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IMPLICATIONS OF AGE-DEPENDENT BILL LENGTH VARIATION IN *EMPIDONAX* FOR IDENTIFICATION OF IMMATURE ALDER AND WILLOW FLYCATCHERS

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Abstract.—Strong circumstantial evidence from measurements of Willow Flycatchers (*Empidonax traillii*) and Alder Flycatchers (*E. alnorum*) captured during migration at Long Point, Ontario, indicated that immature birds have shorter bills than adults. If so, Stein's (1963) equation for identification of the two species is valid only for adults. Immature Least Flycatchers (*Empidonax minimus*) and Yellow-bellied Flycatchers (*E. flaviventris*) had bills that averaged 97.5 and 96.1 percent, respectively, of the lengths of bills of conspecific adults ($P < 0.001$). Significant annual differences in bill lengths were detected in adult and immature Least Flycatchers and in adult Yellow-bellied Flycatchers and bill lengths differed seasonally (spring vs. fall) in adult Yellow-bellied Flycatchers. Shorter bills in younger age classes have been reported previously in three congeners (Johnson 1963). A modification of Stein's equation is proposed to allow interim identification of immature Willow and Alder flycatchers, pending development of more rigorous methods.

IMPLICACIONES DE LAS VARIACIONES DEL TAMAÑO DEL PICO RELACIONADAS CON LA EDAD PARA LA IDENTIFICACION DE INMADUROS DE *EMPIDONAX TRAILLII* Y *E. ALNORUM*

Sinopsis.—Evidencia circunstancial obtenida de medidas tomadas de individuos de *Empidonax traillii* y *E. alnorum* capturados en Long Point, Ontario, durante la migración, tiende a indicar que las aves inmaduras tienen el pico más corto que los adultos. De esto sostenerse, la ecuación de Stein (1963) tan solo sería válida para identificar entre los adultos de estas dos especies. El tamaño promedio del pico de inmaduros de *E. minimus* y *E. flaviventris* es un 97.5 y 96.1%, respectivamente del de sus congéneres adultos ($P < 0.001$). Diferencias anuales significativas en el tamaño del pico fueron encontradas en adultos e inmaduros de *E. minimus* y en adultos de *E. flaviventris.* Diferencias estacionales (primavera vs. otoño) fueron encontradas en el tamaño del pico de adultos de los últimos. Picos más cortos en individuos juveniles de diferentes edades han sido informados en tres congéneres (Johnson 1963). Se propone una modificación de la ecuación de Stein para poder por el momento identificar inmaduros de *E. traillii* y *E. alnorum* en lo que se desarrollan métodos más rigurosos.

Prior to Stein's (1963) study, the Alder Flycatcher (*Empidonax alnorum*) and the Willow Flycatcher (*E. traillii*) were considered conspecific. (I use the former common name, "Traill's Flycatcher," to refer to the two species collectively [A.O.U. 1973].) Stein (1963) provided a morphological criterion for distinguishing between the two species based on bill length and a measurement of wing shape (formula *I*). His analysis showed that among specimens collected in the breeding season, Willow Flycatchers tended to have longer bills and rounder wings than Alder Flycatchers.

During an examination of measurements of Traill's Flycatchers captured in migration at Long Point, Ontario, Canada in1966–1968, I noticed that bills of immatures tended to be shorter than those of adults. Although the distribution of bill lengths depended partly on the unknown proportions of Alder and Willow flycatchers in the samples, the measurements strongly suggested the possibility that immatures of both species had bills that averaged slightly shorter than those of adults. If so, Stein's (1963) formula for separating Willow from Alder flycatchers, based on breeding adults, would not be reliable for immatures.

Further investigation of this question was precluded by uncertainty about the specific identification of the individuals in the sample of immature Traill's Flycatchers. Therefore, I compared bill lengths of adults and immatures of two closely related and more easily identified species of flycatchers, the Least Flycatcher (*E. minimus*) and the Yellow-bellied Flycatcher (*E. flaviventris*), that were also captured during migration at Long Point. In this paper I describe the distribution of bill lengths in Traill's Flycatchers, demonstrate annual, seasonal and age differences in bill length in Least and Yellow-bellied flycatchers and propose an adjustment to Stein's method for identification of immature Willow and Alder flycatchers.

