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COLOR AND SIZE VARIATION IN EASTERN WHITE-BREASTED NUTHATCHES

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ABSTRACT.—An analysis of 928 specimens of White-breasted Nuthatch (*Sitta carolinensis*) collected in eastern North America demonstrates that all nuthatches can be sexed in the hand, but determination of sex at a distance is subject to considerable error, especially in southeastern populations. All but three of the specimens examined can be sexed accurately using presence or absence of gray on the crown. At least 10% of the females in any population in eastern North America will appear to have dark crowns when viewed from a distance in the field; populations in the southeasternmost United States have a high frequency of females with dark crowns—83% in peninsular Florida and 40% in coastal plain populations in Alabama, Georgia, South Carolina, and northern Florida. Wing and bill lengths show a clinal geographic pattern, with the largest birds in the north and the smallest in Florida. Although peninsular Florida populations are the most distinct of any geographic area, I can find no criteria to identify more than 60% of them unequivocally in the absence of collecting locality data. For this reason I recommend that all White-breasted Nuthatches east of the Great Plains be considered one subspecies: *Sitta carolinensis carolinensis* Latham. *Received 25 Jan. 1992, accepted 24 April 1992.*

White-breasted Nuthatches (*Sitta carolinensis*) have been described as sexually dimorphic in plumage at least since Wilson (1808) who noted that the black of the crown of females is "less deep" than that of males. Dwight (1900) was more emphatic about the gray cap of females (at least of northern populations) stating that "females never, even in later plumages [after first winter], acquire enough black on the cap to be mistaken for males." Scott (1890) was apparently the first to notice that some female White-breasted Nuthatches have black crowns, when he used the presence of this feature to help characterize the peninsular Florida populations as a distinct subspecies (*S. c. atkinsi*). He noted that the crowns of some Florida females were partly suffused with gray.

Oberholser (1917) performed the first critical analysis of the species over its entire range in the eastern United States and concluded that Florida birds were indistinguishable from those in South Carolina, but that two forms were recognizable. He characterized *S. c. carolinensis* as occurring throughout the southeastern United States north to North Carolina, Kentucky, southern Indiana, and southern Illinois, and west to eastern Texas, and described a new subspecies *S. c. cookei* as occurring to the north of *carolinensis*. He restricted the type locality of the species to the mouth of the Savannah River in South Carolina. According to his

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analysis (p. 185), *S. c. cookei* differs from *carolinensis* by being "larger; upper parts lighter; lower parts more purely white; bill usually relatively less slender; and female with black of head usually overlaid with plumbeous."

Aldrich (1944) apparently considered crown color to be unimportant taxonomically since he failed to mention it in his revision of the species. He followed Oberholser but placed the zone of intergradation between *cookei* and *carolinensis* in North Carolina through Tennessee and southern Missouri. Mengel (1965) reviewed the differences between the eastern subspecies and concluded that the major difference between the two was in the proportion of black-crowned females, which was considerably higher in *carolinensis.* Greenway (1967) lumped all eastern populations into *carolinensis,* asserting that the northern populations are "distinguished only by the single character of a slightly paler back" (p. 139).

In their aging and sexing guide (United States Fish and Wildlife Service and Canadian Wildlife Service 1991) the Bird Banding Laboratory asserted that in White-breasted Nuthatches the sex of birds with black caps cannot be determined (reliably) in populations south of New Jersey, Pennsylvania and the Ohio River. My own experience with this species, both under banding conditions and in museum collections has suggested that this assertion may be overly cautious, and further search of the literature showed that the patterns of variability in female crown color were not well understood.

Apart from crown color, there seem to be few differences between sexes of White-breasted Nuthatches, and none that discriminates a majority of individuals. Mengel (1965) asserted that mean wing length differed between sexes but no statistical tests were made. The ranges reported in Pyle et al. (1987) also suggest that females have slightly shorter wings but this character was not rigorously examined by them. Both wing and bill lengths have been reported to show geographic variation (e.g., Oberholser 1917, Aldrich 1944) but no statistical analyses have been published.

