banding may allow accuracy rates acceptable for some long-term studies. Also, short duration studies on a limited number of subjects might be possible using only song and territory identification. This study's results are strictly applicable only to *V. celata,* but could guide research on other species.


## Acknowledgements

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(Western)

# Carpal Compression as a Variable in Taking Wing Chord Measurements


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Wing chord length is a commonly taken measurement of banded birds, used (1) to separate species and sex classes of *Accipiter* hawks, (2) in combination with other measurements to separate species and sex classes of *Empidonax* flycatchers, (3) in combination with tail measurements to separate Black-capped Chickadee (*Parus atricapillus*) and Carolina Chickadee (*P. carolinensis*), among other examples (Bird-Banding Manual 1984). Wing chord data have also been used to study wing loadings and flight characteristics of birds (Greenwalt 1975).

Various sources illustrate or discuss different methods for making wing chord measurements. Roberts (1955) describes wing chord as "the distance from the bend of the wing to the tip of the longest feather across the chord of the naturally curved feather." He shows no compression of the bend of the wing in the taking of the measurement. Pettingill (1970) describes it similarly and recommends the measurement be made with dividers without any compression of the bend of the wing.

The Bird-Banding Manual (1984) describes wing chord as "the length of the closed wing in natural position from the bend to the tip of the longest primary." It is taken with a rule equipped with a right-angle end stop with the "bend of the wing firmly against the stop" and the tip of the longest primary allowed to just touch the rule without any flattening or straightening. This method produces compression of the bend of the wing. Spencer (1976) defines wing chord as the "distance of the closed wing from the foremost extremity of the carpus to the tip of the longest primary feather" using a "stopped rule." He acknowledges the existence of three chords:

Method 1—Unflattened wing = Minimum chord
Method 2—Flattened chord = Intermediate chord
Method 3—Flattened and straightened wing = Maximum chord

Svensson (1984) similarly defines three types of wing chord measurements. He recommends a rule with a stop at zero. Further, he compares differences in the three chords from six species whose chords range 59 to 209 mm as follows:

| Comparison | Percent Difference |
|---|---|
| Method 1 vs. Method 2 | 0–2.7 |
| Method 2 vs. Method 3 | 0–5.1 |
| Method 1 vs. Method 3 | 0.5–6.0 |

The methods described and illustrated by Spencer (1976) and Svensson (1984) using stopped rules imply some degree of compression of the carpus.

When I began banding in 1963 and began taking wing chord measurements, I used Roberts (1955) as my information source, and used an "unstopped" rule. Holding a bird in the left hand, I measured the right closed wing by touching the tip of the longest primary to the zero end of the rule, and recording where the front edge of the carpus touched the rule without any flattening. This method involved no compression of the carpus.

Through the years I have noticed other banders using stopped rules, and applying compression of the carpus against the stop while taking wing chord measurements. I became interested in determining what differences, if any, existed in the measurements taken with and without carpal compression.

## Methods

Between 2 December 1984 and 9 June 1985 I took dual measurements on the right wing of some birds I banded or handled as returns at Schenectady, Jenny Lake, and Vischer Ferry, New York. Additionally, I salvaged roadkills of three species (see Table 1) along highways in Saratoga, Warren, Fulton, and Hamilton counties, New York, during February and March 1985. Each bird was measured without carpal compression using a rule without an end stop ("unstopped" wing chord). I compared the stopped rule with the unstopped rule and found that because of the way the end stop had been soldered to the rule, the stopped rule was reading low by 0.7 mm. All measurements taken with it were corrected by adding 0.7 mm. Measurements with both rules were recorded to the nearest 0.5 mm.