METHODS

Field methods are described in detail elsewhere (Hussell 1981, 1982). Bill lengths of Least Flycatchers trapped in 1966–1967 and of Yellow-bellied Flycatchers and Traill's Flycatchers in 1966–1968 were measured with dial calipers to the nearest 0.1 mm, from the anterior edge of the nostril to the tip. Sometimes, bill length was measured from each of the nostrils, in which case the average of the two measurements was used. Wing length (chord) was measured to the nearest 0.1 mm with a stopped ruler, from the bend to the tip of the longest primary of the unflattened wing. For Traill's Flycatchers dial calipers were used to measure, to the nearest 0.1 mm, the distance from the tip of the closed wing to the tip of primaries 10, 6 and 5 (called $T10$, $T6$ and $T5$, respectively) and formula I was calculated as $T6 + T5 - T10$ (Stein 1963).

"Immatures," as used here, are young of the year captured during their first southward migration; all other birds are "adults." Spring birds were those captured before 16 June; fall birds were captured after 30 June.

RESULTS

Traill's Flycatchers.—The distributions of bill lengths and formula I in adult Traill's Flycatchers at Long Point (Fig. 1, Fig. 2 upper) were similar to those graphed by Stein (1963, Figs. 14 and 15), but Long Point immatures were clearly shorter-billed on average (Fig. 2 lower).

The range of bill lengths for adults at Long Point, 7.60–9.85 mm, agrees well with that given by Stein (1963) for eastern Traill's Flycatchers (7.6–10.0 mm, $n = 63$ males and 10 females), but for immatures at Long Point the range of bill lengths was 7.40–9.50 (Table 1). Moreover the differences in ranges between age classes were not due to presence of

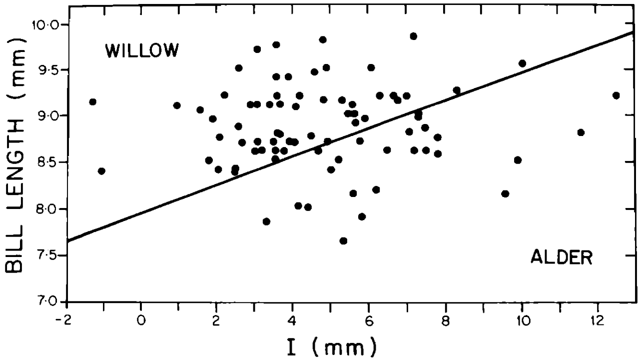

FIGURE 1. Bill length versus formula I (see text) for 80 Traill's Flycatchers trapped during spring migration 1966–1968. The line represents Stein's (1963) equation for separating Willow and Alder flycatchers: $B = 7.95 + 0.15I$ (see text).

exceptional outliers in the data, as the middle 90% of bill length measurements showed a similar difference (Table 1). By contrast, formula I did not show any obvious age-related differences (Table 2, Figs. 1 and 2).

Using Stein's criteria numbers of Willow Flycatchers/Alder Flycatchers in the Long Point samples (Figs. 1 and 2) were spring adults 56/24, fall adults 30/30, and immatures 30/95. The preponderance of putative Alder Flycatchers among the immatures is consistent with a bias in identification resulting from a tendency for immatures to have shorter bills than adults.

Least Flycatcher.—For adults, a two-way ANOVA showed that year (1966, 1967) had a significant effect ($P < 0.001$), but season (spring, fall) had no significant effect ($P = 0.166$) on bill length. Bills were shorter in 1966 than in 1967 (Table 3). If bill lengths differ between the sexes, annual or seasonal differences in bill length could result merely from different sex compositions of the annual and seasonal samples. Had the birds been sexed, this possibility could be examined by including sex in a three-way ANOVA, but such data were not available. However, wing chords of males average longer than those of females (Hussell 1981, Johnson 1963, Phillips et al. 1966), so the effect of sex composition of the samples on bill length can be at least partially examined by including wing chord as a covariate in a two-way ANOVA with year and season as factors. Any remaining effects of year and season, after considering the effects of wing chord, are unlikely to be due to differing sex compositions of the samples.

