Estimating Ages of House Wren Nestlings Based on Body Mass, Wing Chord Length, and Feather Tract Development Patterns

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ABSTRACT

Few studies have assessed the accuracy of using nestling measurements and growth patterns to estimate nestling age or compared age estimates among workers with varying experience levels. We collected body mass and wing chord length observations daily from 109 individually marked House Wren (Troglodytes aedon) *nestlings from 30 broods near Kutztown, PA (Berks County) during the 2008 and 2009 breeding seasons. Qualitative feather tract development data based on digital images were collected daily from 42 nestlings in 2009. Groups of experienced and inexperienced participants used these data to estimate ages of "unknown" nestlings from similar observations of 28 additional nestlings. Age estimates determined from mass and wing chord length were more accurate than those determined from feather tract development patterns (85% vs. 64% overall, respectively). Based on mass and wing chord length, nestling ages were estimated correctly to within one day of their actual age if they were from one to 13 days old, but not from 14 to 16 days old. Accuracy, however, differed between inexperienced (80%) and experienced (89%) participants. Based on feather tract development patterns, nestlings were estimated correctly to within one day of their actual age if they were from two to seven days old (86%), but not for other ages combined (51%). Overall accuracy of age estimates was low for both experienced and inexperienced participants and estimates differed between these groups for 10 of 16 possible nestling ages. We suggest that future studies assess the accuracy of proposed methodology for estimating ages of birds.*

INTRODUCTION

Nestling growth observations have been collected from many species with the intent of using these data to estimate ages of subsequently encountered nestlings (Kautz and Seamans 1986, Reed et al. 1998, Podlesak and Blem 2002, Jongsomjit et al. 2007). Daily growth observations from known nestlings may be averaged (e.g., Murphy 1981) or presented as a smoothed curve or model (Starck and Ricklefs 1998, Brown et al. 2007). Such summarized data are then compared to observations collected from an individual nestling to estimate its age (Holcomb and Twiest 1971, Kautz and Seamans 1986, Coleman and Fraser 1989). Several studies also have noted that feather tract development follows predictable patterns that may be useful for aging nestlings (Boulton 1927, Murphy 1981, Jongsomjit et al. 2007).

There are some difficulties with the otherwise straightforward methodology of estimating nestling age based on morphometric characters or feather tract development patterns. Body mass and wing chord length are the most commonly collected nestling measurements (Murphy 1981). Mass may vary, sometimes widely, over the course of development in many species and limit the ability to predict nestling age (Brown et al. 2007). Models that do not account for negative growth trajectories associated with mass in some species also are not suitable for estimating nestling age (Brown et al. 2007). Wing chord length is less variable than mass, even if young are nutritionally stressed (Pereyra and Morton 2001), and wing chord length cannot exhibit negative growth. As such, wing chord length may be a useful indicator of nestling age or used in conjunction with another character, such as mass, to predict nestling age. Single traits vary in their ability to predict age and the accuracy of estimates based on one trait also may vary with age (Murphy 1981, Kautz and Seamans 1986).

The interpretation and application of growth models are other possible sources of error in estimating the age of unknown nestlings. Field workers may have varying levels of experience measuring young or estimating nestling age or following age estimation protocols and there may be regional or habitat-specific differences in nestling growth. Few studies have presented accuracy assessments of nestling age estimates based on morphometric data or development patterns (e.g., Kautz and Seamans 1986). We know of no studies that compared nestling age estimates from different methodologies or specifically tested if intended age estimation methodology can be applied satisfactorily by workers with varying experience levels.

Our objectives for this study were to determine if nestling age could be 1) accurately estimated based on body mass and wing chord length used together, 2) accurately estimated using qualitative feather tract development scores determined from standardized digital images of nestlings, and 3) accurately and consistently estimated among participants with varying levels of experience. To meet these objectives, we collected House Wren (*Troglodytes aedon*) mass and wing chord length observations and feather tract development scores from known-age nestlings. A portion of known-age House Wren nestlings were treated as "unknowns" and their ages estimated by experienced and inexperienced study participants. The accuracy of age estimation based on mass and wing chord length, qualitative feather tract development scores, and between participant groups is described here.

