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William M. Gilbert

Geroge C. West

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William M. Gilbert
3745 Highland Road
Lafayette, CA 94549
wmglbrt@comcast.net

*George C. West**
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775
kbaybird@aol.com
*Current Address: 700 N. Cedar Bend, Green Valley, AZ 85614

ABSTRACT

Measuring crown patches, or caps, has been an accepted methodology to assist sexing certain species of wood warblers (Parulinae). *Additionally we have developed a system of cap grades to assess the orange crown patches of Orange-crowned Warblers* (Oreothlypis celata). *Our cap grades are based on the extent of orange in individual cap feathers, as well as other features such as extent and shade of orange in the crown. There appears to be a good correspondence between our designated cap grades and ranges of cap length, as those caps were graded and measured in museum specimens. However, the dimensions of caps in our specimens appeared to have been greatly affected by museum shrinkage. A methodology of cap grades may provide an additional tool useful for sexing Orange-crowned Warblers in the field and for evaluating the color structure of the concealed cap and individual cap feathers of this species.*

INTRODUCTION

Some species of wood warblers, Parulinae, display distinctively colored feathers in the medial crown that contrast sharply with the feathers of the remainder of the crown and head. These distinctive feathers are called "crown patches" or "caps" (Dunn and Garrett 1997, Pyle 1997), and can be found in many wood warbler species (Curson et al. 1994), including the North American breeding Yellow-rumped Warbler (*Setophaga coronata*), Wilson's Warbler (*Cardellina pusilla*), Orange-crowned Warbler (*Oreothlypis celata*), and Nashville Warbler (*O. ruficapilla*). Crown patches can be divided into two types. Those found in the Yellow-rumped and Wilson's warblers are "exposed" and, when present, are easily observed in the field at all times. Crown patches found in the Orange-crowned and Nashville warblers usually are "concealed" and often are not evident during field observation. The difference between an exposed and a concealed cap lies in the structure of individual cap feathers. In exposed caps, individual feathers usually are of a solid color throughout. In a concealed cap, while the distinctive, contrasting color of the cap may occupy much of the total length of individual feathers, that color does not extend to the distal end of the feathers. That portion near the distal end, the feather tip, is of a color the same as the remainder of the crown and head. When the crown feathers lie flat on the head; i.e., when the cap is not raised, the feather tips of the cap usually cover and mostly conceal the distinctively colored, lower portions of the cap feathers (Foster 1967, Dunn and Garrett 1997, Pyle 1997, Gilbert et. al 2010, WMG and GCW).

In species where both males and females can possess crown patches, measurements of the length of those patches can be used as an aid in separating the sexes. This has been the case for the Wilson's Warbler, that has an exposed cap, (Otahal 1995, Pyle 1997, Weicker and Winker 2002), and for the Orange-crowned Warbler, that has a concealed cap (Otahal 1994, Pyle 1997). For the Wilson's Warbler, measurement of the exposed cap is unambiguous. For the Orange-crowned Warbler, however, the exact extent of the concealed orange cap in the

crown is more difficult to assess, a difficulty enhanced by variable amounts of orange in the individual feathers of different caps.

The fact that the orange cap of the Orange-crowned Warbler is concealed and the amount of orange in individual feathers is variable has not prevented workers from utilizing cap measurements in published works (Otahal 1994, Pyle 1997) and data sets obtained by banding stations and private banders, including both authors of this paper. We believe that such measurements generally have reflected a difference between the Orange-crowned Warbler sexes and have been useful for sexing.

We have explored an additional methodology for evaluating Orange-crowned Warbler orange caps (or simply "caps") which involves determining "cap grades." We developed this supplemental system when we realized that much variation among the orange caps of different Orange-crowned Warblers involves variation in the amount and distribution of orange in individual cap feathers and not just variation in the dimensions of the caps. Tests we have performed suggest a good correlation between our cap grades and ranges of cap measurements, suggesting that measuring and grading caps might support each other for use in sexing Orange-crowned Warblers.

METHODS

In developing a system of cap grades, we examined 265 museum specimens and 105 live Orange-crowned Warblers netted in central California. We decided on criteria qualitatively defining and describing four different cap grades mainly based on assessing the extent, distribution, and shade of orange seen in tiers of cap feathers lying flat under and behind "lifted" caps of these birds. By lifted cap we refer to one in which a tier of cap feathers is blown or lifted up with a ruler. We assigned a cap grade to the cap of each museum specimen or netted individual we examined. We photographed the head regions of some museum specimens to aid in developing our system of cap grades and to illustrate the different cap grades. Finally, we measured, with a millimeter ruler, the longitudinal distances spanning the orange bands and green feather tips of cap feathers lying flat under the lifted caps of 100 specimens we determined to have grade 4 or 3 orange caps. These longitudinal distances measured in groups of individual feathers under lifted caps should not be confused with lateral or longitudinal distances measured to assess dimensions of entire crown patches. We statistically evaluated, using the Mann Whitney U test, respective longitudinal measurements spanning orange bands and green feather tips of grade 4 and 3 caps.

As a further aid in distinguishing between grade 4 and 3 caps, we collected and photographed 17 individual cap feathers from four netted Orange-crowned Warblers, two that we had determined had a grade 4 caps and two which had grade 3 caps. On these photographs we measured with calipers, at the juncture of the barbs with the rachis, preliminary longitudinal distances spanning "orange band zones" (defined in RESULTS), green feather tips, and dark downy barbs at the bases of the individual cap. We calculated the actual mm distances spanning these feather segments by applying an adjustment factor to the preliminary measurements on photographs, based on a standard separation distance seen in the background of each photograph. We determined total lengths of photographed feathers by adding together the adjusted measurements spanning the three feather segments at the rachis. We evaluated the longitudinal distances spanning respective grade 4 and 3 feather segments using the Student t or Mann Whitney U test to help define and distinguish individual feathers of the two cap grades. The number of cap feathers we were able to use in these analyses was limited by the number of birds (n = 4) we were able to net in the field. Even so, the collected cap feathers appeared to be representative of their respective cap grades.

As we developed our system for grading Orange-crowned Warbler orange caps, we decided on the number of cap grades based on three criteria: (1) how well the different cap grades corresponded to

logical subdivisions of orange distribution in individual cap feathers (e.g., orange bands present vs little or no orange present), (2) how rapidly and accurately field workers might determine a cap grade based on these logical subdivisions, and (3) how effectively the cap grades would distinguish the two sexes.