There was a small, highly significant correlation between bill length and wing length in adults ($r = 0.267$, $n = 515$, $P < 0.001$). In a two-way ANOVA with season and year as main effects and wing length as a covariate, the effect of year on bill length remained significant ($P < 0.001$) and that of season approached significance ($P = 0.055$), with bills

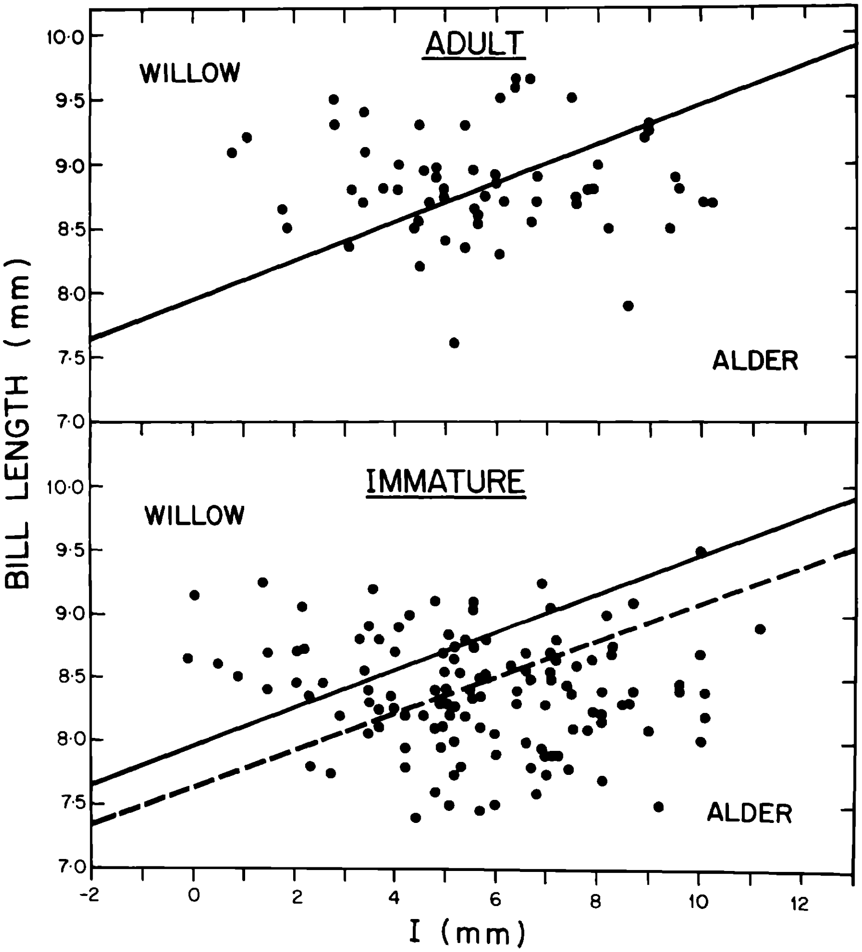

FIGURE 2. Bill length versus formula I (see text) for 60 adult (upper) and 125 immature (lower) Traill's Flycatchers trapped during fall migration 1966–68. The continuous lines represent Stein's (1963) equation for separating Willow and Alder flycatchers: $B = 7.95 + 0.15I$. The broken line in the lower section represents the modified equation for separating immatures: $B' = 7.64 + 0.144I$ (see text).

tending to be shorter in spring than in the fall. Two way interactions between year and season were not significant. Variance explained by season and year increased slightly when wing length was a covariate, indicating that annual and seasonal effects on bill length were probably not dependent on differing sex compositions of the samples.

Mean bill length of immatures was 7.07 mm, which was 97.5% of the mean of 7.25 mm for adults (t-test, $P < 0.001$, Table 3). Although the mean bill lengths of both adults and immatures were shorter in 1966

TABLE 1. Bill lengths[a] of Traill's Flycatchers at Long Point 1966–1968.

