J. Field Ornithol., 68(3):443-449

AGE DETERMINATION OF FREE-LIVING MALE BLACK-THROATED BLUE WARBLERS DURING THE BREEDING SEASON

GARY R. GRAVES

Department of Vertebrate Zoology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560 USA

Abstract.—Male Black-throated Blue Warblers (*Dendroica caerulescens*) can be aged as yearlings (SY) or older (ASY) during the breeding season using binoculars. Significant differences in wing color of SY and ASY males, as revealed by spectrophotometric analysis of museum specimens, are apparent in free-living birds. Error rates in age determination in five field trials averaged 3.1% for ASY males and 0% for SY males (though sample sizes were small for yearlings). Age data from multiple investigators should not be combined for analysis unless individual error rates can be estimated. The statistical effects of error are especially critical when age ratios are calculated for small samples ($n < 25$).

DETERMINACIÓN DE LA EDAD, DURANTE LA ÉPOCA REPRODUCTIVA, DE INDIVIDUOS MACHOS SILVESTRES DE *DENDROICA CAERULESCENS*

Sinopsis.—Durante la época reproductiva, los individuos machos de *Dendroica caerulescens* pueden ser clasificados en individuos de un año (IA) o más viejos (IV) con tan solo observarlos con binoculares. Se pueden notar diferencias significativas en el color de las alas de individuos de ambos grupos utilizando análisis espectrofotométrico de especimenes de museos. Estas diferencias pueden notarse en individuos silvestres. La tasa de error en la determinación de la edad de cinco intentos de campo promedio 3.1% para individuos viejos y de 0% para los jovenes de un año. Los datos tomados por grupos de investigadores sobre la edad de este tipo de aves no debe ser combinada para análisis a menos de que puedan estimarse la tasa de error. El efecto estadístico de los errores es especialmente crítico cuando tratan de calcularse la tasa de edades utilizandose muestras pequeñas ($n < 25$).

Identification of age classes is a critical procedure in avian demographic or behavioral studies. The Black-throated Blue Warbler (*Dendroica caerulescens*), a Nearctic-Neotropic migrant that breeds in eastern North America, has been the focus of intensive demographic and life history investigations at Hubbard Brook, New Hampshire, and on its wintering grounds in the Caribbean (see Holmes 1994 for references). In many respects, this sexually dichromatic species is ideal for study because it is common in prime breeding habitat and nests close to the ground. However, prevailing wisdom (Sliwa and Sherry 1992) posits that yearling and older individuals cannot be aged in the field. As a consequence, demographic censuses on large study plots are difficult because they require labor-intensive mist-netting in order to age birds.

I report the results of field trials that demonstrate that free-living male Black-throated Blue Warblers can be aged under field conditions during the breeding season. These data are supplemented with spectrophotometric data from museum specimens. Finally, I briefly discuss error rates in age determination of birds in demographic studies.

TABLE 1. Numbers of male Black-throated Blue Warblers aged in the field and subsequently collected, with estimations of error rate.

Males	Sullivan-Luzerne, PA	Clinton-Lycoming, PA	Clay, NC	Graham, NC		Totals
Year collected	1994	1994	1995	1995	1996	
Aged SY in the field	0	0	0	3	10	13
Errors[a]	—	—	—	0	0	0
Error rate	—	—	—	0%	0%	0%
Aged ASY in the field	20	21	16	36	37	130
Errors[a]	1	0	1	1	1	4
Error rate	5.0%	0%	6.3%	2.8%	2.7%	3.1%

[a] Number aged incorrectly in the field. Age-diagnostic plumage characters confirmed by comparative examination of specimens in USNM.

MATERIALS AND METHODS

Field methods.—I tested methods of age determination in free-living Black-throated Blue Warblers as an adjunct to studies of their population genetics and morphological evolution (Graves in press, unpubl. data). Hereafter, males in first alternate and definitive alternate plumage will be referred to as yearling or SY (=second year) and older or ASY (=after second year) males, respectively. A detailed description of molt sequence and plumage color is found in Holmes (1994).