Some aspects of this study required knowing unequivocally the sex and age of specimens or field-netted subjects. Sex was based on "primary" features observed or stated on museum tags, such as brood patch, cloacal protuberance, or gonads. For Orange-crowned Warblers, we did not consider plumage sufficient to indicate sex. Age was based on information on museum tags (degree of skull ossification), features of the rectrices (Pyle 1997, WMG), and/or molt limits in netted individuals (Pyle 1997). Standardized coding we used to indicate age conforms to calendar year designations used by the Canadian Wildlife Service (CWS) and Bird Banding Laboratory (BBL: Pyle 1997, p. 33). However, the stated CWS/BBL age designations were too inclusive for our purposes, requiring us to modify the definitions. For purposes of this paper, we considered an "HY" individual to be one between its preformative and first prealternate molts (Howell et al. 2003, Pyle 2008). We found that many such fall/winter collected birds often were called "immature" on museum tags. We considered a "SY" individual to be a sexually mature bird between its first prealternate and second prebasic molts (Howell et al. 2003, Pyle 2008). We found some such spring-collected birds to be labeled "yearlings." We sometimes found it convenient to refer to a combined grouping of HY and SY individuals as HY/SY birds (a group we informally called "subadults"). Finally, we considered an "AHY/ASY" individual to be one that had passed through its second prebasic molt (Howell et al. 2003, Pyle 2008). Many such birds were called "adults" on museum tags.

While most specimens or field-netted individuals used in this study were of confirmed sex and age; in a few cases where we needed additional specimens for analysis, and when sex and age were irrelevant, we evaluated specimens of unconfirmed sex and age.

To explore a correlation of cap grades with cap measurements, WMG and an assistant initially determined the cap grades for a large number of museum specimens. After this grading, the assistant measured the width and length of the orange caps of 44 of these specimens that we had assigned grade 4 caps, and 44 that we had assigned grade 3 caps. Specimens were presented randomly to the assistant without her knowledge of the cap grade that had been assigned. The assistant did not attempt to measure caps of any specimens that had been determined to have grade 2 or 1 caps.

Related to our measurement of graded caps of specimens was the issue of shrinkage in museum specimens (e.g., Kucsynski et al. 2003, Wilson and McCracken 2008). Commonly evaluated in studies of specimen shrinkage are the effects on features such as wing chord, tail, and tarsus. However, we are not aware of a study evaluating the effect of shrinkage on the head region of specimens, or on associated crown patches. Comparing cap measurement data we obtained from specimens with those from netted birds, as well as comparing similar cap data from two corresponding workers, allowed us to make such an evaluation.

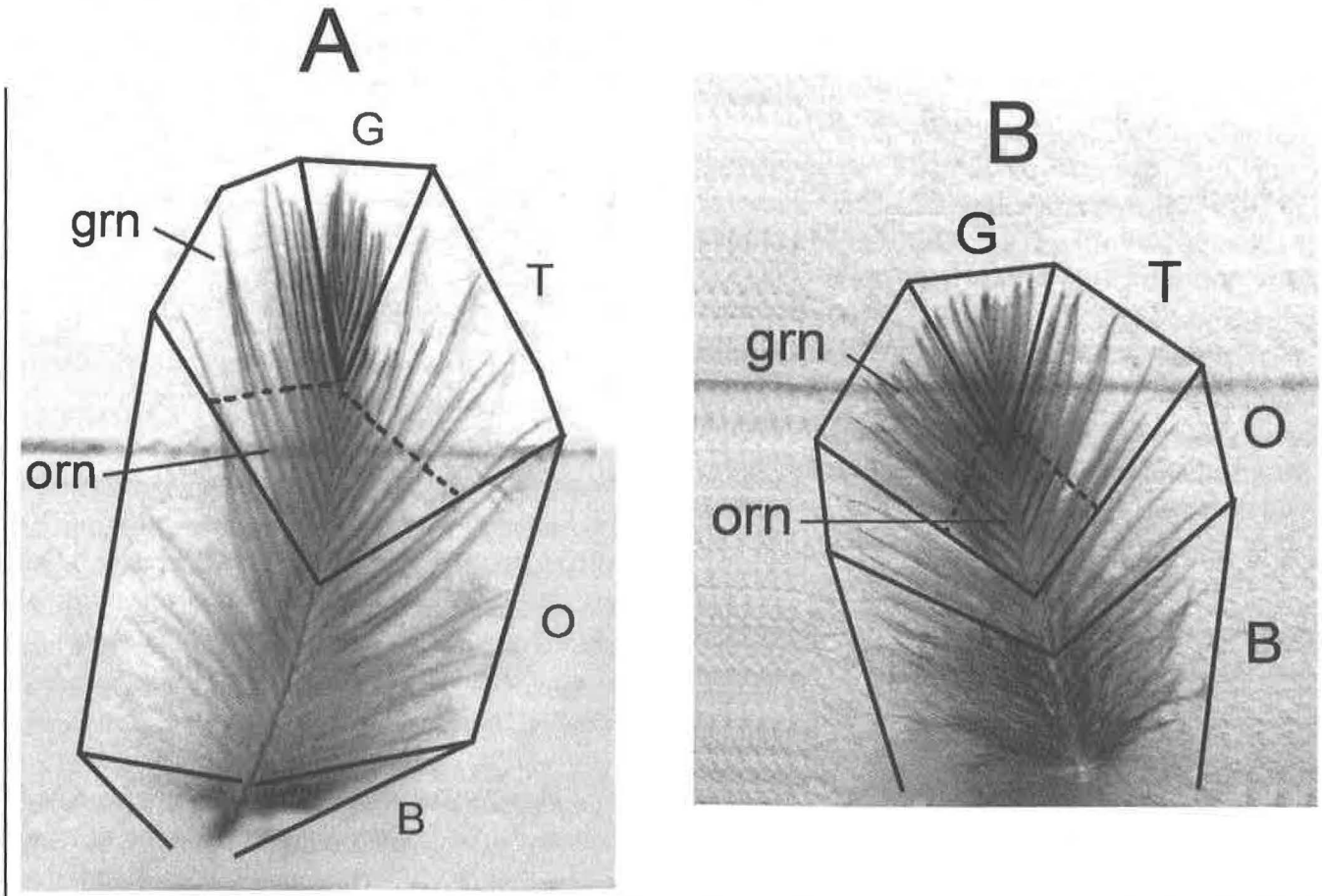
We made most statistical comparisons using either the Student's *t* test or the Mann-Whitney *U* test, while for one comparison we used the Fisher's Exact test. We conducted all statistical tests with the GraphPad InStat, version 3.0b, statistical package.