	Adults		Immatures
	Spring	Fall	Fall
Range (mm)	7.65–9.85	7.60–9.65	7.40–9.50
Middle 90% (mm)	8.00–9.55	8.30–9.50	7.60–9.10
n	80	60	126

[a] Bill length measured to the nearest 0.1 mm from the anterior edge of the nostril to the tip. If the bill was measured from each of the two nostrils, the average of the two measurements was used.

than in 1967, a one-way ANOVA for immatures alone showed that the effects of year on bill lengths of immatures were not significant (P = 0.099). As with adults, wing lengths of immatures were positively correlated with bill lengths ($r = 0.301$, $n = 398$, $P < 0.001$). When wing length was included as a covariate, however, the variance in bill length explained by year increased and became significant ($P = 0.024$), indicating that the effect of year was real and probably not caused by differing sex compositions of the samples.

Yellow-bellied Flycatcher.—A two-way ANOVA for adults showed that both season and year had significant effects on bill length ($P = 0.030$ and 0.004, respectively, $n = 115$). Within years, bill lengths averaged 0.10 to 0.22 mm longer in spring than in fall adults (Table 4). In 1968 adult bills averaged longer than in 1966 and 1967 by 0.28 and 0.31 mm in spring and by 0.24 and 0.18 mm in fall, respectively. There were no significant season-year interactions.

Wing lengths of male Yellow-bellied Flycatchers averaged longer than those of females (Hussell 1982, Phillips et al. 1966), but bill length of adults at Long Point was not significantly correlated with wing length ($r = 0.166$, $n = 114$, $P = 0.078$). Nevertheless, to check whether sex composition of the samples may have influenced mean bill lengths of adults, wing length was added as a covariate in a two-way ANOVA, with season and year as factors. When included in the two-way ANOVA, wing length was marginally non-significant ($P = 0.065$) and variance explained by season and year remained essentially unchanged. These results indicate that seasonal and annual differences in adult bill lengths were probably not influenced by the sex compositions of the samples.

TABLE 2. Formula *I* for Traill's Flycatchers at Long Point 1966–1968.

	Adults		Immatures
	Spring	Fall	Fall
Range (mm)	−1.3–12.5	0.8–10.2	−0.1–11.2
Middle 90% (mm)	1.8–9.6	1.9–9.5	2.1–9.6
n	80	60	126

TABLE 3. Mean and range of bill lengths (mm) of adult and immature Least Flycatchers at Long Point, 1966–1967 (sample sizes in parentheses).

Year(s)	Adult		Immature	I/A ratio[a]
	Spring	Fall	Fall	
1966	7.12 6.1–8.1 (73)	7.11 6.3–8.0 (34)	7.05 6.3–8.0 (214)	0.990
1967	7.23 6.5–8.3 (96)	7.30 6.3–8.3 (313)	7.10 6.2–8.1 (184)	0.975
1966–1967	7.18 6.1–8.3 (169)	7.28 6.3–8.3 (347)	7.07 6.3–8.1 (398)	0.975

[a] Ratio of mean bill length of immatures to mean bill length of spring and fall adults.

Bill lengths of immature Yellow-bellied Flycatchers averaged 7.69 mm, which was 96.1% of the mean of 8.00 mm for all adults (t-test, $P < 0.001$, Table 4). A one-way ANOVA for immatures showed that year had a non-significant effect on bill length ($P = 0.349$). Wing chord was weakly, but significantly correlated with bill length ($r = 0.219$, $n = 123$, $P = 0.016$). Inclusion of wing chord as a covariate in a one-way ANOVA increased the variance explained by year, but it remained non-significant. Thus, there was no evidence that sex composition of the samples influenced this result, and adults clearly differed from immatures in the extent to which bill length was dependent on year.

DISCUSSION

Bill length variation.—Immature Least and Yellow-bellied flycatchers had bills that were 97.5 and 96.1 percent, respectively, of the lengths of bills of adults of the same species. Significant differences in bill length in different years were detected in adult and immature Least Flycatchers and in adult Yellow-bellied Flycatchers. Adult Yellow-bellied Flycatchers had significantly longer bills in spring than in fall, but in Least Flycatchers there was a small, marginally non-significant, tendency for bills to be shorter in spring.