Five field trials were conducted during June in the Appalachians of Pennsylvania (1994) and North Carolina (1995 and 1996). Territorial males were attracted with broadcast of tape-recorded song and observed with Zeiss 10 × 40 binoculars. All males encountered during the field trials were aged on the basis of diagnostic plumage characters (discussed in Results), and a fraction were subsequently collected for voucher specimens. Because geographic variation in plumage color and size and shape characters of Black-throated Blue Warblers are best evaluated in ASY males, only a few SY males were purposefully collected during the trials in order to test for possible bias in aging (Table 1). Age determination in females was not studied because they were more difficult to observe and were not collected. All specimens were prepared as rounded skins with associated skeletons and frozen tissues, and are deposited in the National Museum of Natural History (USNM), Smithsonian Institution. Age-diagnostic plumage characters that are difficult to observe under field conditions can be unequivocally confirmed in museum specimens. I estimated the error rate for each age class as the number of males aged incorrectly in the field as SY or ASY, respectively, divided by the total number aged as SY or ASY in the field.

Plumage characters.—Young (SY) male Black-throated Blue Warblers have dull primary (retained juvenal) coverts and olive margins on the alula coverts and can be distinguished in the hand from older (ASY)

males (Dwight 1900, Holmes 1994). However, the extent of the olive margins and relative dullness is variable, and some specimens are difficult to age by these criteria, especially in the absence of comparative material. Moreover, these characters can only be observed in free-living birds under ideal field conditions (i.e., in bright light at close range).

There are a suite of characters associated with SY plumage that are more easily observed than the alula and primary coverts under field conditions. The primaries and secondaries of SY males, which are retained from juvenal plumage, appear browner (less black) in the field than those of ASY males. Outer webs of the remiges, and especially the secondaries and tertials (S7–S9), are edged with bluish-gray or bluish-olive, as opposed to dark blue in ASY males. This results in less contrast between the white patch at the base of the primaries and the remainder of the flight feathers in SY males. A small percentage (8%, $n = 182$) of SY males possess one or more "adult" tertials (definitive alternate plumage). The wings of ASY males have a markedly "black and white" appearance under field conditions; the wing tips of ASY males appear blacker and often longer than those of yearlings. Wing color is most easily assessed in the field when individuals are near eye level and facing away from the observer.

Another indicator of SY plumage is the reduced size of white spots on the inner webs of the rectrices (Pyle et al. 1987). ASY males have large white tail spots that, when viewed from below in the field, appear to be broadly contiguous with the white undertail coverts. From underneath, the profile of the tail in SY males is narrower, less rounded, than in ASY males. Other less frequent indicators of SY status include traces of white in the superciliary or throat, faint yellowish washes on the flanks and vent area, and a reduced amount of black on the sides and flanks.

Colorimetric differences.—Wing color of SY (yearling) and ASY (older males) warblers from population samples collected in North Carolina and Pennsylvania was evaluated with a Color Mate reflectance spectrophotometer (Milton Roy). The portion of the wing immediately posterior to the secondary coverts and above the white wing patch (base of primaries 1–6) was centered over the aperture of the spectrophotometer (9.4 mm diameter). SY males subjected to colorimetric tests had juvenal tertials. The circular aperture covered both vanes of the tertials and the outer vanes of the secondaries and primaries. Data in Table 2 were compiled from the averages of three measurements per specimen (wing removed from aperture between trials).

Colorimetric characters were described in terms of opponent-color coordinates (L, a, b) (Hunter and Harold 1987). This quantitative scheme is based on the hypothesis that signals from the cone receptors in the human eye are coded by the brain as light-dark (L), red-green (a), and yellow-blue (b). The rationale is that a color cannot be both red and green or yellow and blue at the same time. "Redness" and "greenness," therefore, can be expressed as a single value a, which is positive if the color is red and negative if the color is green. In a similar fashion, "yellowness" or "blueness" is expressed by b for yellow and $-b$ for blue. The third

TABLE 2. Spectrophotometric measurements ($\bar{x} \pm SD$) of wing color of male Black-throated Blue Warblers. Asterisks indicate that character means of yearlings (SY) and older males (ASY) within populations were significantly different at $P = 0.0017$ ($= 0.01/6$).

