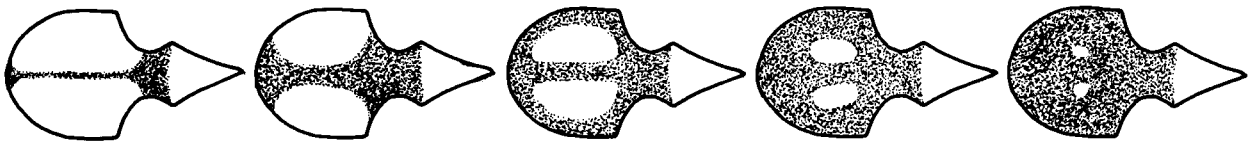

FIGURE 1

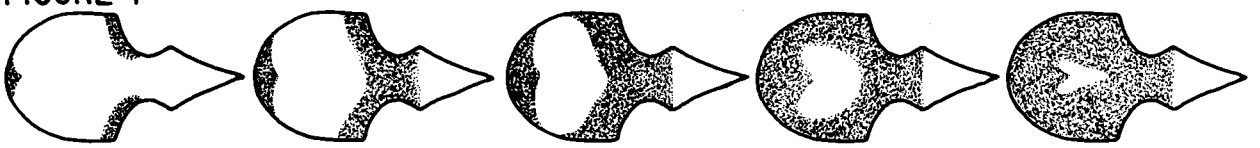

FIGURE 2

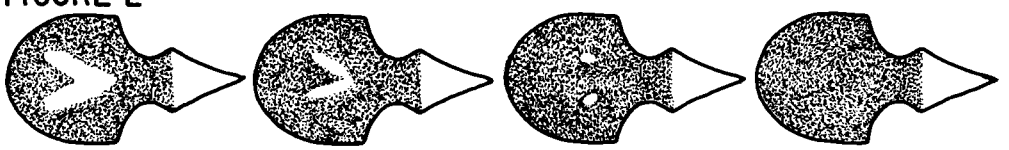

FIGURE 3

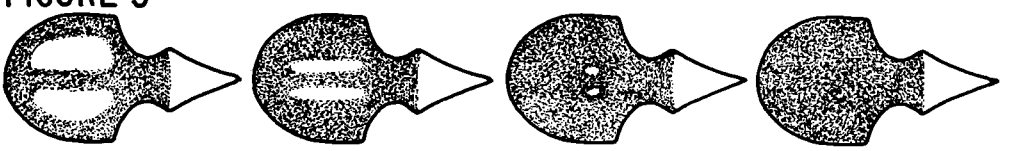

FIGURE 4

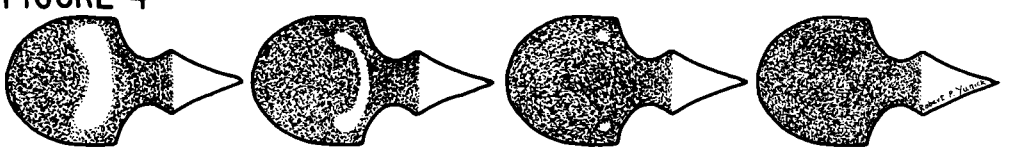

FIGURE 5

Figures 1—5. Skull patterns seen from above depicting the advance of pneumatization from left to right. The unshaded areas represent unpneumatized windows in the bone structure, and the shaded areas are pneumatized.

1—Typical median line pneumatization
2—Typical peripheral pneumatization
3—A variant form of peripheral pneumatization
4—A variant form of median line pneumatization
5—Another variant form of peripheral pneumatization

individual irregularities, the patterns depicted here illustrate the more basic differences.

The American Goldfinch showed only the crescent-shaped variant illustrated in Figure 5. Some few Purple Finches showed very laterally dispersed windows resembling the nearly final position of the American Goldfinch; however, not enough intermediate patterns have been recorded to determine how the positioning of these lateral windows developed. In all likelihood the Pine Siskin *(Carduelis pinus)* belongs on the peripheral pneumatization list. However, since 3 of the 34 patterns recorded for this species showed median line tendencies, the assignment remains tentative. The House Finch *(Carpodacus mexicanus)*, however, showed a great deal of ambiguity among the 104 patterns recorded. Examples of each of Figures 1, 2, and 5 were present in substantial number, and the species could not be classified.