METHODS

Sixty Peterson-style nest boxes (see Davis and Roca 1995) were set up during March 2008 at two locations on Kutztown University property near Kutztown, Berks County, PA (approximately 40° 32' 24" N, 75° 48' W; Kern et al. 2009). Nest boxes were checked nearly every day, weather permitting, until eggs hatched. Each nestling was marked uniquely on all toenails with a colored paint marker. After hatching was completed, each nest box was visited nearly every day until fledging or nest failure to collect measurements from every nestling. Measurement data from failed nests were excluded. Nests were visited during the mid- to late afternoon, with few exceptions, to maintain consistency among measurements. Mass was recorded to the nearest 0.1 g from digital scales. Unflattened wing chord measurements were recorded to the nearest 0.5 mm from stainless steel rulers fitted with a wing stop. Observations from 109 different House Wren nestlings from 30 different broods were collected during the 2008 and 2009 breeding seasons and represent our known-age nestlings.

Digital images of individual House Wren nestlings from a lateral perspective and a dorsal perspective were collected during the 2009 breeding season to score feather tract development. Following the nomenclature and methodology of Jongsomjit et al. (2007), six tracts – capital, dorsal, alar, femoral, crural, and caudal – were scored for each nestling. The crural tract was obscured from view on some older nestlings due to holding them by the legs during photography. The most advanced stage of feather development in each feather tract was recorded for each nestling based on the following qualitative codes: N (Not visible), V (Visible, including visible below the skin), P (Pin, feathers have broken through the skin), U (Unsheathing, feather partially exposed), and F (feather fully unsheathed). Daily feather tract development scores of 42 nestlings were tabulated by ALA and WPB and used to estimate the age of individuals from our sample of unknown-age birds.

Mass, wing chord length, and digital images were collected nearly every day from a separate sample of 28 known-age nestlings from five different nests during the 2009 breeding season by MEZ and WPB. Measurements and images of six to nine randomly selected individuals at each day of development were compiled from this sample of nestlings and represent our "unknown-age" nestlings. Mass and wing chord length observations of unknown-age nestlings were provided to the five authors and eight volunteer participants for age estimation. Separately, a set of 103 pairs of digital images, with each pair of images representing the dorsal and lateral perspective of an individual nestling, also were provided to the authors and seven of the eight volunteers (one volunteer did not estimate nestling age based on feather tract development patterns). Based on provided methodology (see Aging Nestlings), participants returned an age estimate, from one to 16 days, for each pair of measurements (mass and wing chord length). We collected very few observations from nestlings older than 16 days of age and did not consider those birds here. Each participant also determined feather tract development scores from each pair of digital images for each nestling and returned an age estimate based on previously tabulated feather tract scores (see Aging Nestlings). Five participants (the authors) handled and measured House Wren nestlings for at least one field season prior to estimating nestling ages and were considered here to be "experienced". The other eight "inexperienced" participants had never handled a bird and had not previously been exposed to any kind of age estimation protocols.

Aging Nestlings - In order to estimate age, mass and wing chord measurements of unknown nestlings were compared to those of known ages (Table 1). If the measurements from an unknown nestling spanned a range of possible ages, the midpoint of the age range was selected as the estimated age. For example, an individual nestling with a mass of 10.2 g might be any age between nine and 16 days old, inclusive. If there was an even number of days in the age range, as in this example, the smaller of the two midpoint values was chosen as the estimated age, or 12 days in this case. Age estimates based on wing chord length were determined in a similar manner. If age estimates based on mass and wing chord length differed, the more conservative (smaller) age estimate of the two was selected.