	Colorimetric variables		
Males	L light-dark	a red-green	b yellow-blue
Yearlings (SY)			
NC	24.9–28.4 *27.2 ± 1.1	−0.35–1.46 0.70 ± 0.62	0.38–4.79 *3.10 ± 1.44
PA	28.0–31.2 *29.6 ± 1.2	0.32–1.57 *0.90 ± 0.38	2.81–5.97 *3.88 ± 0.91
Older (ASY)			
NC	19.9–23.9 21.9 ± 1.4	−0.18–0.88 0.16 ± 0.33	−1.29–0.92 −0.62 ± 0.65
PA	22.4–28.0 25.0 ± 1.82	−1.00–0.42 −0.29 ± 0.43	−2.55–0.68 −0.74 ± 0.87

coordinate, *L*, ranging from 0 to 100, describes the "lightness" of color; low values are dark, high values are light. In other words, greater reflectance yields higher *L* values.

Colorimetric differences between SY and ASY males were evaluated with two-sample *t*-tests (Wilkinson 1989). Significance of probability values was adjusted for the number of simultaneous tests. I used principal components analysis (PCA) on untransformed variables to reduce the colorimetric data from three to two dimensions. Unrotated principal components were extracted from correlation matrices (Wilkinson 1989).

RESULTS

Field trials.—Many variables affected the efficiency of age determination, most notably ambient light, cloudiness and rain, forest density, and stage of nesting cycle (affecting response to tape playback). Because of steep topography, deep shadows, and frequent morning mists, I often waited until 0830 h before attempting to age individuals. Males that responded aggressively to playback were aged within a few seconds, while others required more than an hour of playback and observation to age. SY males responded less aggressively to tape playback, even when mated, and were more reluctant to descend to eye level than ASY males.

In five field trials, I aged 143 males that were subsequently collected (an additional 153 males were aged but not collected). Error rates in age determination of ASY males varied among samples from 0 to 6.3%, averaging 3.1% overall (Table 1). No errors were committed on the much smaller sample ($n = 13$) of males aged in the field as SY. In each case where individuals were mis-aged, SY males were erroneously classified as ASY males. In fact, most males that I judged to be difficult to age eventually proved to be SY males with unusually dark wings. However, the

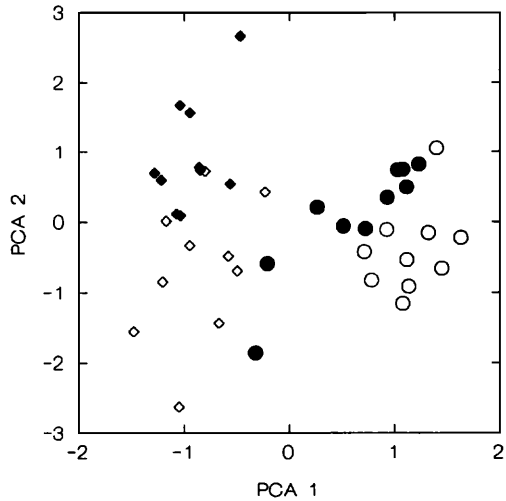

FIGURE 1. Bivariate plot of factor scores from a principal components analysis of wing color for SY (circles) and ASY male (diamonds) Black-throated Blue Warblers collected in North Carolina (filled) and Pennsylvania (empty).

majority of SY and ASY males are easily aged and errors were made under less-than-ideal field conditions (overcast skies or mist).

Univariate comparisons within populations show that wing color of SY males is significantly lighter (L), redder (a), and yellower (b) (=browner) than that of ASY males (Table 2). Both SY and ASY males from North Carolina have darker wings than the respective age classes from Pennsylvania, reflecting the difference in plumage melanism between northern and southern populations of the Black-throated Blue Warbler (Graves, unpubl. data).