No discussion of possible mis-sexing of museum specimens occurs in any of the reports cited above. Such specimens, if unrecognized, can lead to significant errors in analyses. For example, the number of female nuthatches with black crowns may be much inflated. Considerable personal experience with museum collections has demonstrated that, for species with even moderate sexual dimorphism in plumage, as many as 5% of the specimens in a collection are likely to have been mis-sexed. Parkes (1989) provides an extensive discussion on the prevalence of mis-sexed museum specimens.

In this study I have assessed the differences in external characteristics between male and female White-breasted Nuthatches east of the Great

TABLE 1
SPECIMENS OF WHITE-BREASTED NUTHATCH USED IN THIS STUDY

	Area[a]	Total males	Total females	Dark-crowned females (%)
1	Northeast	182	157	9.6
2	North central	50	37	10.8
3	Southern Appalachians	55	35	31.4
4	South central	40	22	22.7
5	Southeast	54	30	10.0
6	Florida and Georgia	71	43	62.8
7	Western edge	97	56	12.5
	Total	549	380	18.9
Alabama, Georgia, Florida, South Carolina samples				
A	Peninsular Florida	22	17	82.3
B	Coastal Plain	47	28	39.3
C	Piedmont	11	8	37.5

[a] See Fig. 1 for limits of geographic areas.

Plains. The following specific questions are addressed: (1) Can mis-sexed museum specimens be recognized? (2) What are the patterns of variation in crown color with respect to age, sex, and geography; are any differences significant? (3) Do significant differences in bill length or wing length exist between ages, sexes, or populations? (4) For which populations can live birds be reliably sexed in the hand? (5) For which populations can birds be reliably sexed at a distance in the field? and (6) What are the taxonomic implications?

MATERIALS AND METHODS

I measured 928 specimens of White-breasted Nuthatches collected east of the Great Plains (Table 1), from museum collections in the eastern United States and Canada (see acknowledgments for list). For each specimen, the following data were taken: location, date, sex, age, wing length (unflattened chord to the nearest 0.5 mm), bill length (from the distal margin of the nares to the tip of the upper mandible, to the nearest 0.1 mm), and crown color. For crown color, I divided the forehead, crown, and nape into five regions. Using the terminology of Pettingill (1985) these are: (1) anterior half of forehead; (2) posterior half of forehead; (3) crown except occiput; (4) occiput; and (5) nape. For each region I scored the color as: 0 = black; 0.5 = trace of gray (a few feathers); 1 = presence of gray but area appears dark; 2 = considerably gray (most feathers have gray tips). Other data were taken from the specimen labels.

White-breasted Nuthatches are considered non-migratory by most authors. Scattered anecdotal evidence of movements of individuals has been reported, especially for the fall season (e.g., Griscom and Snyder 1955, Mengel 1965), but there is no evidence of long-distance movements by members of this species; southern populations are not diluted by northern migrants during the winter. In this study I assumed that each specimen represented