MASS						WING CHORD LENGTH					
Age	Mean	SD	Min	Max	*n*	Age	Mean	SD	Min	Max	*n*
1	1.4	0.3	0.9	2.1	109	1	5.1	0.6	4.0	6.5	103
2	2.0	0.4	1.3	3.3	102	2	5.9	0.7	4.0	8.0	102
3	2.9	0.4	2.1	4.0	90	3	7.0	0.8	5.5	9.0	89
4	4.0	0.6	2.2	6.2	105	4	8.3	1.0	6.5	11.0	99
5	5.6	0.8	4.1	7.4	82	5	11.1	1.3	8.5	14.0	82
6	6.8	1.1	4.9	9.3	104	6	13.9	1.8	11.0	19.0	104
7	8.0	0.9	5.9	10.2	93	7	16.9	1.9	13.0	22.0	93
8	8.9	0.9	6.7	10.8	107	8	19.9	1.8	15.5	26.0	107
9	9.7	0.9	7.3	11.4	107	9	23.4	2.2	18.0	28.0	107
10	10.3	1.0	7.9	12.5	95	10	26.9	2.3	20.5	32.5	95
11	10.5	0.8	7.9	12.2	77	11	30.1	2.1	24.5	35.0	77
12	10.6	0.7	8.6	12.5	83	12	32.8	1.9	27.0	36.5	83
13	10.3	0.7	8.9	12.1	68	13	35.3	2.0	30.3	38.5	67
14	10.2	0.9	7.7	11.9	61	14	37.2	2.1	31.0	40.0	55
15	10.0	0.7	8.7	11.5	36	15	38.7	1.7	34.0	42.0	31
16	10.2	0.6	9.0	11.4	16	16	40.8	1.3	38.0	42.5	12

Table 1. The average mass (g) and wing chord length (mm) of House Wren nestlings with increasing age (days). Measurements of 109 nestlings from 30 broods were collected approximately daily during the 2008 and 2009 breeding seasons near Kutztown, PA (Berks County).

Each participant scored feather development for the six feather tracts of each unknown-age nestling in their random sample. Individually determined feather tract scores were then compared to tabulated scores from our 42 known-age nestlings (see Table 2). As with estimating age based on morphometric measurements, if a range of possible ages existed, the midpoint of the range was selected as the age estimate. Individual feather tracts retained identical scores for up to seven days in a row for nestlings eight to 14 days of age. Our conservative methodology would result in an age estimate of 11 days for all of these nestlings. In some cases, such as with more completely feathered nestlings, it was not possible to view some feather tracts. If this occurred, no score was entered for that tract. A minimum of four out of six feather tract scores was required to estimate nestling age.

Age estimates were considered accurate if they were within one day of the actual nestling age. Accuracy estimates were compared between methods and between inexperienced and experienced participants with a χ^2 test. Differences in average daily age estimates between inexperienced and experienced participants were compared with *t*-tests.

RESULTS

The mass of nestling House Wrens in our sample of known-age birds increased in a sigmoidal manner, reached a slight peak at 11 and 12- days of age, then decreased and remained approximately constant from 13 to 16 days of age (Table 1). Wing chord length also increased in a sigmoidal pattern but did not reach an asymptote by the time of fledging. The six feather tracts we examined developed differentially, starting with the caudal and alar

Age	Capital	Dorsal	Alar	Femoral	Crural	Caudal	*n*
1	N	N	NV	N	N	NVP	32
2	NV	NV	NVP	NV	NV	NVP	37
3	NV	NV	NVP	NV	NV	NVP	40
4	NV	NVP	VP	NVP	NV	NVP	41
5	NV	NVP	VP	NVP	NV	VP	30
6	NVP	NVP	P	VPU	VP	VP	40
7	VP	PU	PU	PU	VPU	VPU	39
8	PU	PU	PU	U	VPU	PU	41
9	PU	U	U	U	U	PU	38
10	U	U	U	U	U	U	42
11	U	U	U	U	U	U	36
12	U	U	U	U	U	U	37
13	U	U	U	U	U	U	30
14	U	U	U	U	U	U	31
15	UF	F	UF	U	U	UF	21
16	F	F	F	F	F	F	11