RESULTS

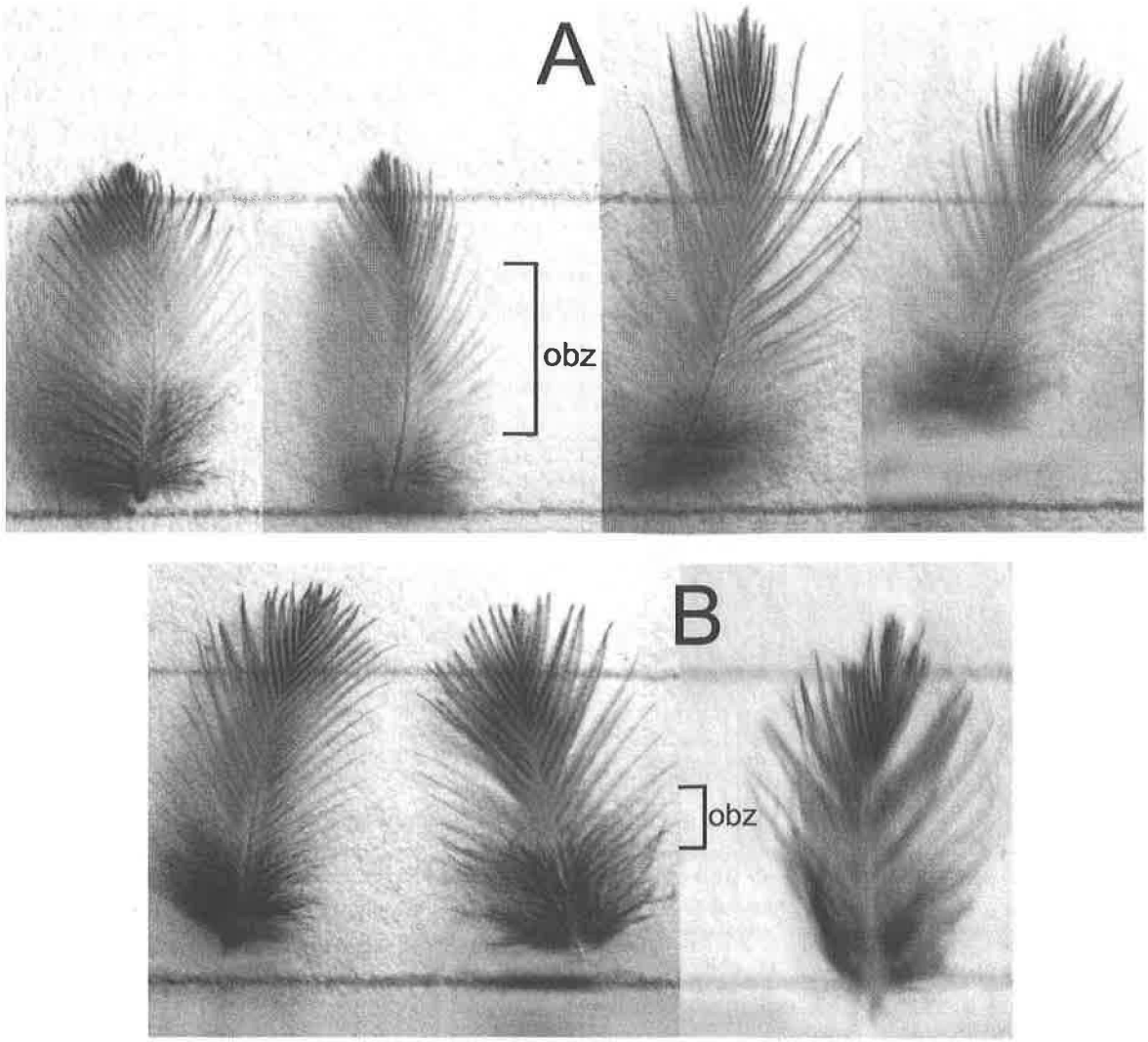
The distribution of orange in cap grades 4 and 3 feathers – Determining the distribution of orange in individual feathers of cap grades 4 and 3 was facilitated by considering three new terms: the "orange band zone", the "orange barb zone" and the "transition barb zone" (Figs. 1A-B). We defined

the orange band zone as the area of a cap feather containing contiguous orange in its barbs (thus, "O" plus "orn" in Figs. 1A-B, and "obz" in Figs. 2A-B). However, the orange band zone is not composed of completely orange barbs radiating vertically away from the rachis. The barbs generally are not completely orange, and they project upward at about a 45 degree angle from the rachis (Figs. 1A-B). The barbs lower along the rachis in the orange band zone contain a relatively large amount of orange, 80% or more, and we considered them to reside in the orange barb zone (O in Figs. 1A-B). Higher along the rachis the barbs contain orange at their base (orn), but blend toward their tips into colors that are pale green, or pale shades not clearly orange or green ("grn" in Figs. 1A-B). We considered these barbs to lie in the transition barb zone ("T" in Figs. 1A-B). Because barbs project from the rachis at about a 45 degree angle, both the orange color in the orange barb zone and the orange color near the base of barbs in the transition barb zones contribute to what is perceived as the orange band zone (Figs. 1A-B, 2A-B). The longitudinal distance spanning an orange band, as seen under a lifted cap, approximately would equal the longitudinal distance spanning the orange band zone of an individual feather of that cap. This distance, in turn, would be the same as the longitudinal distance spanning the orange and transitional barb zones at the rachis. Other sections we recognize in individual cap feathers are the green tip barbs and the black base barbs ("G" and "B" in Figs. 1A-B).

Color photos of OCWA annotated with cap grades may be found at:
www.westernbirdbanding.org/WBBAPhotos/NABB38-2-Gilbert/index.html



Figs. 1A. 1B. Grade 4 and 3 cap feathers, divided into color sections as they are seen upon close examination. B = black base barbs, O = orange barb zone, T = transition barb zone, G = green tip barbs, orn = orange color in barbs of T, grn = pale orange/green or green color in barbs of T. O and orn together form the orange band zone of an individual feather. For further explanation, see DISCUSSION.