**Table 1. Wing chord summary by species.**

| | | Unstopped Wing Chord | | | | |
|---|---|---|---|---|---|---|
| Species | Scientific name | Average (mm) | Range (mm) | Difference (mm) | Difference Percent | Sample size |
| Common Yellowthroat | *Geothylpis trichas* | 55.02 | 52-57 | 0.78 | 1.42 | 24 |
| Swamp Sparrow | *Melospiza georgiana* | 60.90 | 58-65 | 0.80 | 1.31 | 5 |
| Yellow Warbler | *Dendroica petechia* | 61.78 | 57.5-74.5 | 0.65 | 1.05 | 23 |
| Lincoln's Sparrow | *Melospiza lincolnii* | 63.19 | 59.5-66 | 0.74 | 1.17 | 8 |
| American Redstart | *Setophaga ruticilla* | 63.88 | 61-66.5 | 0.87 | 1.36 | 8 |
| Black-capped Chickadee | *Parus atricapillus* | 64.77 | 59.5-69 | 0.97 | 1.50 | 48 |
| Song Sparrow | *Melospiza melodia* | 65.70 | 63-68 | 0.85 | 1.29 | 30 |
| Red-breasted Nuthatch | *Sitta canadensis* | 66.91 | 65-70 | 1.05 | 1.57 | 16 |
| Chipping Sparrow | *Spizella passerina* | 70.40 | 67-73 | 0.80 | 1.14 | 5 |
| Yellow-rumped Warbler | *Dendroica coronata* | 70.60 | 67-75 | 0.87 | 1.23 | 15 |
| American Goldfinch | *Carduelis tristis* | 71.36 | 67-78.5 | 0.77 | 1.08 | 143 |
| White-throated Sparrow | *Zonotrichia albicollis* | 71.64 | 68.5-76 | 1.03 | 1.44 | 11 |
| Northern Waterthrush | *Seiurus noveboracensis* | 72.00 | 70.5-74.5 | 0.90 | 1.25 | 5 |
| Pine Siskin* | *Carduelis pinus* | 72.80 | 68.5-77.5 | 1.05 | 1.44 | 43 |
| Dark-eyed Junco | *Junco hyemalis* | 76.10 | 70-81.5 | 0.80 | 1.05 | 31 |
| House Sparrow | *Passer domesticus* | 76.60 | 73-78 | 1.16 | 1.51 | 10 |
| House Finch | *Carpodacus mexicanus* | 78.02 | 72.5-85.5 | 0.83 | 1.06 | 275 |
| Purple Finch | *Carpodacus purpureus* | 81.29 | 76-85.5 | 0.85 | 1.05 | 45 |
| Red Crossbill* | *Loxia curvirostra* | 84.32 | 81-89 | 1.17 | 1.39 | 11 |
| White-winged Crossbill* | *Loxia leucoptera* | 87.14 | 82.5-92 | 1.67 | 1.92 | 11 |
| Gray Catbird | *Dumetella carolinensis* | 91.56 | 87-96 | 1.21 | 1.32 | 27 |
| Northern Cardinal | *Cardinalis cardinalis* | 92.07 | 88-95.5 | 0.80 | 0.87 | 7 |
| Veery | *Catharus fuscescens* | 98.92 | 93-104.5 | 1.14 | 1.15 | 6 |
| Brown-headed Cowbird | *Molothrus ater* | 102.54 | 95-111.5 | 1.05 | 1.02 | 12 |
| Rose-breasted Grosbeak | *Pheucticus ludovicianus* | 104.09 | 99-107 | 0.83 | 0.80 | 16 |
| Wood Thrush | *Hylocichla mustelina* | 108.11 | 103-114 | 0.63 | 0.58 | 9 |
| Red-winged Blackbird | *Agelaius phoeniceus* | 112.30 | 97-128 | 1.55 | 1.38 | 10 |
| American Robin | *Turdus migratorius* | 129.69 | 119-138 | 1.11 | 0.86 | 16 |
| Blue Jay | *Cyanocitta cristata* | 135.11 | 131-139 | 1.30 | 0.96 | 9 |
| Common Grackle | *Quiscalus quiscula* | 137.00 | 125-147 | 1.80 | 1.31 | 14 |
| Mourning Dove | *Zenaida macroura* | 145.19 | 134-154 | 1.91 | 1.32 | 50 |

*Measurements taken from fresh road kills.

For each species for which I had five or more measurements, I averaged each set of wing chord data and determined an average difference per species. For a reason given later, I also grouped all of the "unstopped" wing chords by 5-mm intervals, i.e., 50.5-55.0 mm, 55.5-60.0 mm, etc., regardless of species, and performed a similar averaging analysis.

## Results

I collected measurements on 973 birds of 50 species. I had five or more measurements per species on 31 species representing 943 individuals. These are summarized in Table 1. In Figure 1 I plotted the average wing chord differences (WCD) for these species against the average "unstopped" wing chord. A regression analysis on these data points gave the following equation (r = 0.6785):

WCD(mm) = 0.2647 + 0.008886 ("Unstopped" Wing Chord, mm)

Because some of the species had wing chord ranges of up to 31 mm (owing primarily to sexual dimorphism), and in the belief that such a wide range might affect the placing of the data point on the wing chord axis in Figure 1, I also analyzed the data by 5-mm intervals for comparison purposes. In the analysis I included the 30 additional measurements for species for which I had fewer than five measurements per species. These data are summarized in Table 2, and the WCDs are plotted in Figure 2. A regression analysis of these points gave the following equation (r = 0.8287):