Table 2. Daily feather tract development scores for each of six tracts in the House Wren. Codes follow Jongsomjit et al. (2007): N - feathers in tract not visible above or below the skin; V - some feathers in tract visible, even if they are below the skin; P - some feathers in tract are in the pin stage; U - some feathers in tract are unsheathing; F - some feathers in tract are fully unsheathed, or are complete feathers. More than one code may be listed in a cell if different individuals of the same age developed at different rates. The most advanced feathers in a tract were scored based on examination of digital images collected daily from 42 nestlings during the 2009 breeding season near Kutztown, PA (Berks County).

tracts (Table 2). The capital and crural tracts were generally the last to develop, although patterns differed among individuals. Feathers from all six tracts were unsheathing by eight days of age and continued in that state of development until day 14. Based on examination of digital images, some feathers appeared fully formed in all six tracts by 16 days of age (Table 2).

Using mass and wing chord length observations only, the ages of unknown nestlings were accurately estimated (± one day) if they were from one to 13 days of age. The ages of nestlings greater than 13 days old were underestimated by our methodology, generally by a day or two (Fig. 1). Using qualitative feather tract development scores only, the ages of unknown nestlings were estimated accuurately if nestlings were from two to seven days old (86% for combined days in that range), when feather tract development was most variable (Fig1).

It was not possible to estimate nestling age accurately between eight and 14 days of age (35% combined) because all feather tracts were in the same qualitative state of development, or unsheathing. Based on our conservative methodology, age estimations of all nestlings with feathers unsheathing in five or six tracts would be 10 or 11 days old.

The accuracy of age estimates based on mass and wing chord length was generally high until nestlings were 13 days of age (77%–100% of estimates were within one day of the nestling's actual age; Fig. 2). The accuracy of age estimates based on feather tract development was high or satisfactory until nestlings were seven days of age (63%–97% accurate), after which it varied from 0% (nine-day-old nestlings) to 89% (15-day-old nestlings; Fig. 2). The high variability in age estimation accuracy of older nestlings was due to our conservative aging methodology. Overall, age estimates determined from mass and wing chord length observations were more accurate than those determined from feather tract development patterns (85% vs. 64%, respectively; χ^2=158.6, df=1, p<0.001). Based on t-tests, age estimates between the two methods differed (p<0.05) for all ages except those determined for nestlings four and five days of age (see Figs. 1–2).

