A FURTHER EXAMINATION OF WING AND TAIL FORMULAE IN *EMPIDONAX* AND *CONTOPUS* FLYCATCHERS

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ABSTRACT.—Useful new information on identifying and sexing specimens of *Empidonax* and *Contopus* flycatchers, two of the most critically examined genera of North American birds, is presented in a format most useful for in-hand determinations.

As first emphasized by Allan Phillips (1944a, 1944b) differences in wing formulae, as well as the length of the wing minus the length of the tail (WG-TL), have proven important means to identify *Empidonax* and *Contopus* flycatchers in the hand (Johnson 1963; Stein 1963; Phillips et al. 1964, 1966; Phillips and Lanyon 1970; DeSante et al. 1985). Since these original examinations were published, some refinements to the differences have been suggested (Unitt 1987, Hussell 1990, Seutin 1991); however, little further work on this topic has been performed. Phillips et al. (1966) also noted that the distance from the tip of the tail to the tip of the uppertail coverts could be used to separate many young male Eastern (*Contopus virens*) from Western (*C. sordidulus*) wood-pewees; but no analyses have been performed on other age/sex groups, nor any information on wing formulae in wood-pewees been published.

The use of wing formulae to identify flycatchers is complicated by intraspecific variation according to age, sex, feather wear and geography, factors that have been recognized but not thoroughly documented in most original works. Published ranges of wing formula and wing-tail measurements, furthermore, may contain anomalous or mis-classified individuals, or may not have been based on adequate samples; thus, intraspecific ranges useful in separating 95% of populations are usually not known. In addition, formulae based on different primary tips and various methods of representation have been published for different species groups, making genus-wide comparisons difficult (e.g., see Table 1 in Pyle et al. 1987). Wing-tail figures in Pyle et al. (1987) were based on a quick appraisal of 10-15 specimens of each taxon (unpubl. data). A standardized reassessment of wing and tail formulae in *Empidonax* and *Contopus* flycatchers, is therefore needed.

In revising and attempting to clarify the information on flycatcher identification in Pyle et al. (1987), I have measured certain wing and tail formulae on 517 specimens of twelve taxa found north of Mexico. Specimens were selected in consideration of age, sex, season and geographic location of collection. Here I present some new information on identifying and sexing *Empidonax* and *Contopus* flycatchers in the hand, using standardized methods of measurement analysis and representation.

METHODS

In addition to the two wood-pewees, ten taxa of *Empidonax* flycatchers were considered: Yellow-bellied *(E. flaviventris),* Acadian *(E. virescens),* Alder *(E. alnorum),* Willow *(E. traillii),* Least *(E. minimus),* Hammond's *(E. hammondii),* Dusky *(E. oberholseri),* Gray *(E. wrightii),* "Pacific-slope" *(E. [d.] difficilis)* and "Cordilleran" *(E. [d.] occidentalis hellmayri)* flycatchers; a taxonomic opinion on the latter two forms, the "Western" Flycatchers (see Phillips 1994, Johnson 1994), is beyond the scope of this paper. All specimens were housed at the California Academy of Sciences (CAS), Museum of Vertebrate Zoology (MVZ), and Western Foundation of Vertebrate Zoology (WFVZ). For the pewees, only birds collected on or near the allopatric breeding grounds were measured. For Alder and Willow flycatchers only specimens identified by song-type or collected during the breeding season within allopatric ranges (see Stein 1963, Zink and Fall 1981) were included.

Forty specimens of each taxon were included in core analyses, ten each of the four age/sex classes young female, adult female, young male, and adult male; "young" birds being those in first basic or first alternate plumage but with juvenal flight feathers, and "adults" those with definitive flight feathers. Because the "Traill's" Flycatchers are difficult to separate (Browning 1993 and references therein), 37 additional specimens (12 Alders and 25 Willows) were measured to increase sample sizes. Age was based on flight feather wear and shape in consideration of each taxon's molt strategy (Pyle et al. 1987), and sex, presumably based on internal examination, was that recorded on specimen labels. An attempt was made to select specimens representing all times of year and throughout the entire geographic distribution of each taxon, although smaller samples of some of the less-represented taxon/age/sex groups (e.g., young wood-pewees and Acadian and known Alder flycatchers) precluded much choice of selection. Beyond these two considerations, specimens were chosen at random. Two seasons were defined for analyses: fall (end of the prebasic molt through December) and spring (January through beginning of the prebasic molt).