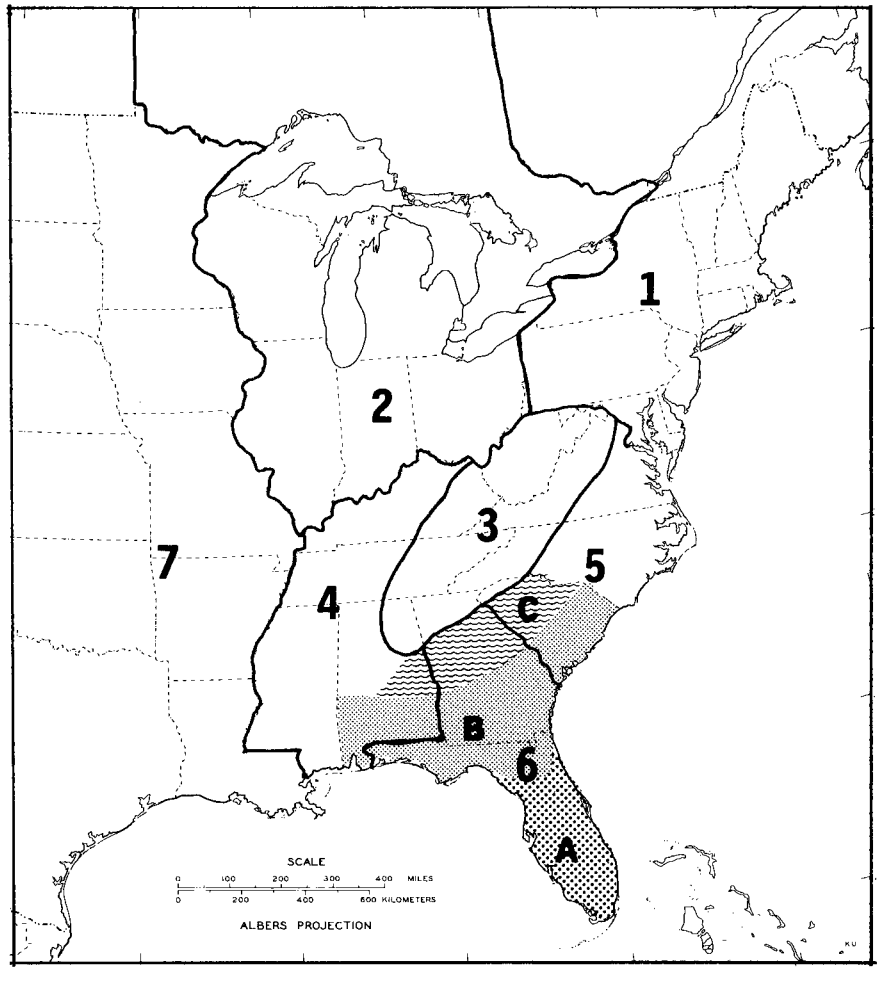

FIG. 1. Geographic regions used in this study. Outlined and numbered regions are the primary divisions; shaded and lettered regions are for the subsequent finer analyses.

the resident populations of the collecting locality, regardless of the date of collection. Each specimen was allocated to one of seven geographic regions (Table 1, Fig. 1). These were chosen (1) to reflect the conclusions of previous workers as indicated by the ranges of the subspecies each recognized and (2) to be sure that variation between broad ecogeographic units (such as between populations in the southern Appalachians and the adjacent piedmont) was not overlooked. Because the analysis using the original seven regions did not permit unequivocal taxonomic conclusions, I further divided the specimens from Alabama, Florida, Georgia, and South Carolina into three sub-regions corresponding to broad physiographic

areas recognized by Wayne (1910), Howell (1932), Burleigh (1958), and Imhof (1976); peninsular Florida; coastal plain north of peninsular Florida; and piedmont (Table 1, Fig. 1).

To assess the occurrence of mis-sexed museum specimens, I used a series of 40 carefully sexed recent specimens in the Carnegie Museum collections to evaluate plumage characteristics other than crown color that might provide suitable discrimination. I also compared ranges for wing and bill lengths of specimens of unequivocal sex to evaluate their discriminatory utility.

Few museum specimens bore any indication of age on the label, and no aging criteria are available that would apply to study skins (Pyle et al. 1987). To assess the effects of differences in wing length due to age, I used data from 208 birds (mostly in fresh fall plumage) banded at Powdermill Nature Reserve (the field station of Carnegie Museum of Natural History, located in Westmoreland County, Pennsylvania) for which sex (determined by crown color; equivocal individuals not included) and the plumage of the remiges were known. This sample was evenly divided between males and females and birds with first basic remiges and those with second or later basic remiges. An examination of the data from museum specimens used in this study showed that very young birds had much shorter bills than adults but that the adult length was attained within a few months of hatching. To reduce the age bias as much as possible in the analysis of bill length variation, I eliminated specimens with bill lengths shorter than the minimum for specimens taken between November and March (i.e., shorter than 11.0 mm for females and 11.8 mm for males), and I also eliminated any specimens taken during the period May through August that were marked as immature on the label.