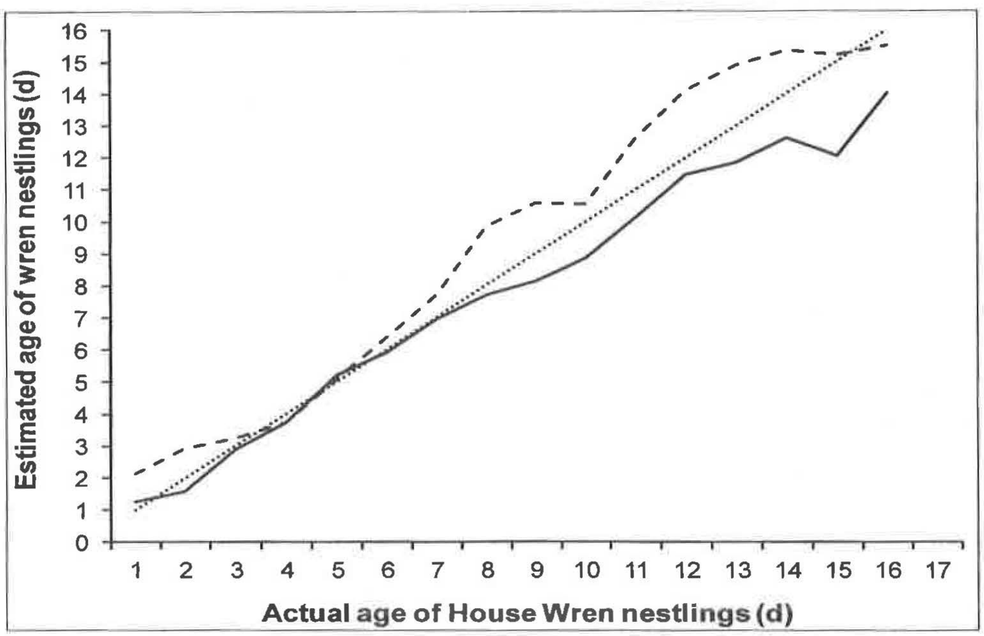

Fig. 1. A comparison of estimated age versus actual age, in days, of House Wren nestlings. Average age estimates determined from body mass and wing chord length by five experienced participants and eight inexperienced participants are indicated by the solid line. Average age estimates determined from qualitative feather tract scores by five experienced participants and seven inexperienced participants are indicated by the broken line. The actual age of nestlings is indicated by the dotted line.

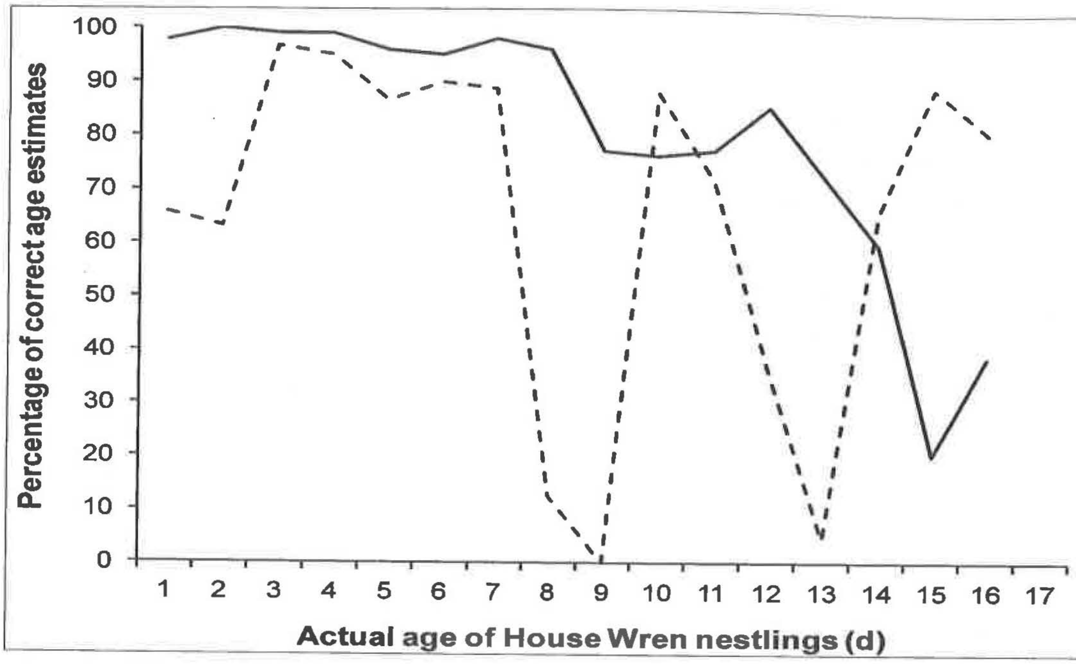

Fig. 2. The percentage of age estimates within one day of actual nestling age based on mass and wing chord length (solid line) and feather tract development patterns (broken line), for all observers. Sample sizes ranged from 10 to 80 estimates for House Wren nestlings aged 1 to 15 days old, and 5 to 8 estimates for nestlings that were 16 days old.