Based on previous work, the following distance measurements (to the nearest mm) were recorded: tip of the longest primary to tip of primary 6 (LP-P6; primaries numbered proximally), tip of P6 to tip of P10 (P6-P10), tip of P9 to tip of P5 (P9-P5), tip of longest primary to tip of longest secondary (LP-LS), and WG-TL. Additionally, the tip of the tail to the tip of the uppertail coverts (TL-UTC) was measured to the nearest mm on all wood-pewees and bill (anterior of nares to tip, to the nearest 0.1 mm) was measured on each Alder and Willow flycatcher. Wing formula measurements were performed on the closed wing with a clear plastic ruler (see Figure 10 in Pyle et al. 1987) and the wing measurement was that of the chord. All wing measurements were performed on the right wing; specimens with broken or extremely worn primary tips were excluded.

Ranges are represented here as 95% confidence intervals, estimated by mean + 2 S.D. This form of representation is advocated over true range to lessen the influence of anomalous individuals or mis-classified (e.g., mis-sexed; see Parkes 1989) specimens, and to help ensure that full statistical ranges are represented. It is also strongly advocated over such vague terms as "P9 usually > P5", as it allows one to know when a bird falls into a zone of overlap. Assuming normal distributions of measurements and adequate samples, use of these ranges (considering birds in overlap zones indeterminable) enables separation of populations with over 97.5% accuracy. Analysis of variance (ANOVA) was used to test for significant differences between populations.

RESULTS AND DISCUSSION

Results of this study (Table 1) generally confirm those of previous works indicating the usefulness of certain wing and tail formulae in separating similar species of *Empidonax* flycatchers. In addition, several previously unemphasized differences were found that may be of additional use in identification, e.g., differences in LP-P6, P9-P5, LP-LS and WG-TL in the Yellow-bellied-Acadian-Western flycatcher group and differences in P6-P10 and WG-TL in the Least-Hammond's-Dusky-Gray flycatcher group. As clearly presented in Table 1, these measurements plus additional information on plumage features and bill size and color (Phillips et al. 1964, 1966; DeSante et al. 1985; Pyle et al. 1987) should enable easy separation of these taxa in the hand. It should be noted, how-

TABLE 1
95% CONFIDENCE INTERVALS (MM) AND INTRASPECIFIC DIFFERENCES BY AGE AND SEX FOR WING AND TAIL FORMULAE IN *CONTUPUS* AND *EMPIDONAX* FLYCATCHERS; N=40 FOR EACH MEASUREMENT OF EQUAL AGE AND SEX DISTRIBUTION (SEE TEXT).

SPECIES	LP-P6	P6-P10	P9-P5	LP-LS	WG-TL
Western Wood-Pewee	10.3-14.8	2.7-7.8[b]	14.5-20.5[s]	22.3-29.7[s]	19.0-28.3
Eastern Wood-Pewee	9.6-15.5	1.7-8.2[b]	14.5-19.5	17.3-26.4	16.2-26.2
Yellow-bellied Flycatcher	2.2-6.7	1.9-6.3	5.8-11.5[s]	10.3-17.5[s]	12.2-18.7
Acadian Flycatcher	5.2-9.3[s]	-2.9-1.7[s]	8.6-14.4[s]	13.3-23.5[s]	11.6-21.3
Alder Flycatcher	3.8-7.4[s]	-1.2-3.5[s]	6.9-11.1[s]	10.2-17.1[s]	12.4-20.3[s]
Willow Flycatcher[c]	1.8-5.2[s,a]	1.4-6.4	4.7-9.7[s,a]	10.3-17.4[s]	6.2-17.4[a]
Least Flycatcher	0.8-3.7	2.7-7.0[s]	3.4-7.8[a]	9.0-15.7[s]	6.5-13.0
Hammond's Flycatcher	1.8-5.5[s]	2.8-8.0[s]	5.6-11.6[s]	13.3-20.6[s]	10.7-18.9
Dusky Flycatcher	0.0-3.0	6.0-10.8	2.2-5.5	9.2-15.2	3.2-11.8
Gray Flycatcher	0.9-4.6	4.1-8.1[a]	3.5-8.8[s]	9.0-16.9	8.2-16.4
Pacific-slope Flycatcher	0.2-4.4[s,a]	4.7-9.2	2.8-8.4[s]	8.6-16.1[a]	6.3-13.3
Cordilleran Flycatcher	1.2-3.8[s]	6.4-9.8	5.0-9.8[s]	10.8-17.1[s]	7.2-14.9