The crown color of birds marked as immature or juvenile, especially those with rectrices still partly sheathed or those with very short bills, was examined to assess the variation in this character due to age. The juvenile plumage (especially the crown) appears to be replaced very soon after fledging and is very similar to postjuvenal plumages, except that any black on the crown is dull rather than shiny. In color, first basic plumage is essentially identical to later plumages; White-breasted Nuthatches do not have an alternate plumage. In analysis of crown color, all ages were pooled. I used the mean of the five crown scores to characterize overall crown color for each specimen. The distribution of gray on the crowns of females is not random; in all but a few instances, birds with reduced amounts of gray have the least on segments 3–5, and the most on segment 1. This permitted the following simple criterion for birds that would appear to have dark crowns when viewed at a distance (field criterion): any specimen with a score of less than 2 on crown segment 2 was noted as dark-crowned.

Analysis of numerical data was done using the BIOM statistical package (Rohlf 1989). Patterns of variation between sexes and geographic regions were evaluated using analysis of variance and the *GT2* method of pairwise multiple comparisons (Sokal and Rohlf 1981; programs BASTAT, NESTAN, MCPAIR, and RXC of BIOM). The comparison of frequency of black-capped females between peninsular Florida and the coastal plain areas was done using a contingency table and chi-square.

RESULTS

Identification of mis-sexed individuals.—Mensural characters are not useful for discriminating the sexes of White-breasted Nuthatches (see results below). However, Robert C. Leberman and Robert S. Mulvihill, banders at Powdermill Nature Reserve, suggested that the color of the outer margins of the secondaries and greater secondary coverts might discriminate the sexes. Careful examination of the reference series in

strong daylight confirmed this. On the closed wing, the outer edges of the secondaries produce a band of blue-gray color dorsal to the mostly dark edges of the primaries. In males the blue-gray of these secondary edges shows no hint of brownish or greenish wash, whereas in females the blue-gray is duller and with a greenish or brownish cast (when compared directly to a typical male). This distinction often applies to the back feathers as well, although it is more difficult to assess. Examination of the crown color of the birds in the reference series showed that males invariably had shiny black crowns with no trace of gray on the tips of any feathers (some birds had a few *white* feathers mixed in with the black near the base of the bill, but these were quite different from the gray-tipped feathers typical of females). Females, on the other hand, always had gray tips to at least some crown feathers. In the reference sample, most showed a nearly solid gray cap (nearly all feathers had gray tips), but a few birds had so little gray as to appear black from any distance.

Applying the wing color criterion to a much larger sample, including all specimens for which crown color and label information appeared to disagree (specimens marked as male but with gray in the crowns; specimens marked as female but with dark crowns) revealed that, with three exceptions, all specimens with female-type wings also had at least a few gray feathers in the crown, and all specimens with male-type wings had solid shiny black crowns. The remaining three specimens (all from U.S. National Museum: 195759, Washington, D.C., 15 May 1888; 352989, Middleboro, Kentucky, 20 September 1938; 524553, Washington, D.C., 6 February 1899) are labeled as females and have female-type wings but have no traces of gray in the crowns. These birds I treated as females in subsequent analyses. Of the 928 specimens I examined, I believe 38 were incorrectly sexed; 11 males that were recorded as females, and 27 females that were recorded as males. Many of the latter had solid gray crowns; apparently earlier workers assumed these birds were mis-sexed since there is no mention in their reports of males with gray crowns.

Patterns of variation between sexes and among geographic regions.— Males always have entirely shiny black crowns, regardless of population; there is no geographic variation in this character. Significant variation exists among geographic areas for overall female crown color (Table 2; $F = 12.90$, df = 7,334, $P < 0.001$). However, this is entirely accounted for by Region 6 (Florida and Georgia) which differs significantly from all others ($GT2 \geq 3.253$, $P < 0.01$). No other significant differences were detected between geographic areas. Females from Region 6 have, on average, much darker crowns than birds in other parts of the eastern United States. Table 1 lists the percentage of dark-crowned females (field criterion rather than mean crown score) recorded for each geographic region.