It is possible that some of the variability in bill length derived from differences in technique among persons taking the measurements. Some individuals took a disproportionate number of measurements in certain years and seasons and consistent differences in measurement techniques could contribute to small seasonal, annual, and even age differences in mean bill lengths. However, the consistency of the differences in bill lengths between age classes, within and between species, argues against such an interpretation. Moreover, annual, seasonal and age differences in bill lengths of passerines have been detected previously and therefore are not unexpected.

In several passerines, the bill is longer in summer and seasonal changes

TABLE 4. Mean and range of bill lengths (mm) of adult and immature Yellow-bellied Flycatchers at Long Point, 1966–1968 (sample sizes in parentheses).

	Adult		Immature	
Year(s)	Spring	Fall	Fall	I/A ratio[a]
1966	7.97 6.7–8.8 (32)	7.77 7.4–8.4 (6)	7.63 6.9–8.6 (49)	0.961
1967	7.94 7.0–8.5 (20)	7.84 7.3–8.5 (16)	7.71 7.2–8.6 (56)	0.977
1968	8.25 7.5–8.8 (24)	8.02 7.5–8.4 (17)	7.77 7.0–8.8 (18)	0.953
1966–1968	8.05 6.7–8.8 (76)	7.91 7.3–8.5 (39)	7.69 6.9–8.8 (123)	0.961

[a] Ratio of mean bill length of immatures to mean bill length of spring and fall adults.

tend to be greatest in species with a winter-summer feeding switch from seeds to insects (Morton and Morton 1987). In the Mountain White-crowned Sparrow (*Zonotrichia leucophrys oriantha*) annual differences in bill length were also noted (Morton and Morton 1987).

Bill length differences among age classes have been less frequently reported, but Johnson (1963) presented such information for three species of western *Empidonax*. His results showed that, for each sex, mean bill lengths of the juvenile-immature age class were invariably less than those of older birds (Table 5). The ratios of the bill lengths of the two age classes ranged from 0.930 to 0.999 and averaged 0.956 (Table 5). The juvenile-immature age class included any birds that had not completed the first prenuptial molt, so it may have included birds both younger and older than those covered by my definition of immature. Nevertheless, most of the birds in Johnson's juvenile-immature group are likely to have been fledged young on the breeding grounds or fall migrants. The ratios of bill lengths of the younger/older age classes reported by Johnson are in good agreement with my ratios of 0.975 and 0.961 for Least and Yellow-bellied flycatchers, respectively (Tables 3 and 4). Moreover, the distribution of bill lengths in adult and immature Traill's Flycatchers are consistent with these results (Table 1, Figs. 1, 2). I conclude that immature *Empidonax* usually have bills that are shorter than those of adults by up to 7%.

Identification of immature Alder and Willow flycatchers.—Stein's (1963) criterion for identification of Alder and Willow flycatchers was the equation:

$$B = 7.95 + 0.15I,$$

where I is a measure of wing shape based on the lengths of the longest,

TABLE 5. Age class differences in bill lengths in three species of *Empidonax*.[a]

Species	Sex	Mean bill length (mm)[b]		I/A[c] ratio
		1st yr + Ad	Juv-Imm	
Hammond's Flycatcher	M	7.22	6.80	0.955
E. hammondii	F	6.91	6.90	0.999
Dusky Flycatcher	M	8.22	7.64	0.930
E. oberholseri	F	7.89	7.45	0.944
Gray Flycatcher	M	9.38	8.87	0.946
E. wrightii	F	9.02	8.69	0.963

[a] Data from Johnson (1963).

[b] Sample sizes within age-sex categories range from 16 to 84 and average 40.6. Juv-Imm are birds that have not completed the first prenuptial molt. 1st yr + Ad are older birds and their mean bill lengths were calculated from Johnson's (1963) data for the separate age groups.