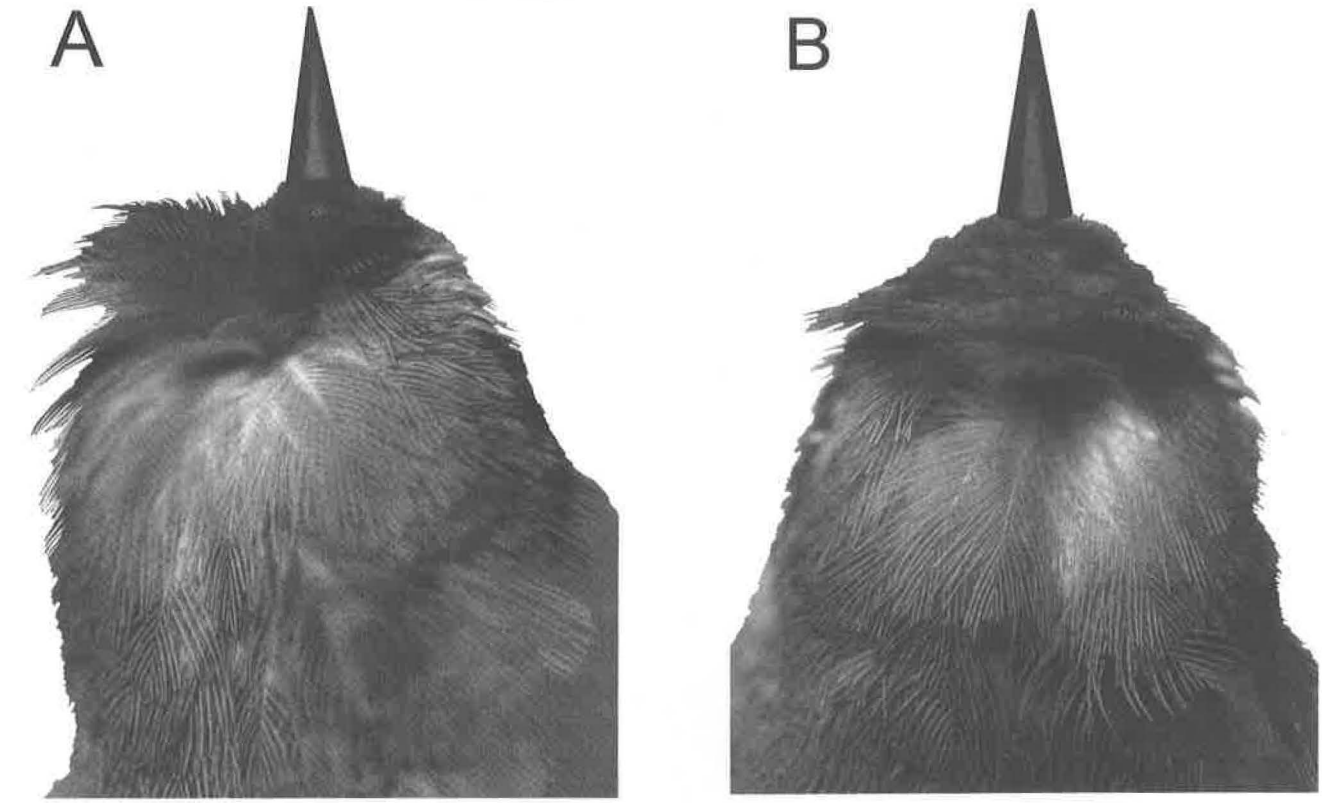


Figs. 2A, 2B. Grade 4 and 3 cap feathers, obtained from netted individuals. The orange band zone of these feathers (obz) has been highlighted to show contrast between that zone and the green tip and back base barbs.

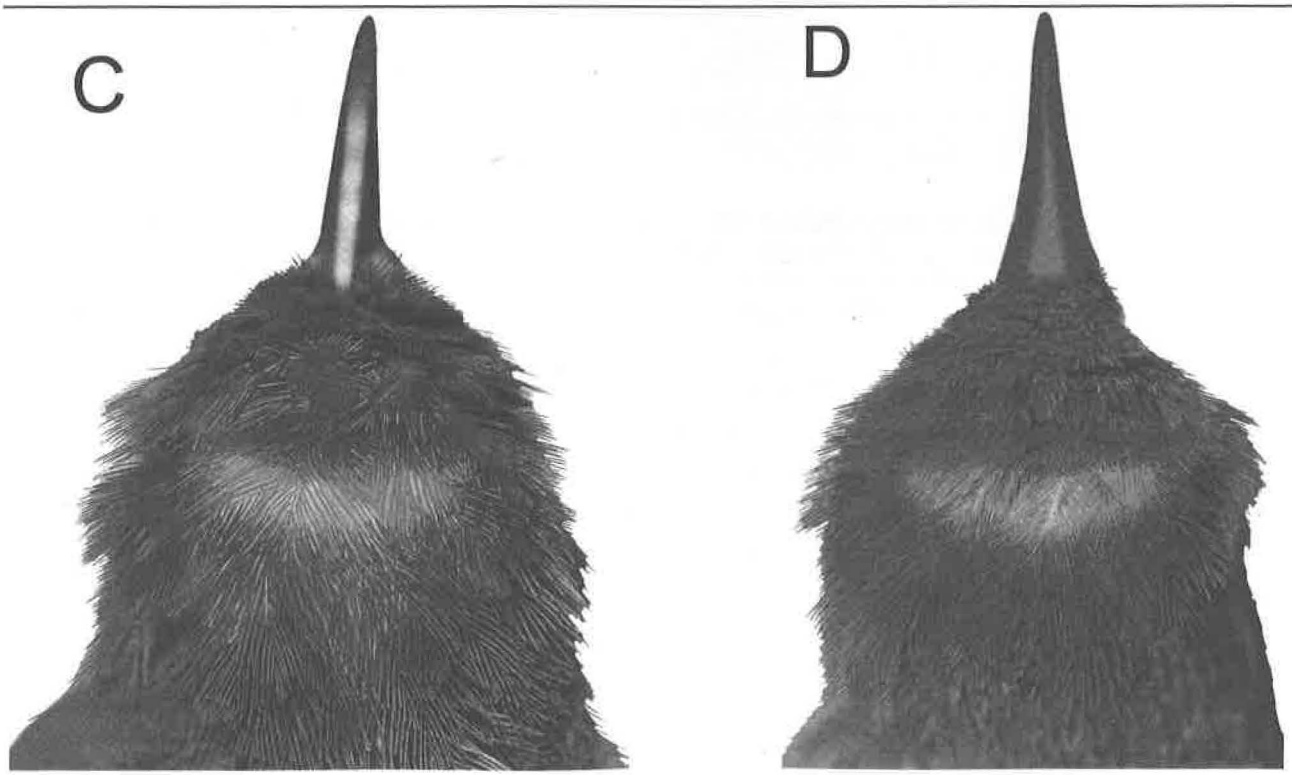
Development and use of a cap grading system - We concluded that four cap grades would best describe variation in the amount and distribution of orange found in the caps of Orange-crowned Warblers. The number of cap grades tended to be a compromise between ease of using our system and precision of separations, and four cap grades seemed to be the most reasonable compromise.

The distinction between cap grades 4 and 3, the only two cap grades showing distinct orange bands across feathers under lifted caps, is based largely on the relative longitudinal distances spanning those bands (Figs. 3A-D), and spanning the orange band zones of individual feathers of those caps (Figs. 1, 2).