TABLE 2
BASIC STATISTICS FOR WING AND BILL LENGTHS AND CROWN COLOR BY SEX AND GEOGRAPHIC AREA

Region	Males		Females	
	N	Mean (± SE)	N	Mean (± SE)
Wing				
1	164	89.6 (±0.15)	132	88.6 (±0.16)
2	48	89.3 (±0.30)	28	88.4 (±0.46)
3	49	89.0 (±0.23)	29	86.8 (±0.31)
4	35	88.0 (±0.33)	19	85.8 (±0.44)
5	51	88.2 (±0.29)	26	86.7 (±0.49)
6	63	86.9 (±0.27)	39	85.3 (±0.39)
7	91	88.6 (±0.28)	48	87.1 (±0.35)
Bill				
1	153	14.34 (±0.92)	120	13.13 (±0.56)
2	45	13.38 (±0.92)	29	13.07 (±0.12)
3	46	13.45 (±0.72)	24	12.81 (±0.92)
4	34	13.10 (±0.90)	19	12.45 (±0.16)
5	51	13.17 (±0.83)	27	12.48 (±0.20)
6	61	13.24 (±0.73)	36	12.59 (±0.95)
7	84	13.44 (±0.63)	44	12.86 (±0.86)
Crown color				
1			134	1.81 (±0.40)
2			30	1.76 (±0.76)
3			29	1.56 (±0.95)
4			19	1.49 (±0.15)
5			27	1.75 (±0.81)
6			39	1.06 (±0.85)
7			48	1.79 (±0.59)
A			17	0.68 (±0.83)
B			28	1.05 (±0.92)
C			8	1.02 (±0.21)

No significant differences in bill length were found between sexes ($F = 3.64$, df = 1,13, $P > 0.05$), but significant variation was demonstrated among geographic areas ($F = 11.56$, df = 13,737, $P < 0.001$). For comparisons between areas, data for both sexes were pooled; basic statistics are shown in Table 2. Seven comparisons were found to show significant differences: Region 4 versus Regions 1, 2, 3, and 7 (smallest $GT2 \geq 3.15$, $P < 0.05$); Region 5 versus Regions 1 and 7 ($GT2 = 3.05$, $P < 0.05$); and Region 6 versus Region 1 ($GT2 = 5.33$, $P < 0.01$). Bill length averages larger in the north and smaller in the south. Populations in the southern

Appalachians are more like those to the north than they are to other populations of similar latitude.

Mean wing lengths for the Powdermill Nature Reserve banding sample were: immature female 88.173 (SD = 2.303, N = 52); immature male, 90.040 (SD = 4.723, N = 50); adult female, 90.367 (SD = 3.341, N = 49); adult male, 91.316 (SD = 3.488, N = 57). Analysis of variance demonstrates that most of the variation is attributable to age (between sexes $F = 1.38$, $P > 0.5$; between ages $F = 23.86$, $P < 0.01$). Immature females are significantly smaller than any other age and sex class (versus adult female, $GT2 = 5.93$, $P < 0.01$; versus immature male, $GT2 = 5.07$, $P < 0.01$), and immature males are significantly smaller than adult males ($GT2 = 5.93$, $P < 0.01$; versus immature male, $GT2 = 5.07$, $P < 0.01$), and immature males are significantly smaller than adult males ($GT2 = 3.54$, $P < 0.01$). In the sample taken from museum specimens, I was not able to separate first year birds from those older than one year. The Powdermill data suggest that, with ages pooled, differences detected between sexes might be actually due to age because the inclusion of immature females should lower the mean for females more than the inclusion of immature males would lower the mean for males. This turned out not to be a problem because the specimen data failed to show significant variation between sexes ($F = 2.83$, df = 1,14, $P > 0.05$); the sexes were pooled in subsequent analyses. Significant variation was found among geographic areas ($F = 14.26$, df = 14,835, $P < 0.01$). In geographic comparisons, Region 6 (with the smallest mean) was significantly different from all others except Region 4 (vs Region 5, $GT2 = 4.148$, $P < 0.01$). Region 1 (with the largest mean) was significantly different from all others except Region 2 (vs Region 3, $GT2 = 3.37$, $P < 0.05$). In addition, Region 2 was significantly different from Regions 4 and 5 (vs Region 5, $GT2 = 3.49$, $P < 0.05$). No other comparisons were significant.