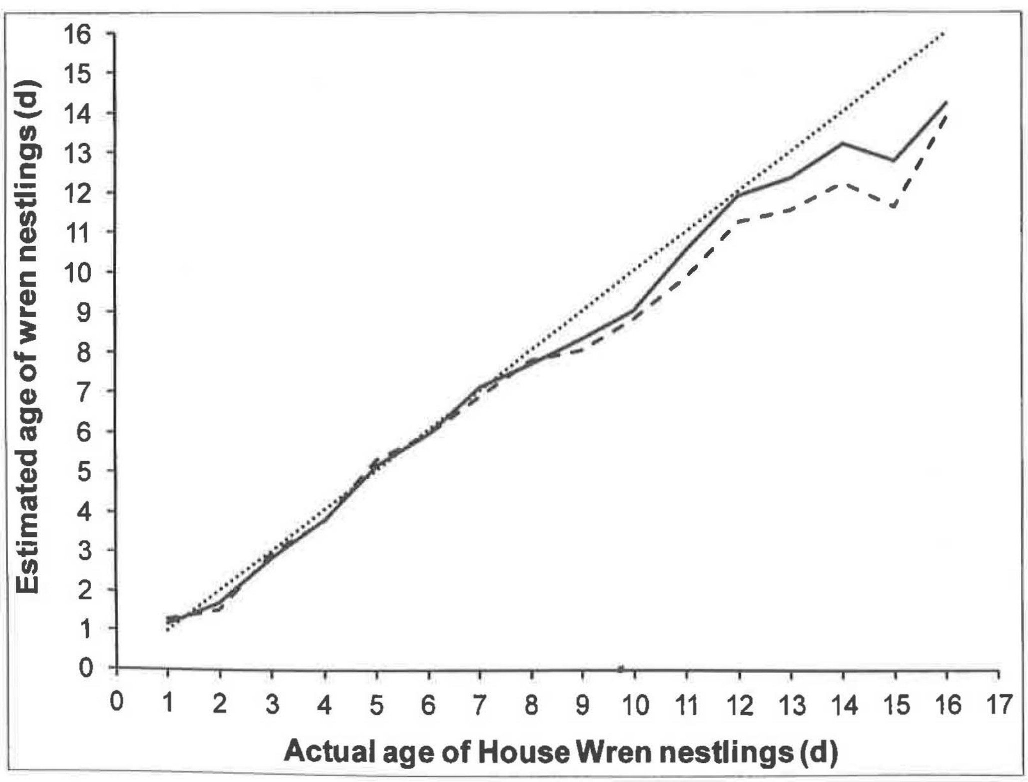

Fig. 3. Age estimates of House Wren nestlings determined by mass (g) and wing chord length (mm) combined as determined by five experienced participants (solid line) and eight inexperienced participants (broken line). Actual nestling age is indicated by the dotted line. Due to conservative aging methodology, both sets of participants tended to underestimate the ages of the oldest nestlings. Based on *t*-tests, age estimates differed (p <0.05) between the two groups for 11-, 13-, and 15-day-old nestlings.