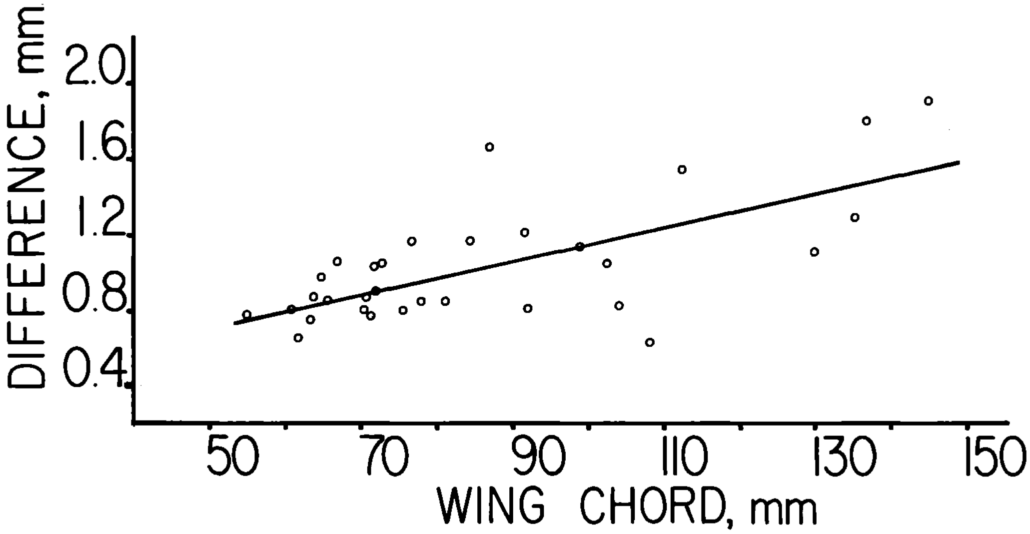
WCD (mm) = 0.06584 + 0.01048 ("Unstopped" Wing Chord, mm)

Figure 1 illustrates that the average wing chord measurements of individual species, made with the stopped rule, were 0.63 to 1.91 mm less than those made with a rule not having an end stop, over the range of 55–145 mm. The differences at the extremes of the regression line were 0.75 and 1.55 mm over the same range. When the measured differences were expressed as percentages of the wing chord length, the differences by species ranged between 0.58 and 1.92 percent, tending to decrease with increased wing chord length. At the extremes of the regression line the differences were 1.37 and 1.07 percent, decreasing with increasing length.

**Table 2. Wing chord summary by wing chord interval.**

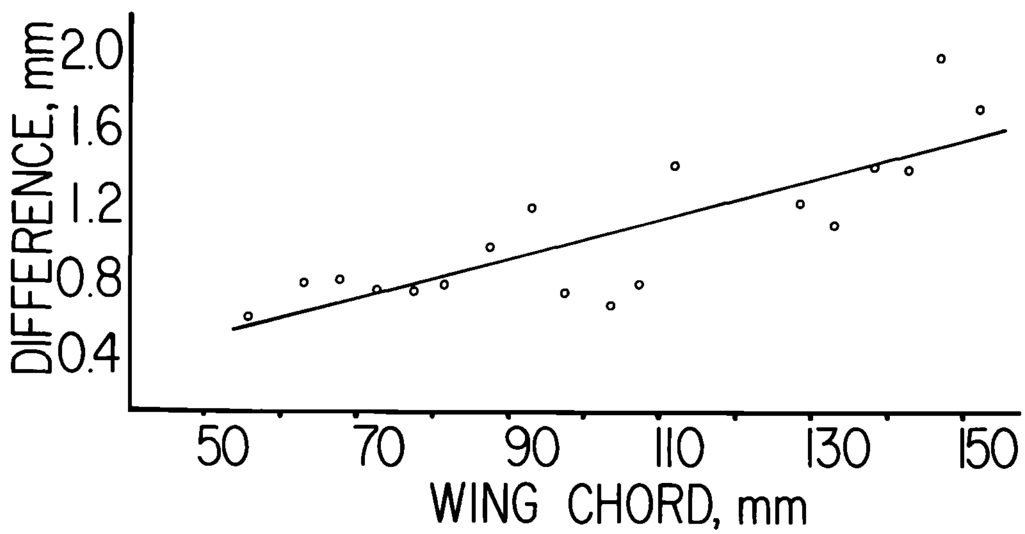
| Wing Chord Interval (mm) | Wing Chord Average (mm) | Difference (mm) | Difference Percent | Sample Size |
|---|---|---|---|---|
| 55-60 | 55.87 | 0.70 | 1.25 | 34 |
| 60-65 | 63.28 | 0.88 | 1.39 | 80 |
| 65-70 | 68.11 | 0.90 | 1.32 | 125 |
| 70-75 | 72.79 | 0.84 | 1.15 | 197 |
| 75-80 | 77.90 | 0.84 | 1.08 | 254 |
| 80-85 | 81.99 | 0.88 | 1.07 | 84 |
| 85.90 | 87.91 | 1.08 | 1.23 | 27 |
| 90-95 | 93.19 | 1.28 | 1.37 | 26 |
| 95-100 | 97.44 | 0.83 | 0.85 | 16 |
| 100-105 | 103.78 | 0.77 | 0.74 | 16 |
| 105-110 | 107.58 | 0.88 | 0.82 | 12 |
| 110-115 | 112.00 | 1.50 | 1.43 | 5 |
| 125-130 | 128.54 | 1.30 | 1.01 | 13 |
| 130-135 | 133.04 | 1.19 | 0.89 | 13 |
| 135-140 | 138.40 | 1.50 | 1.08 | 10 |
| 140-145 | 143.15 | 1.49 | 1.04 | 23 |
| 145-150 | 146.95 | 2.07 | 1.41 | 22 |
| 150-155 | 152.25 | 1.80 | 1.18 | 6 |