[c] Ratio of mean bill lengths of Juv-Imm to those of 1st yr + Ad.

tenth, sixth, and fifth primaries (see Stein 1963 for details) and *B* is the calculated bill length that separates the species. Willow Flycatchers had longer bills and Alder Flycatchers shorter bills than calculated by this equation, which correctly separated about 91% of Stein's sample of known song-type birds collected throughout the North American ranges of the two species.

Stein's criterion was based on measurements of breeding adults. If immature Alder and Willow flycatchers have shorter bills than adults, as suggested by measurements presented here (Table 1) and supported by evidence that immatures of 5 other species of *Empidonax* have shorter bills than adults (Tables 3–5), then Stein's criterion will not be as accurate for immature birds as for adults. Using his equation, there will be a tendency to misidentify many immature Willow Flycatchers as Alder Flycatchers. Is there a rational basis for modifying Stein's equation for identification of immatures? I suggest that there is.

Bill lengths of immature Yellow-bellied and Least flycatchers averaged smaller than those of adults (96.1% and 97.5% respectively). Given that there are seasonal changes in bill length and that bills of immatures eventually become as long as those of adults, immature-adult differences in bill length measured at Long Point may be influenced by the timing of breeding and migration of the two species. Therefore, I consider the Yellow-bellied Flycatcher to provide a better model for age-related bill length differences in Alder and Willow flycatchers than the Least Flycatcher, because its migrations and breeding season correspond very closely with those of the Alder and Willow flycatchers (Hussell 1982), whereas those of the Least Flycatcher differ substantially (Hussell 1981, 1982 unpublished data). Thus, as a first approximation, I estimate that bill lengths of immature Willow and Alder flycatchers average 96.1% of those of adults and Stein's equation should be modified for immatures to:

$$B' = 0.961(7.95 + 0.15I) = 7.64 + 0.144I.$$

An alternative way of achieving the same result is to divide the bill length of immatures by 0.961 before applying Stein's unmodified equation. Application of this formula changes the number of immature Willow/Alder flycatchers in the Long Point sample from 30/95 to 53/72. For both adults and immatures, however, I prefer to leave unidentified those birds whose bill lengths do not differ from the calculated value by at least 0.15 mm.

This procedure is subject to the criticism that it is not based on measurements of immatures of known Alder and Willow flycatchers, but the weight of evidence suggests that it is a reasonable approximation. Moreover, division by 0.961 of the bill length range values for immatures in Table 1 brings them into good agreement with the values for adults (range, immatures (corrected): 7.70–9.89, adults: 7.60–9.85; middle 90%, immatures (corrected): 7.91–9.47, adults 8.00–9.55). Until more definitive information becomes available on age-related bill length variation in Willow and Alder flycatchers, I suggest that my modification of Stein's formula is preferable for identification of immature Alder and Willow flycatchers to the use of his original equation.

More rigorous methods for morphological identification of immature Alder and Willow flycatchers are needed. To achieve this it will be necessary to measure banded immatures in the fall that are of known species parentage or whose species is known from their song-types (which presumably would usually have to be determined in subsequent breeding seasons). Alternatively, it may become possible in future to accurately identify immature Alder and Willow flycatchers biochemically (e.g., from mitochondrial DNA [see Mack et al. 1986]), but lack of differentiation of karyotypes (Shields et al. 1987) and low interspecific differentiation of these two taxa at the protein level (Seutin and Simon 1988) indicate that related approaches may also prove to be fruitless. Regardless of what methods are used to identify the birds, improved morphological criteria could be developed for both adults and immatures by measuring a large number of variables and using discriminant analysis methods to determine the best set of variables for separating the species.

In the meantime, banders are faced with the question of whether they are justified in attempting to identify Alder and Willow flycatchers in the hand. Twenty-five years after publication, Stein's (1963) method remains the only one available for identifying adults. Despite the possibility that there may be geographic variation in both I and bill length, his method probably accurately identifies many adult Alder and Willow flycatchers. If a high degree of confidence is required for identification of individuals, however, Stein's method (with my modification for immatures) is likely to be unsatisfactory except for birds that show the most extreme values of bill length and I for each of the species. Thus the equations for identifying both adult and immature Alder and Willow flycatchers should be used primarily for studying populations, rather than for identification of isolated individuals.

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