[a] Significant intraspecific differences by age were found. Most of these reflected differences in season. See text.
[b] All P6-P10 values in wood-pewees should be negative as P6 < P10 vs. P6 > P10 in most *Empidonax* flycatchers.
[c] Measurements of Willow Flycatchers are based on 20 each of western and eastern birds (see text), both of equal distributions of age and sex.
[s] Significant intraspecific differences by sex were found. See Table 2 for confidence intervals of the more significant (P<0.0001) of these.

ever, that slight differences may occur between measurements of specimens and of live birds (Winker 1993); e.g., WG-TL appears to average slightly smaller on live birds than on specimens (pers. observation). Similar analyses to those of this study are encouraged, based on data taken from live birds at banding stations.

Many significant sex-specific differences in wing formulae and wing-tail measurements were found within taxa (Table 1), indicating that males have more pointed wings than females (Phillips et al. 1966). In all taxa, males averaged larger LP-P6, P9-P5 and LP-LS whereas females averaged larger P6-P10. Intrasexual confidence intervals for the more significant of these differences (where P<0.001 according to ANOVA) are listed in Table 2. Most notable was the difference in LP-LS in Acadian Flycatcher; assuming that values < 17 mm indicated females and values > 19 mm indicated males, 57.5% of birds were accurately sexed and only one male (MVZ107140 with LP-LS = 15 mm) was inaccurately sexed according to specimen labels. I suspect that the latter bird was a missexed specimen. By combining measurements into a formula (see Phillips et al. 1966) higher percentages of birds can be accurately sexed. In Acadian Flycatcher, for example, the formula LP-LS / (P6-P10 + 5), resulting in confidence intervals of 1.06-4.50 in females and 2.76-8.14 in males, correctly sexed 82.5% of birds according to specimen labels. This or similar formulae based on larger samples of correctly sexed specimens might be useful for even more accurate sex determinations in Acadian and other *Empidonax* flycatchers (see Table 2 and Phillips *et al.* 1966).

TABLE 2

95% CONFIDENCE INTERVALS (MM) FOR EACH SEX,
WHERE DIFFERENCES AT P<0.001 WERE FOUND (SEE TABLE 1).

SPECIES	MEASURE	FEMALES	MALES
Yellow-bellied Flycatcher	LP-LS	10.5-15.3	11.4-18.4
Acadian Flycatcher	P9-P5	8.4-12.9	9.9-14.8
Acadian Flycatcher	LP-LS	13.2-18.8	16.9-24.1
Willow Flycatcher	LP-LS	10.3-15.3	12.6-17.5
Least Flycatcher	LP-LS	8.4-14.6	10.5-15.9
Hammond's Flycatcher	LP-LS	12.8-19.2	14.7-21.0
Pacific-slope Flycatcher	LP-P6	0.0-3.6	1.0-4.7
Cordilleran Flycatcher	LP-P6	1.3-2.8	1.8-4.0
Cordilleran Flycatcher	LP-LS	10.0-16.5	12.9-17.8

There were not as many significant differences in wing formulae by age (Table 1) and no differences were significant at P<0.001. In all significant cases adult birds averaged longer measurements than young birds. All but one of these age-related differences were also significant by season; in each case fall birds had larger measurements than spring birds. Wearing of flight feathers appears to reduce certain measurements, especially those involving the wing tip: LP-P6, P9-P5, and WG-TL. Differences in feather wear likely contributed to these age-specific differences, especially in species (e.g., Willow, Least, Dusky, Gray and Western flycatchers) where adults molt on the winter grounds and young retain juvenal flight feathers through their second summer (Pyle *et al.* 1987). Multiple ANOVA in those cases indicated that the effects of season usually swamped those of age, supporting this conclusion.