Figure 1. A comparison of wing chord length with the difference in the measurement of the unflattened chord using rules with and without an end stop. Each datum point represents a species from Table 1, and the line represents the regression line referred to under Results.




Similar results are illustrated in Figure 2, though with slightly less scatter of the data. Differences ranged from 0.70 to 2.07 mm and increased with increasing length, while the percentages varied from 0.74 to 1.41 percent. The regression line differences increased from 0.65 to 1.66 mm with increasing wing chord length, while percentage differences declined from 1.17 to 1.09 with increasing length.

Figure 2. A comparison of wing chord length with the difference in the measurement of the unflattened chord using rules with and without an end stop. Each datum point represents the average of a 5-mm wing chord interval from Table 2, and the line represents the regression line referred to under Results.



## Discussion

The analyses by species and by wing chord interval showed that compression of the feathering on the leading edge of the carpus by a rule with an end stop gave shorter wing chords than did a rule with no end stop. This applied to all species and all individuals that I measured. The amount of compression generally increased with increasing size, but declined slightly on a percentage basis. Among different species there was a degree of variability in the amount of this compression. In some birds, such as the Wood Thrush and American Robin, the carpus felt very bony or hard, while in others, such as the Mourning Dove, the carpus felt softer or more resilient when the rule was applied to the wing. This feeling of the softness or hardness of the carpus is reflected quantitatively in Table 1. The Wood Thrush had the smallest measured compression (in mm and percent) of any of the birds measured. The Mourning Dove had one of the higher percentages of compression, and as the largest species measured had the largest absolute difference.

These differences in compression of unflattened wing chords ranged between 0.58 and 1.92 percent for the species measured (1.07 to 1.37 percent using the regression line) and fall within the 0.0 to 6.0-percent range of differences created by flattening and/or straightening the chord according to Svensson (1984). They are smaller than the 3.5-mm, or 5-percent, maximum difference noted on any individual bird from a sample of 401 tower-killed White-throated Sparrows measured by each of four persons (Nisbet, Baird, Howard, and Anderson 1970). However, they are greater than the 0.37-mm, or 0.52-percent, maximum difference of mean wing chord values (70.57–70.94 mm) noted by the same four persons on the same sample.

These differences in compression appear small (0.58–1.92 percent) and perhaps not very significant at first glance; however, their true significance—possibly changing the species, age, or sex determination of a bird whose determining scheme relies on differences in wing chord length—must be viewed on an individual basis. In addition to the examples referred to earlier, there are other species in which there is a significant overlap, varying from species to species, between male and female measurements. Typically, females are identified by some wing chord value ≤ A, and males by ≥ B. Birds falling between A and B are classified as unknowns.