We thus have defined a cap grade 4 as having an orange band, and individual feathers having orange band zones spanning > 4 mm in a proximal-distal (longitudinal) direction. These distances are seen in Fig. 1A as the combined length of O and orn along the rachis, in Fig. 2A as obz, and the longitudinal distances spanning the orange bands in Figs. 3A-B. We have defined a cap grade 3 as having an orange band, and individual feathers with orange band zones spanning < 4 mm in a proximal-distal direction. These distances are seen in Fig. 1B as the combined length of O and orn along the rachis, in Fig. 2B as obz, and the longitudinal distances spanning the orange bands in Figs. 3C-D.



Figs. 3A, 3B. Grade 4 caps, based on unmodified photographs from museum specimens. The orange bands across the cap feathers of museum specimens tend to be more distorted than would be seen in a netted bird.



Figs 3C, 3D. Grade 3 caps, based on photographs from museum specimens in which the orange bands across the cap feathers have been adjusted in brightness and shape to illustrate better the condition as it would be seen in a netted bird. Adjustments to the photographs were considered necessary because contrast between the shades of orange and green were not sufficient in the grayscale photographs to illustrate the grade 3 cap.

We qualitatively have described a cap grade 4 as having an orange band that is relatively elongated longitudinally as the band is seen across feathers under a lifted cap (Figs. 3A-B), a cap that usually is relatively saturated in color, a cap that is more elongated anterior to posterior than it is wide, and a cap that frequently is noticeable without lifting or parting the crown feathers. We qualitatively have described a cap grade 3 as one having an orange band that is relatively abbreviated longitudinally as the band is seen across cap feathers under a lifted cap (Figs. 3C-D), a cap that usually is relatively dull in color, a cap that is about equally elongated anterior to posterior as it is wide, and a cap that infrequently is noticeable without lifting or parting the crown feathers.

We have defined and described a cap grade 2 as one having no orange band seen across cap feathers under a lifted cap, but one that does show traces of dull orange color in some barbs of some cap feathers (Fig. 3E). We have defined and described a cap grade 1 as one showing no traces of orange in any barb of any cap feather (Fig. 3F).

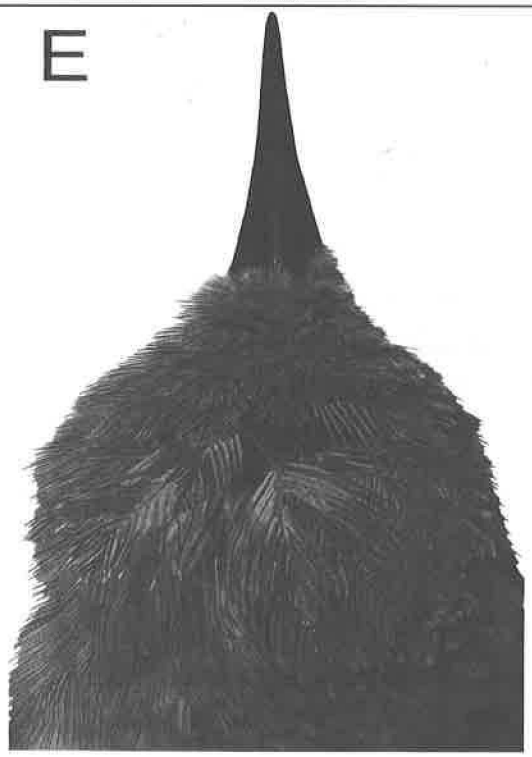


Fig. 3E. Grade 2 cap, based on a photograph from a museum specimen in which orange traces in barbs have been adjusted in brightness to better illustrate the condition as it would be seen in a netted bird. Adjustments were considered necessary as explained in Figs. 3C, 3D.

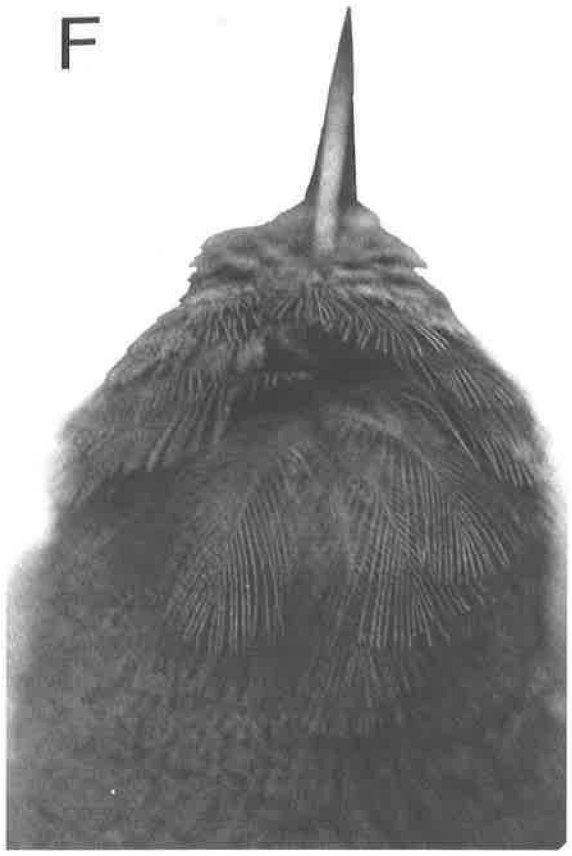


Fig. 3F. Grade 1 cap, based on an unmodified photograph from a museum specimen.

While cap grades 4 and 3 usually would be separated in the field based on the qualitative criteria stated above, we have quantitatively evaluated the differences between the two cap grades in Tables 1A and 1B.Table 1A indicates that the mean longitudinal distance spanning the orange band zones of a cap grade 4 individual feather sample was significantly longer than for a cap grade 3 individual feather sample, and that there was no overlap in the ranges of the orange band zones of the two samples. Table 1A also indicates that the mean total length of cap grade 4 feathers was significantly longer than for cap grade 3 feathers. However, the mean longitudinal distance across the green tips of cap grade 4 feathers was significantly shorter than for cap grade 3 feathers. There was no significant difference between the mean longitudinal distances across the black bases of cap grade 4 and 3 feathers. Table 1B similarly indicates that the mean longitudinal distance spanning orange bands, as seen under lifted caps, was significantly longer for

Table 1. Comparison of grade 4 and grade 3 orange caps, as seen in individual feathers of those caps, and across tiers of feathers under lifted caps. All measurements taken in mm, and at the junction of barbs and rachis for feathers, and differences evaluated by Student's t or Mann-Whitney U test.