Except in Willow Flycatcher (see below), only three significant differences due to geographic variation were found, geographic division being based on both north-south and east-west midpoints in the distributions of all taxa. LP-LS averaged longer in northern than in southern populations of Hammond's and Dusky flycatchers. The only significant difference at P < 0.001 was WG-TL in Dusky Flycatcher, birds collected along the Pacific Slope and in the Sierra Nevada region having a 95% confidence interval of 3.2-9.6 mm, and birds collected in the Rocky Mountain region having an interval of 4.5-12.8 mm.

EASTERN vs. WESTERN WOOD-PEWEE

The two North American wood-pewees have been notoriously difficult to separate in the hand (Phillips et al. 1966), to the point at which their species recognition has been questioned based on specimen evidence alone (Ridgway 1907, Grinnell 1928, van Rossem 1940, Rand 1948, Jewett et al. 1953). Phillips et al. (1966) proposed that the distance from the tail tip to the tip of the longest uppertail covert (TL-UTC) could separate most immature males but fewer immature females; this difference in adults was not examined. In the present analysis it was found that TL-UTC is quite useful in identifying all birds, with a 95% confidence interval of 24.9-33.9 mm for Western and 31.4-40.1 mm for Eastern Wood-Pewee. A cutoff of 32.5 correctly identified 37 of 40 Western Wood-Pewees (true range 26-34 mm) and 38 of 40 Eastern Wood-Pewees (true range 32-41 mm): 93.8% of all pewees measured, regardless of age, sex, geographic location, or season. Caution is advised, however, as some specimens of Western Wood-Pewee were missing the longest coverts (due to collection/preparation procedures or molt), resulting in spurious TL-UTC values indicating Eastern Wood-Pewee.

A new result of this study was that LP-LS averaged significantly ($P < 0.0001$) longer in Western than in Eastern Wood-Pewee (Table 1). The formula TL-UTC - LP-LS thus provided the best means of distinguishing the two species, with a 95% confidence interval of -1.2 to 7.0 mm in Western and 7.0-19.9 mm in Eastern Wood-Pewee. A cutoff of 6.5 mm correctly identified 97.5% of all measured specimens, with only one adult male Western Wood-Pewee with a value of seven and one young male Eastern Wood-Pewee with a value of six being mis-identified according to this formula. It should be noted that this formula is based on specimens. Preliminary data suggests that the cutoff for live birds is higher, perhaps 9-10 mm. More study is needed on these formula in live birds.

WILLOW vs. ALDER FLYCATCHER

Hussell (1990) currently provides the best method for separating these two difficult species, based on modifications of Stein's (1963) original formula with the inclusion of "buffer zones," within which birds should be left unidentified. The concept of a buffer zone is equivalent to that of the overlap between confident intervals in this paper. I did not measure the distance from p10-p5, so cannot presently examine the reliability of Stein's and Hussell's separation methods. Some other differences were found (Table 1), however, which could be useful in separating some or most birds.

Among Willow Flycatchers, there were highly significant differences between western populations (collected west of Minnesota and including *E. t. brewsteri, adastus, extimus,* and *campestris* in part; see Browning 1993) and eastern populations (including *campestris* in part and *traillii*), in all formula measurements except LP-LS (see also Unitt 1987). P6-P10 was greater in western Willows whereas LP-P6, P9-P5, and WG-TL were greater in eastern Willows (Table 3); in all cases the formulae of eastern Willows more closely approached those of Alder Flycatchers (Table 3). By combining measurements, the best separation formula using this data set was (LP-P6 + P9-P5 + WG-TL) / (P6-P10 + Bill), or "Formula R" in Table 3. Use of the confidence intervals for this formula in Table 3 allowed separation to species of 75% of Alder Flycatchers, 64% of eastern Willow Flycatchers and 100% of western Willow Flycatchers.