In a principal components analysis (Fig. 1), all three colorimetric variables had high positive factor loadings on the first PCA axis (L = 0.81, a = 0.86, b = 0.95; variance explained = 76.4%) but loadings of mixed sign on the second PCA axis (L = −0.57, a = 0.46, b = 0.07; variance explained = 18.1%). Significant differences in wing color between SY and ASY males are evident in a bivariate plot of PCA factor scores (Fig. 1). The few individuals near the center of the plot (SY males from North Carolina) would be the most difficult to age under field conditions.

DISCUSSION

To my knowledge, error rates in age determination of mist-netted and free-living birds have not been addressed in the literature. The results reported here indicate that free-living ASY male Black-throated Blue Warblers can be aged by experienced observers with relatively little error during the breeding season. SY males may also be aged accurately, but my sample sizes are too small to confidently estimate error rates. It is

unknown whether the error rate reported here is any different from those generated in demographic or behavioral studies that capture and release warblers (e.g., Holmes et al. 1992).

Diagnostic evidence (e.g., specimens, photographs, or plucked feathers) of mist-netted birds is rarely taken unless the individual is thought to be unusual in some way. Thus, age determinations can rarely be independently confirmed. Field workers whose primary objective is to band quickly or color-mark and release birds, often place secondary importance on diagnostic age characters. The likelihood of aging error will increase when data are collected by a variety of students, assistants, and volunteers, few of whom have sufficient experience with museum specimens and the natural range of age-related plumage variation in the focal species. Unfortunately, statistics used to test for differences in age ratios (e.g., chi-square) are sensitive to the effects of classification error in small samples ($n < 25$). In any event, investigators should be cautious of combining age data collected by several observers for analytical purposes unless investigator error rates can be estimated. Age class data for free-living birds should only be collected by investigators with extensive museum and field experience.

When the distinction between yearling (SY) and older (ASY) passerine species is important, I recommend either that specimens be preserved or that diagnostic feathers be saved for future reference. The choice of feathers will naturally depend upon the species and sex. For Black-throated Blue Warblers, at least three feathers (alula covert, secondary remex [S4–S6], and outermost rectrix) should be clipped for future reference and independent assessment.

ACKNOWLEDGMENTS

I am grateful to Ray Chandler, Peter Pyle, Chris Thompson, and Kevin Winker for comments on the manuscripts. I appreciate Phil Angle, Jim Dean, Carla Dove, Chris Milensky, and Brian Schmidt for preparing specimens. I thank the North Carolina Wildlife Resources Commission, the Pennsylvania Game Commission, and the U.S. Fish & Wildlife Service for issuing permits, and the Smithsonian Research Opportunities Fund for field support.

LITERATURE CITED

DWIGHT, J. 1900. The sequences of plumages and moults of the passerine birds of New York. Ann. New York Acad. Sci. 13:73–360.

GRAVES, G. R. In press. Geographic clines of age ratios of Black-throated Blue Warblers (*Dendroica caerulescens*). Ecology.

HOLMES, R. T. 1994. Black-throated Blue Warbler (*Dendroica caerulescens*). No. 87 *In* A. Poole and F. Gill, eds. The birds of North America. Academy of Natural Sciences, Philadelphia and The American Ornithologists' Union, Washington, D.C.

———, T. W. SHERRY, P. P. MARRA, AND K. E. PETIT. 1992. Multiple brooding, nesting success, and annual productivity of a neotropical migrant, the Black-throated Blue Warbler (*Dendroica caerulescens*), in an unfragmented temperate forest. Auk 109:321–333.

HUNTER, R. S., AND R. W. HAROLD. 1987. The measurement of appearance. 2nd edition. Wiley, New York, 411 pp.

PYLE, P., S. N. G. HOWELL, R. P. YUNICK, AND D. F. DESANTE. 1987. Identification guide to North American passerines. Slate Creek Press, Bolinas, California.

SLIWA, A., AND T. W. SHERRY. 1992. Surveying wintering warbler populations in Jamaica: point counts with and without broadcast vocalizations. Condor 94:924–936.
WILKINSON, L. 1989. SYSTAT: The system for statistics. SYSTAT, Inc., Evanston, Illinois.

Received 21 Jul. 1996; accepted 31 Oct. 1996.