A. - Feather comparisons

		Total Length	Orange Band Zone	Green Tip	Black Base
Grade 4	Mean ±SE	08.89 ± 0.36	05.39 ± 0.20	02.55 ± 0.26	0.96± 0.09
(n = 10)	Range	07.20 - 10.60	04.77 - 06.54	01.18 - 03.50	0.61 - 01.38
Grade 3	Mean ±SE	07.42 ± 0.28	2.89 ± 0.19	03.34 ± 0.19	01.19 ± 0.30
(n = 7)	Range	06.29 - 08.19	02.50 - 03.99	02.97 - 04.19	0.45 - 02.57
Difference		1.47	2.50	0.79	0.23
		t = 3.01	U' = 70.00	t = 2.24	t = 0.84
P		0.0089	0.0001	0.0407	0.4116

B. - Lifted Cap Comparisons

		Orange Band	Green Tip
Grade 4	Mean ± SE	5.15 ± 0.04	2.04± 0.06
(n = 69)	Range	4.5 - 6.0	1.0 - 3.0
Grade 3	Mean ± SE	3.63 ± 0.09	3.10 ± 0.10
(n = 31)	Range	3.0 - 4.0	2.0 - 4.0
Difference		1.52	1.06
		U = 2139.00	U = 1911.00
P		<0.0001	<0.0001

cap grade 4 than for cap grade 3, and that the mean of green feather tips was significantly longer for cap grade 3 than for cap grade 4.

In spite of the differences between cap grades 4 and 3, and between individual feathers associated with those cap grades, determining the cap grades of some birds with intermediate features can be challenging. However, caps with such intermediate features seem uncommon, and less than 5% of specimens that we determined to have either a cap grade 4 or 3 required close and extended scrutiny to decide on a cap grade. For the field worker, if the cap of a netted bird appears to have features intermediate between cap grades 4 and 3, one alternatively might not attempt to grade the cap, or might assign a cap grade 3, since that would be the more conservative decision in sexing.

We have observed variations in the shades of orange in caps, and cap feathers can range from pale, dull orange to bright "burnt" orange to a darker "rusty" orange. We determined that an apparent greater saturation of orange color in many cap grade 4 feathers, compared with cap grade 3 feathers, might result, in part at least, from a greater overall expanse of orange color seen in cap grade 4 feathers.

The objective criteria of traces of orange seen in some barbs of some feathers of cap grade 2, and no orange present in feathers of cap grade 1, usually are sufficient to distinguish those two cap grades. While cap grade 3 is distinguished from cap grade 2 by the presence of a distinct orange band extending laterally across feathers under lifted caps, in a relatively few individuals (2-5% of specimens) it was not immediately clear if the orange among cap feathers was sufficient to constitute a band across cap feathers.

Frequencies of different cap grades among sex/age groups of Orange-crowned Warblers –
Table 2 indicates the frequencies and percentages of different cap grades among sex/age groups.

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A. - Feather comparisons

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Frequencies of different cap grades among sex/age groups of Orange-crowned Warblers – Table 2 indicates the frequencies and percentages of different cap grades among sex/age groups.

Table 2. Frequencies of cap grades among sex/age groups and races of museum specimens of Orange-crowned Warblers. For definitions of calendar year age groups and their informal designations, see text.

Age	Sex	Race	Cap Grades				Totals
			4	3	2	1	
AHY/ASY ("adult")	males	*celata*	26	1	0	0	27
		lutescens	40	2	0	0	42
		orestera	46	2	1	0	49
		sordida	8	0	0	0	8
		combined	120 (95%)	5 (4%)	1 (1%)	0 (0%)	126
AHY/ASY ("adult")	females	*celata*	0	1	8	5	14
		lutescens	2	4	2	6	14
		orestera	0	2	2	9	13
		sordida	0	2	0	6	8
		combined	2 (4%)	9 (19%)	12 (24%)	26 (53%)	49
HY/SY ("subadult")	males	combined	16 (36%)	6 (14%)	6 (14%)	16 (36%)	44
	females	combined	0	0	3 (14%)	19 (86%)	22
SY ("yearling")	males	combined	13 (54%)	4 (17%)	4 (17%)	3 (12%)	24
	females	combined	0 (0%)	0 (0%)	2 (15%)	11 (85%)	13
HY ("immature")	males	combined	3 (15%)	2 (10%)	2 (10%)	13 (65%)	20
	females	combined	0 (0%)	0 (0%)	1 (11%)	8 (89%)	9
combined	combined	combined	138 (57%)	20 (8%)	22 (9%)	61 (25%)	241

Among AHY/ASY and SY males, cap grade 4 predominates, while among AHY/ASY and SY females cap grade 1 predominates. Among HY individuals of both sexes, cap grade 1 predominates.

Association of cap grades with cap measurements– Table 3 indicates that both the mean cap lengths and widths are significantly greater for cap grade 4 than for cap grade 3, suggesting that cap grade 4 tends to have greater area than cap grade 3. Additionally, the difference between the mean length and width of cap grade 4 is significantly greater than for cap grade 3. In effect, cap grade 4 tends to be rectangular, while cap grade 3 tends to be square. These findings also suggest that cap lengths would better separate cap grade 4 from 3 than would cap widths, and we thus have only considered cap lengths to further explore the relationships of cap grades and cap measurements.

In addition to comparing the means of cap grade 4 and 3 lengths (Table 3), we tested the relationship of the two variables with a 2 x 2 contingency table. The results (Fisher's Exact test, rel. risk = 39.26, P = <0.0001) similarly indicated a close association between the two cap grades and their respective lengths.

The shortest length we recorded for a cap grade 3 in a specimen was 6.8 mm (Table 3). That measurement might be close to the minimum that we would consider could be obtained from measuring orange caps of specimens. Applying a 3-mm shrinkage adjustment factor (explained in DISCUSSION), the shortest measurable cap we would consider could be obtained from a live Orange-crowned Warbler might be close to 10 mm. Below an approximate cap measurement of 7 mm for specimens and 10 mm for live birds, Orange-

Table 3. Two way comparisons of length and width measurements (means ± SE) of grade 4 and grade 3 orange caps of museum specimens. All measurements in mm and differences evaluated with Student's t test.

Cap Grade	Length	Range	Width	Range	Difference	*df*	*t*	*P*
4 (n = 44)	12.47 ±1.15	10.0 - 15.6	9.29 ± 0.75	8.0 - 10.0	3.18	86	15.37	<0.0001
3 (n = 44)	9.35 ± 1.10	6.8 - 11.4	8.18 ± 1.07	5.3 - 10.0	1.17	86	5.06	<0.0001
Difference	3.12		1.11					
t	12.98		5.64					
P	<0.0001		<0.0001					

crowned Warblers may display no contiguous orange caps, and thus we would consider them to have cap grade 2 if some traces of orange can be seen, or cap grade 1 if no orange can be seen.