Variation between populations in the southeastern United States.—No significant difference was detected in bill length between any of the three physiographic regions A, B, and C, or for any character between the piedmont and the coastal plain. Wing length, however, differed significantly ($F = 9.76$, df = 1,113, $P < 0.01$) between peninsular Florida and the coastal plain populations. While mean crown color did not differ significantly between peninsular Florida and coastal plain populations, a contingency table testing the independence of geography (peninsular Florida vs coastal plain) and crown color (using the field criterion) demonstrated that these were not independent (peninsular Florida, 14 dark-crowned, 3 gray-crowned; coastal plain, 11 dark-crowned, 17 gray-crowned; G-statistic > 7.3, $P < 0.01$). Table 1 lists the percentage of dark-crowned females in each of the three physiographic subregions of the southeastern

United States. Populations in peninsular Florida show a frequency of 82%, nearly twice that of the adjacent coastal plain or piedmont populations. Peninsular Florida birds average smaller in wing length and have a higher percentage of females with dark crowns than coastal plain populations in Alabama, Georgia, and South Carolina.

DISCUSSION

Use of museum collections.—Museum collections are exceedingly important resources for answering many kinds of biological questions (and may be the only source of data pertinent to some questions). One unfortunate reality is that errors exist in the data associated with these specimens. A fundamental part of any study involving museum collections must be the assessment of such errors. In the present study, if the label data regarding sex were used uncritically, the conclusions would have been quite different (e.g., an assertion that males could have gray crowns). Considerable experience suggests that for sex information, an error rate of 5% is not unexpected. The error rate detected in this study is just over 4%, for a species in which sexual dimorphism in plumage is not glaringly obvious.

Variation due to age and sex.—With the exception of sex differences in crown and wing color, White-breasted Nuthatches show little variation between age and sex classes. The mean wing length for birds in first basic plumage is shorter than for birds in later plumages, but the ranges overlap to a great extent. Immature females tend to have especially short wings. The bills of juvenile birds do not reach adult length for several months after fledging, but otherwise there are no differences between age and sex classes for this character. Juvenal plumage is duller (especially the crowns of males) than first basic plumage, but first basic plumage, which is attained rather quickly after fledging, is essentially identical to subsequent plumages. Crown color and the color of the outer margins of the secondaries are sexually dimorphic.

Geographic variation.—Variation in bill and wing lengths in White-breasted Nuthatches appears to be clinal in the eastern United States; populations with the largest means for these characters are in the Northeast, whereas the smallest are in the southern states. Populations in the southern Appalachians are intermediate but larger than those in other areas at the same latitude. Crown color of females shows the strongest geographic patterning: the average crown color of females in Florida and Georgia (south of the Appalachians) is significantly darker than in any other population; other populations show no significant differences in this character. The frequency of females with crowns that would appear black at a distance is significantly higher in peninsular Florida than for popu-

lations on the southeastern coastal plain, and is higher for populations in the southern United States (including those in the Appalachians) than in the north.