TABLE 3
95% CONFIDENCE INTERVALS (MM) USEFUL FOR IDENTIFYING ALDER(N=52) AND WILLOW (EASTERN [MINNESOTA AND EAST] N=25 AND WESTERN N=40) FLYCATCHERS, OF ROUGHLY EQUAL AGE AND SEX DISTRIBUTIONS

MEASURE	ALDER	EASTERN WILLOW	WESTERN WILLOW
LP-P6	4.0-7.4	3.1-5.9	1.7-4.8
P6-P10	-1.4-3.3	0.9-4.5	2.0-7.0
P9-P5	7.2-11.6	6.3-10.2	4.7-9.1
WG-TL	12.4-20.3	11.2-20.1	7.1-14.6
Bill	7.7-9.2	8.1-9.9	8.4-10.3
Formula R[a]	2.4-4.7	1.8-2.9	0.9-2.2

[a] Formula R = (LP-P6 + P9-P5 + WG-TL) / (P6-P10 + Bill); bill is measured from the anterior point of the nares.

It should be noted that, in the present sample of eastern Willow Flycatchers, 74.6% of the specimens (all at MVZ) were collected in Minnesota by R. M. Zink (see Zink and Fall 1981), at the northern limits of the species' range, where longer wing formula measurements (closer to Alder Flycatcher) might be expected. Further examination of wing and tail formulae to separate these taxa is encouraged, using individuals of known song-type throughout the eastern range of Willow Flycatcher.

PACIFIC-SLOPE AND CORDILLERAN FLYCATCHERS

Few wing or tail formula measurements on their own appeared useful in separating more than small percentages of Pacific-slope and Cordilleran Flycatchers (Table 1), as was also found by Johnson (1980). The most useful measure on its own was P9-P5, where the confidence intervals presented in Table 1 separated 45% of Pacific-slope and 18% of Cordilleran Flycatchers. The best formula using a combination of measurements was (P6-P10 + LP-LS + WG-TL) P9-P5, yielding 95% confidence intervals of 61.7-283.5 in Pacific-slope and 157.8-331.0 in Cordilleran, and allowing separation of 47.5% of Pacific-slope and 30.0% of Cordilleran Flycatchers. By calculating confidence intervals for each sex, 75-216 for female Pacific-slopes, 88-299 for male Pacific-slopes, 156-279 for female Cordillerans and 191-346 for male Cordillerans, 55.0% of known-sex Pacific-slope Flycatchers and 37.5% of known-sex Cordilleran Flycatchers in the present sample were reliably separated. This represents the best in-hand measurement criteria thus far proposed for the separation of these two taxa.

CONCLUSIONS AND A COMMENT ON SPECIMEN COLLECTIONS

With relatively little effort useful new information on identifying and sexing *Empidonax* and *Contopus* flycatchers, two of the most critically examined genera of North American birds, has been presented in a format most useful for in-hand determinations. This study is just a small indication of the wealth of information that still can be gathered from the many extensive North American specimen collections, not only on taxonomic (including subspecific) determinations but on other subjects, e.g., molt as related to age determinations (Pyle 1995, Pyle and Howell 1995). Preliminary information from brief specimen examination indicates, for example, that wing formulae, when properly analyzed, can be used to separate, among other things, *Myiarchus cinerascens* (P9-P5 3-7 mm) from *M. nuttingi* (P9-P5 -1 to 3 mm) and the races of *Zonotrichia leucophrys* (*gambelii* having a much longer P9 than *nuttalli*, at least), and they could also prove very useful in separating the species and subspecies complexes of other taxa, such as *Tyrannus meancholicus/couchii, Catharus* spp., *Vireo solitarius, Dendroica petechia, Geothlypis trichas, Passerculus sandwichensis, Melospiza melodia,* etc., among many other potential examples. Let us not let these great collections sit unused. Rather than inadequately rehashing old information (e.g., Pyle et al. 1987, Seutin 1991), arm waving (Winker 1991), or complaining about the lack of available specimens or funding for further collecting (e.g., Phillips 1994, Johnson 1994, Remsen 1995), I suggest that time is better spent critically examining specimens for new information on biodiversity and life history. Only through such efforts and ensuing publication of results, will further judicious collecting (to increase knowledge not attainable with presently available specimen material), and collection management, be encouraged and funded by the career-opportunists of the ornithological community.

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