Comparison of cap measurements from museum specimens and live birds – The mean length of cap grade 4 from museum specimens of mixed races was 12.47 (±1.15 mm SD, Table 3), and that of cap grade 4 from live, netted *O. c. lutescens* individuals was 17.04 (± 1.41 mm SD, n = 68, WMG, unpublished data). The 4.57 mm difference in the means of these two samples was significant (U' = 2972.00, P = <0.0001). Similarly, the mean cap length for male *O. c. lutescens* museum specimens from Alaska was 11.80 (± 1.80 mm SD, n = 28, L. Peyton, unpublished data), and that of caps from netted Alaska males of that race was 14.78 (± 2.66 mm SD, n = 89, G. Baluss, unpublished data). The 2.98 mm difference between the means of these samples was significant (U = 2045.5, P = <0.0001). The difference in mean cap lengths of specimens and comparable samples of netted birds most likely results from specimen shrinkage (Kucsynski et al 2003, Wilson and McCracken 2008), and the mean reduction in Orange-crowned Warbler cap lengths from specimen shrinkage thus appears to be approximately 3 – 4.5 mm, or 20 – 27%.

DISCUSSION

A previous system of grading Orange-crowned Warbler caps – Foster (1967) used a cap grading system to help describe molting patterns in Orange-crowned Warblers. We considered employing cap grade criteria similar to those of Foster (1967), but found that the cap grades she designated did not function well to separate sex and age groups of the species. Since separation of the sexes was the primary intended function of our system, we developed cap grading criteria that better suited that purpose.

Possible benefits of a cap grading system – Given the good correspondence we found between cap grades and ranges of cap measurements, one might question the value of a cap grading methodology. Why not just measure caps? There may be several reasons to also consider cap grades. Initially, the good correspondence we determined between cap grades and ranges of cap measurements should allow either or both systems to be used as aids in sexing and should allow comparison, and thus a backup, for results obtained using either system. Second, an understanding of cap grades may facilitate a better understanding of the distribution of orange in individual cap feathers, and in the overall crown. Third, our evaluation suggests that relatively short cap measurements (<7 mm in specimens and perhaps <10 mm in live birds) are not measurements of contiguous orange caps, but rather measurements of traces of orange scattered within crowns, and caps with such traces of orange may better be designated by a cap grade (cap grade 2) than by a measurement. Fourthly, there currently

is no detailed study relating sex, age, and race to cap measurements in living Orange-crowned Warblers, and determinations of cap grades as they relate to sex, age, and race could facilitate such a study. Finally, in some cases at least, it may be quicker to determine and record a cap grade than to take a measurement, although we acknowledge that a quantitative measurement may be a more certain evaluation than a qualitative cap grade.

Cap grades, cap measurements, and shrinkage in museum specimens – The measurements of both cap grade 4 and 3 (Table 3) likely were affected by specimen shrinkage. It also seems possible that these measurements might have been affected by variable skin preparation technique, although there is no empirical support for this. In either case, there is no evidence that cap grades 4 or 3 might have been affected differentially, and the data presented in Table 3 thus likely reflect relative mean lengths for the two cap grades in specimens. Because of specimen shrinkage, however, the data in Table 3 would not reflect cap lengths one would expect in living birds. We suggest that adding a conservative shrinkage adjustment factor of 3.00 mm to specimen cap lengths might extrapolate to approximate values closer to measurements in netted birds.

Based on our measurements in Table 3, 11 mm would seem to be a convenient "cutoff" point between cap grades 4 and 3 in specimens, since it lies outside of one standard deviation from the mean of each cap grade. Applying a shrinkage adjustment factor of 3 mm to that measurement would give an approximate cap grades 4 and 3 cutoff measurement of 14 mm for living birds. This figure should just be considered an aid in separating the two cap grades in the field, however. In the future, more reliable relationships between cap grades and cap measurements might be established directly based on netted individuals. Related to this, we suggest that cap measurements for Orange-crowned Warblers, and for other species with measurable caps, be taken prior to specimen preparation, and that the data be entered on museum labels.

The degree of cap shortening we established for Orange-crowned Warblers (20 – 27%) presumably based on specimen shrinkage, seems remarkable given the values established by other workers working with other bird species, and measuring other morphological features, such as wing chord, tail, tarsus, and bill. These shrinkage values generally range below 5%, although some exceed this (e.g., Kucsynski et al. 2003, Wilson and McCracken 2008). We speculate that this wide difference between previous results and ours may relate to the fact that avian morphological features normally measured (wing chord, tarsus, tail, bill, etc.) are supported by relatively strong anatomical structures (bone, shafts of feathers). Crown patches, however, only are supported by the skin covering the skull. One might expect that shrinkage of this soft tissue might be greater than for bone and shafts of feathers.

Sexing based on cap grades – Cap grades may prove useful to separate the sexes of Orange-crowned Warblers, especially when cap grades are considered along with associated cap measurements, and when both cap parameters are considered with wing chord measurements (WMG and GCW, unpublished data). Regarding the sexing of HY/SY individuals, 25% (5/20) of HY males and 71% (17/24) of SY males displayed cap grade 4 or 3 (Table 2). By way of contrast, no HY/SY female (0/22) we examined displayed a cap grade 4 or 3 (Table 2). Therefore, any HY/SY Orange-crowned Warbler with a cap grade 4 or 3 likely would be a male. However, even though all (22/22) HY/SY females had either cap grade 2 or 1, no HY/SY bird with a cap grade 2 or 1 should be sexed as a female based on cap alone, since 50% (22/44) of HY/SY males also had cap grades 2 or 1 (Table 2).

Regarding AHY/ASY individuals, we determined that 95% (120/126) of male specimens displayed cap grade 4 (Table 2) and cap grade 4 appears to be characteristic of that sex/age group. However, 4% (2/49) of adult female specimens also had cap grade 4 (Table 2). Since all (2/2) such females were of the *lutescens* race, however, suggestive of the findings

of Foster (1967), it would appear that cap grade 4 may develop infrequently, if at all, in females of races other than *lutescens*. These findings suggest that an AHY/ASY individual with a cap grade 4 most likely would be a male, especially in races other than lutescens. It is cautioned, however, that our analysis was based on just 35 AHY/ASY non-*lutescens* female specimens (Table 2), and future investigation may reveal a higher frequency of cap grade 4 in females of non-*lutescens* races.

We found no (0/126) cap grade 1 in AHY/ASY male Orange-crowned Warbler specimens (Table 2). Similarly, less than 1% (1/126) of AHY/ASY males had a cap grade 2, the exception being one specimen of the *orestera* race (Table 2). This preliminary evidence suggests that most netted AHY/ASY Orange-crowned Warblers with cap grade 2 or 1 would be females. Captured AHY/ASY birds determined to have cap grade 3 should not be sexed based on cap alone, however, since we found 4% (5/126) of AHY/ASY males and 19% (9/49) of AHY/ASY females possessed cap grade 3 (Table 2).