Understanding the variability in shape and position of these pneumatization patterns is of value to the bander using pneumatization as an age-determining technique. Because of the looseness of the skin on the neck and the back of the head of most passerines, the back of the skull is the area most easily examined. Once the feathers are wet and matted, the skin may be moved back and forth easily to discern the bone structure beneath. This method suffices in the late summer and early autumn during the early stages of pneumatization. However, as the process advances, most pneumatization is completed on the forward quadrants of

the skull where examination is more difficult as the result of the tightness of the skin in this area, and because of the proximity of the eyes. Thus, it is helpful to know what to look for and where to look for it in order not to overlook individuals in the final stages of completion of the process. It is in this vein that these results are presented to make banders aware of these variations.

The patterns used for this analysis were drawn while the birds were in the hand. Most were examined under a 20-watt, illuminated, 10X magnifier. Generally, the median line group completed the process with the last remaining windows centered in the middle of the skull, or in the front quadrants—sometimes laterally dispersed. Those in the peripheral group, except for the American Goldfinch, showed very little lateral scatter. Completion occurred at or near the median line, rarely in the back quadrants, mostly at the center, and occasionally well forward to near the eyes.

Literature on pneumatization patterns of North American species is scarce. Nero (1951) showed the change in patterns for the House Sparrow *(Passer domesticus)* at age 15 days to completion at 181-221 days. The patterns he illustrates are similar to the median/line pattern described here, but with some slight variation.

Mellencamp (1969) illustrated the nearly completed patterns of the White-throated Sparrow and Dark-eyed Junco in her Figures 2a and b, respectively. Both are consistent with the median line classification given here; however, she portrays the junco pattern as that of the slit variant of this Figure 4. This pattern was less common than the more usual pattern of Figure 1. She also shows two Purple Finch patterns as Figures 2c and d. Both appear to fall in the median line group with 2c being the more normal pattern illustrated here as Figure 1; and 2d showing the less common case of completion of the process at the orbits. This pattern may be the precursor to the lateral variant referred to earlier. However, she does not illustrate the steps in the process that led to this pattern.

Leberman (1970) studied the pneumatization process in the Ruby-crowned Kinglet and concluded that two basically different patterns (Type A and B) existed in this species. His illustrations agree with the peripheral group assignment made here; however, it is suggested that the two types he described are not really basically different patterns but simply the two variants shown here in Figures 2 and 3 — wherein the only difference in the final pattern is the rate at which the inner wedge of the V grows forward. If it grows rapidly, it gives the pattern in Figure 3, or Leberman's Type A, by cleaving the V into two windows. If it grows slowly, the window always remains as a single window as in Figure 2 here, or his Type B. Regardless of which rate of growth is prevalent, the two variants still involve only peripheral growth and not median line growth.

This interpretation is supported by the patterns of a very closely related species, the Goldcrest *(Regulus regulus)* recorded by Hogstad (1971). He pictures skull patterns from autumn specimens from near Oslo, Norway (his Figures 1A and B) in which no median line process is shown. However, at the last stages (his Figures 1C and D), the V-shaped window cleaves into more than one window similar to that shown here in Figure 3.

Stewart (1972) reviewed the advance of pneumatization of eight species to determine the applicability of the method for determining age of these species in autumn in California. He rated the advance on a five-stage scale. The pattern he illustrates as his Figure 1 is that of peripheral pneumatization. My findings do not agree with his assignment of the Fox Sparrow to this group.

Conclusion

Examination of the skulls of 17 passerine species revealed the existence of two basic pneumatization patterns termed median line and peripheral pneumatization. A high degree of variability in the positioning of these patterns exists and is believed due to variations in the directional rates of growth of the bone structure undergoing pneumatization. Knowledge of variations in these patterns should aid banders who use skull pneumatization as an age-determining method.

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1527 Myron St., Schenectady, NY 12309.

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