In the examples given below from the Bird-Banding Manual (1984) and Wood (1969), the overlap range between the largest reliable female wing chord and the smallest reliable male wing chord varies from 2.9 to 15 percent of the wing chord length. Because these overlap ranges are larger than the maximum difference of 1.92 percent determined here for carpal compression, it is not likely that a male of one of these species would be mistaken for a female or vice versa, based on carpal compression alone. However, carpal compression can shorten a wing chord and thereby skew more males into the overlap zone (AB), and similarly place unknown intermediate birds into the smaller female range (A). This is possible for measurement differences as small as one mm. For birds in the wing chord range of 60 to 140 mm (examples in the next paragraph), a difference of one mm represents 1.67 to 0.71 percent of the wing chord, and these percentage differences are within the range of shortening caused by carpal compression.

Among examples in the Bird-Banding Manual (1984) are Brown-headed Cowbird, Pine Siskin, Red-eyed Vireo (*Vireo olivaceus*), and Ovenbird (*Seiurus aurocapillus*). In Wood (1969) some species so affected include Tufted Titmouse (*Parus bicolor*), Blackpoll Warbler (*Dendroica striata*), Common Grackle, Dark-eyed Junco, and White-crowned Sparrow (*Zonotrichia leucophrys*).

From some other sources are White-throated Sparrow (Atkinson and Ralph 1980), Common Redpoll (*Carduelis flammea*) (Brooks 1973), Bay-breasted Warbler (*Dendroica castanea*) (Howard 1968); and from Klimkiewicz and Shepard (1976) the following species: Brown Creeper (*Certhia americana*), American Robin, Swainson's Thrush (*Catharus ustulatus*), Tennessee Warbler (*Vermivora peregrina*), Wilson's Warbler (*Wilsonia pusilla*), Bobolink (*Dolichonyx oryzivorus*), and Eastern Meadowlark (*Sturnella magna*). Wing chord data on the age and sex classes of the Wood Warblers (Parulidae) are given in Robbins (1964).

Similarly affected, though in reverse, because females are larger than males, is the Northern Saw-whet Owl (*Aegolius acadicus*) (Mueller and Berger 1976, and Buchholtz, Edwards and Weir 1984). Among shorebirds (Charadriiformes) whose sex may be determined by wing chord length, there are examples of both kinds of dimorphism, that is, males larger than females and vice versa (Robbins 1963).

Therefore, it is important that age-, sex-, and species-separation schemes, that rely on wing chord and the method measurements, clearly define the kind of wing chord and the method of measurement that were used. Then, the method, the extent of separation of the measurements of the groups being considered, and other factors should be weighed to determine their significance. Carpal compression should be one of the factors considered.

## Summary

The compression of the carpus caused by a wing chord rule with an end stop shortened the recorded unflattened wing chord lengths on 31 species of birds by 0.63–1.91 mm, or 0.58–1.92 percent, over the wing chord range of 55–145 mm. The amount of compression increased on an absolute scale as bird size increased, but decreased slightly on a percentage basis as size increased.

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(Eastern)

# Fall Migration of Twelve Species of Wood Warblers through Coastal Virginia


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Based on four fall seasons of mist-netting, Hall (1981) reported on the migration of 12 species of wood warblers through the mountains of West Virginia. Curves were constructed showing total numbers of birds captured in 5-day intervals during the fall migration, with data from four fall seasons (1973, 1974, 1976, and 1977) pooled. My purpose in writing this paper is to compare patterns of fall migration among the 12 species of wood warblers reported on by Hall from his inland mountain station with patterns for the same species at the coastal station at Kiptopeke Beach in eastern Virginia. The data used were gathered during the 7 years 1974-1980.

### Methods

As I am comparing my data with data published by Hall (1981) I am, in general, following Hall's lead in the procedure for presenting the data. Thus, I am pooling data in the same 5-day intervals used by Hall. In gathering the data I am using, mist nets were operated at the Kiptopeke station from 31 August through 3 November 1974, from 30 August through 26 October 1975, from 4 September through 31 October 1976, from 22 August through 6 November 1977, from 28 August through 28 October 1978, from 30 August through 28 October 1979, and from 29 August through 26 October 1980, for a total of 141,531 mist-net hours. The resulting graphs furnish the basis for comparison of seasonal trends in numbers of birds captured at the two stations. Because of the difficulty of standardizing capture effort in different situations, comparisons are made of numbers of warblers captured at the two stations only when the difference clearly was not merely a result of difference in capture effort.

Birds were aged according to the degree of pneumatization of their skulls.

## Results and discussion

In Figures 1 and 2 curves are shown indicating numbers captured in 5-day periods of hatching-year (HY) and after-hatching-year (AHY) wood warblers of 12 species migrating through the Kiptopeke station in eastern Virginia. A comparison of these curves with curves for the same species presented by Hall (1981) for his inland station in West Virginia reveals both differences and similarities.