Potential conflicts between our cap grades and a de facto definition of crown patches – Pyle (1997, Fig. 281) provides a *de facto* definition for an exposed crown patch (cap) for the Wilson's Warbler and essentially indicates that a cap exists in any crown where black coloration is seen. This indicates that a Wilson's Warbler with no black in its crown (e.g., Pyle 1997, Fig. 281A) would not be considered to have a crown patch. Pyle (1997, p. 449), in referring to cap illustrations for the Wilson's Warbler to describe the cap of the Orange-crowned Warbler, essentially uses the same *de facto* definition in reference to the concealed cap of the Orange-crowned Warbler. Pyle (1997) would seem to indicate that if any orange color is present in the crown of an Orange-crowned Warbler, then that bird would be considered to possess a crown patch.

For our study, however, it seemed necessary to alter the *de facto* meaning of crown patch provided by Pyle (1997) in two ways. Initially, to compare cap grades 4 and 3 with respective cap measurements (e.g., Table 3), we needed to grade and measure contiguous orange caps as they would be formed by orange bands under lifted crowns. We did not try to determine the extent of small traces of orange in a crown, and then consider that area to define the extent of a crown patch. Therefore, we did not consider crowns with only scattered traces of orange (i.e., cap grade 2) to have measurable crown patches. We found 6.8 mm to be the minimum measurable cap in a specimen. This differs from Pyle (1997, p. 449), who refers to Orange-crowned Warbler caps in the 0 – 6 mm range.

Second, while Pyle (1997) would not consider a crown containing no orange to possess a crown patch (e.g., Pyle 1997, Fig. 281A), we found it convenient to apply the term "cap grade" to crowns containing little or no orange (i.e., cap grade 2 and 1), even though such caps are not metrically measurable. In essence, we found it convenient to apply the term cap grade to crowns which potentially could develop measurable orange caps during subsequent molts.

The possible functions of different cap grades in different Orange-crowned Warbler sex/age groups – The orange cap of Orange-crowned Warblers would appear to have a limited number of functions: in establishing a territory (or in other possible male-male conflicts) and possibly in attracting and retaining a mate. Two conclusions logically might follow: 1) all males should have completely developed orange caps (presumably grade 4) by their first breeding season so as to optimally compete for breeding territories and mates, and 2) no female should ever develop an orange cap, much less a cap grade 4, during its lifetime, since such a cap would not seem to be adaptive (Foster 1967). Our study shows, as did Foster's (1967), that these conclusions do not pertain, and that a wide range of orange cap development exists among the different sex/age groups (Table 2). What might explain these inconsistencies?

Initially, while SY males are sexually mature, we found that just 54% (13/24) of such males had cap grade 4, compared with 95% (120/126) of AHY/ASY males (Table 2). This suggests that a relatively large percentage of SY males may not be competing for territories and mates, and that certain aspects of their physiology, behavior, and morphology may not be adapted to those roles. The fact that 5% (6/126) of AHY/ASY males still do not have fully developed cap grade 4s going into their second breeding season or beyond (Table 2) further suggests that those males still might not be competing for territories and mates, or that they are doing so with suboptimal morphology for those purposes.

The development of orange caps in females requires a different line of reasoning. One possible clue regarding this apparently non-adaptive feature presented itself on 30 Mar 2011, when WMG netted a color-banded female *V. c. lutescens* in his study area and assigned the bird a cap grade 3. Records showed that the female had been banded on 31 Mar 2009 and that, at that time, WMG had assigned the bird a cap grade 1. This change in the female's cap grade over two years suggests that at least some females may acquire more orange in their caps over progressive feather molts. We speculate that a female acquiring more orange in its cap with age could, in turn, be a function of hormone balance. With decreased female hormones with age, androgens dictating more male-like features may become more dominant. Even though orange caps in females may provide little or no functional advantage, there may be insufficient disadvantage to them to select for altering underlying hormonal mechanisms. A similar situation has been noted by GCW in female Anna's Hummingbirds (*Calypte anna*), which tend to acquire more red (a male trait) in their crowns as they age.

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News, Notes, Comments

Notes on Acetal Color Bands

During the last three years, I have been using acetal color bands in combination with darvic color bands to mark Black-capped Vireos. I use the smallest size, that with an inside diameter of 2.3 mm. As certain colors have become unavailable in darvic, I have switched to similar colors manufactured from acetal. Here, I wish to report on my experiences with acetal color bands.

The acetal color bands that are available currently are formed by injection molding. During manufacture, hot molten plastic flows through channels known as sprues where it diverts into smaller channels, known as runners, to fill the mold for each individual band. When the plastic cools and solidifies, it remains in the form of not only the bands, but also the attached sprues and runners. The bands come in sets of 10 bands attached to their 10 runners and one larger sprue.

The acetal bands need to be smoothed before use. For example, a small, rough projection remains if one simply breaks the thin runner to detach a band from the sprue. Other irregularities result when the two halves of the mold and, hence, the two sides of each individual band are not in perfect alignment. This leaves step-like irregularities on the ends and sides of the bands. The steps on the lower end of the band create a corner that would constantly rub against the top of the toes potentially leading to an injury. Another common irregularity is in the form of thin projecting fins where molten plastic leaked into the space between the two halves of the mold. I recommend that you cut away any irregularities with a sharp hobby knife or file them smooth with a fingernail file. It is best to do this indoors with good light in advance of a banding session.

My colleague, Mike Heimbuch, and I assessed how well the color of acetal bands holds up against prolonged sun exposure. We tested only the ten colors that we currently use. We slid two bands of each color onto a wire approximately the diameter of a vireo's leg and then hung them on a chain link fence where they would be in direct sunlight all day. We left them for seven months. Eight of the colors fared well: red, yellow, light green, medium green, light blue, dark blue, orange, white. These bands showed little or no apparent fading. The two remaining colors we tested, hot pink and purple, did not perform as well. The hot pink had faded to a very pale pink. It was still recognizably pink, but a very different shade than the original. Purple faded to a color that was difficult to distinguish from that of the light blue bands. Furthermore, most of this fading occurred during the first two months. Our test likely exposed the bands to more sun than they would get if on the legs of birds and so fading probably was accelerated. However, the rapid fading of the purple bands remains a cause for concern.

Acetal bands can be sealed shut with a heat source such as a small soldering iron. However, I do not seal them and the vireos apparently are unable to open and remove them. I do attempt to close them as tightly as possible, ideally with the butt ends touching. I accomplish this by squeezing the bands in the smallest hole of European-style banding pliers (i.e., those with five holes). It usually requires