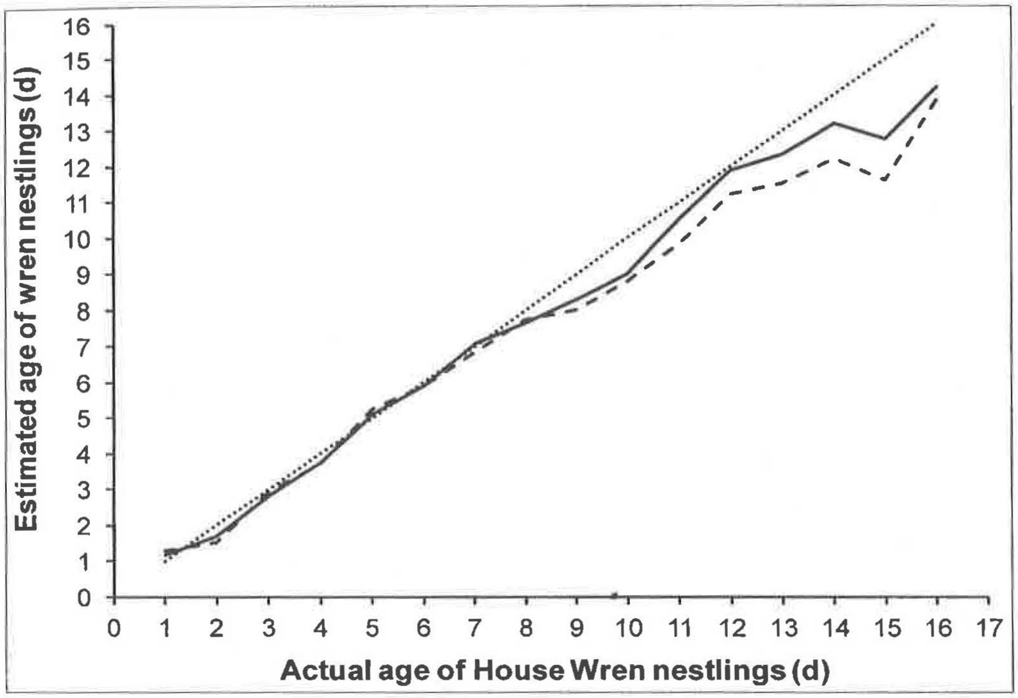

Fig. 4. Age estimates for House Wren nestlings determined by qualitative examination of feather tract development patterns. Age estimates from five experienced participants are indicated by the solid line, those from seven inexperienced participants are indicated by the broken line, and actual nestling age is indicated by the dotted line. Based on the same conservative methodology, age estimates between the two groups differed (p <0.05 based on t-tests) for 10 of 16 possible ages.

Nestling age estimates determined by inexperienced participants based on mass and wing chord length were more variable for every age than those of experienced participants. The two groups produced significantly different average age estimates based on these morphometric observations for three of 16 possible ages (day 11, 13, and 15). In each of the three cases, age estimates from inexperienced participants were lower than those of experienced participants ($p < 0.05$ based on t-tests; Fig. 3). Accuracy of age estimates based on mass and wing chord length differed between inexperienced and experienced participants. Experienced participants produced age estimates within one day of actual nestling age on 89.5% of all attempts and inexperienced participants were accurate for 80.2% of all attempts (χ^2=21.7, df=1, p<0.001).

Age estimates determined by experienced and inexperienced participants based on feather tract development patterns differed for 10 of 16 possible ages (Fig. 4). The general pattern was for inexperienced participants to produce greater age estimates for younger nestlings than experienced participants did, and to produce lower age estimates for older nestlings (Fig. 4). For both groups, age estimates based on feather tract development were more variable than age estimates based on morphometric observations (see Figs. 3 and 4).

DISCUSSION

Most House Wren nestlings were aged accurately to within one day of their actual age based on mass and wing chord length observations until they were 13 days of age. Accuracy of age estimates based on these morphometric characters was greatest for young nestlings (>95% accuracy for nestlings less than nine days of age), decreased for nestlings nine to 13 days old ($\geq$72%), and was not satisfactory for nestlings near fledging age, or those 14 days of age and older (<60%). The inability to estimate the age of the oldest nestlings successfully may be due to increased variability in body measurements and the weight recession observed in some individuals (see also Zach 1982). Increased morphometric variability resulted in a greater range of possible age estimates for an individual nestling. Selecting the mid-point of a larger range of age possibilities based on our conservative methodology produced lower age estimates for the most variable, or oldest, nestlings. The tendency of participants to underestimate ages of the oldest House Wren nestlings was similar to results from a study of Rock Pigeons (*Columba livia*), in which Kautz and Seamans (1986) correctly predicted the age (± one day) of 92% of young pigeons but accuracy decreased to 66% for older nestlings. Suggested reasons for underestimating ages of older nestling Rock Pigeons included size differences between early and late season young (Kautz and Seamans 1986). Zach (1982), however, found no temporal difference in mass between first and second broods of House Wrens. The developmental patterns and dimensions of House Wren nestlings provided here are similar to those described in other parts of the species' range (Johnson 1998), but it is not known if our results generalize to other populations.