Determining the sex of live birds.—In the hand, the sex of virtually all White-breasted Nuthatches can be determined correctly using the criterion of crown color (3 of 928 would have been mis-sexed in this sample): if any crown feathers have gray tips, the bird is a female; if the crown is solid shiny black and no feathers have gray tips, the bird is a male. Males may have a few white feathers mixed in with the black near the base of the upper mandible, but these feathers are all white, not dark with gray tips. In females with dark crowns, the feathers with gray tips are usually on the forehead, but are on the nape in a few individuals. It should be emphasized that even in the hand some females have so little gray as to be easily overlooked, especially in poor light. However, such females occur at very low frequencies (less than 1–2%) in all populations, even those in Florida and Georgia. The color of the edges of the secondaries can be used to corroborate the conclusions drawn from crown color, but this criterion is difficult to apply without a reference (e.g., an adult male study skin in fresh plumage).

Determining the sex of birds in the field at a distance is considerably more difficult. East of the Great Plains, at least 10% of all females regardless of population have little enough gray in the crown to be easily mistaken for males (Table 1). During the breeding season, when the birds are paired, careful observation should be able to separate the sexes in most cases. However, after the young have fledged and the birds are in family groups, determining the sex of individuals with dark crowns will be subject to an error rate approaching 10%. In Florida and Georgia south of the Appalachians, the field situation is far worse: 40%–80% of the females appear to have dark crowns. I suspect that the only way to keep the error frequency low when working with these populations is to use color markers.

Taxonomic implications.—Oberholser (1917) suggested that the colors of the back, underparts, and (in females) crown differed between northern (i.e., New England) and southern (i.e., Florida) White-breasted Nuthatches. He also thought southern birds were smaller than northern ones. Aldrich (1944) restricted the principal distinction between Oberholser's races (*Sitta carolinensis carolinensis,* and *S. c. cookei*) to back color, *S. c. cookei* was considerably lighter in color. Mengel (1965) carefully reassessed these characters as they applied to Kentucky birds (where the two races supposedly intergraded) and concluded that, while it was possible that average color differences existed, such characters were of little use in

assigning specimens to one or the other race. He thought the principal difference between the races was the frequency of dark-crowned females in the populations: such birds were common in populations of *S. c. carolinensis,* and rare in populations of *S. c. cookei.* Like Mengel, I am not able to appreciate the difference in back or underpart colors between southern and northern birds; the range of variation in these characters appears to my eye to be very similar in most populations. Mensural characters, being clinal for this species, also do not distinguish sets of populations at a subspecific level. Female crown color, however, shows a more distinct geographic pattern. Populations in the southeastern United States (especially Georgia and Florida) show a much higher frequency of dark-crowned females. Finer analysis shows that the populations in peninsular Florida account for much of this difference. Although Mengel (1965) considered all populations south of the Ohio River to show a similar frequency of black-crowned females, my analysis indicates otherwise. At least one of the black-crowned females used in Mengel's analysis was, I believe, mis-sexed, and others have varying amounts of gray in the crowns (I was not able to reassemble all of his material). While the populations of my Region 4 (which includes the part of Kentucky with Mengel's southern birds) show a higher frequency of dark-crowned females than areas to the north, the average crown color is not significantly different.

My data suggest that like a number of other species (Howell 1932), populations of White-breasted Nuthatch in peninsular Florida have followed a somewhat different evolutionary history from those in other areas. Peninsular Florida birds have significantly shorter wings than those to the north, and the frequency of females with dark crowns (83%) is nearly twice that of any other region. Populations on the coastal plain to the north of peninsular Florida are most similar to the Florida birds; they average smaller than birds from farther north and have a higher percentage of dark-crowned females than more northern populations. I do not, however, recommend that two subspecies be formally recognized east of the Great Plains. Such recognition implies that individuals can be assigned relatively unambiguously to one or the other taxon in the absence of data on geographic origin. I am unable to provide criteria that would correctly assign more than 60% of the specimens in my sample.

It is possible that historic changes have taken place in some of these nuthatch populations; the species is believed to be close to extinction in peninsular Florida (Stevenson 1978). Many of the specimens in the relatively small sample from the southeastern United States are from nearly a century ago and may not accurately represent the morphology found in

current populations. Much more collecting and field study of this species is needed in Alabama, Georgia, Florida, and South Carolina to clarify the present patterns of morphological characteristics.

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