In addition to mass and wing chord length, tarsus (Murphy 1981), head-bill length (Reed et al. 1998), body length (Hanson and Kossack 1957), and feather length, wear, and molt patterns (Boulton 1927, Kautz and Seamans 1986, Nesbitt and Schwikert 2005, Jongsomjit et al. 2007) are commonly collected from birds in the field and used to indicate age. Mass and wing chord length were chosen here as quantitative estimators of nestling age because they are the most commonly collected observations (Starck and Ricklefs 1998, Jongsomjit et al. 2007) and because more than one character should be used to estimate age, if possible (Murphy 1981, Kautz and Seamans 1986). Despite the prevalence of collection, body mass has consistently been described as a variable to highly variable character (e.g., Murphy 1981, Zach 1982, McDonald 2003, Brown and Roth 2004) and has been used to indicate nestling age even though it may not be suitable for that purpose (Murphy 1981, Brown et al. 2007). Wing chord length may be more useful than mass for estimating nestling age because of the monotonic growth trajectory exhibited by wings (Brown et al. 2007), even during periods of limited food availability (Coleman and Fraser 1989, Podlesak and Blem 2002), and because it is less variable than mass (Coleman and Fraser 1989, Carlsson and Hörnfeldt 1994, Brown and Roth 2004). Ideally, characters that exhibit rapid growth are most useful for estimating age. Choice of character may therefore change over the course of nestling development (Holcomb and Twiest 1971, Murphy 1981). Some studies have provided keys to aging nestlings that take advantage of differential character development (Kautz and Siemens 1986).

Age estimates based on feather tract development patterns were acceptably accurate for House Wren nestlings aged two to seven days (63% to 97% accurate). These age estimates, however, were not as accurate and were more variable among participants than estimates determined from morphometric characters. Low aging accuracy for nestlings eight to 14 days of age was due primarily to the lack of variability in feather tract development scores, when feathers in all tracts were unsheathing. Based on our conservative aging methodology, nestlings with unsheathing feathers in five or six tracts were estimated to be 10 or 11 days old, or halfway between 7 and 14 days of age. This methodology, therefore, resulted in accurate age estimates of 10- and 11-day-old nestlings and estimates with very low accuracy for 8-, 9-, 12-, and 13-day-old nestlings, all of which would have been estimated as either 10 or 11 days old. Studies of the Brown Falcon (*Falco berigora*) also noted that developmental patterns were not useful for aging nestlings (McDonald 2003). Horwich (1966) suggested that plumage ontogeny was useful to indicate approximate ages of nestling Northern Mockingbirds (*Mimus polyglottos*) but no assessment of accuracy was provided.

Any lack of accuracy in estimation of nestling age based on quantitative or qualitative measures of development may be due to errors in the initial study or due later to observer interpretation of presented data or methodology. For example, there may be initial error in assigning age to individual nestlings within a brood when the exact time of hatch for each is not known (Pereyra and Morton 2001). Error also may be due to lack of precision in initial measurements, multiple observers collecting data (Kuczynski et al. 2003), inappropriate choice of morphological character(s) to indicate nestling age, or incorrect methodology, such as choice of growth model (Brown et al. 2007), to indicate nestling age. Given that many of these possible sources of error occurred in our study, there was nevertheless a generally high level of accuracy in estimating the age of House Wren nestlings until 13 to 14 days of age based on mass and wing chord length by all participants, and near 90% overall accuracy by experienced participants. Lower levels of accuracy were achieved based on feather tract development patterns. Age estimation differences existed between groups of experienced and inexperienced participants for older nestlings, particularly estimates determined from feather tract development patterns. Reasons for these differences are not clear but we suspect they may be related to motivation and training. Improvements in consistency of estimation within both groups could come from practice (Winker 1998). If the intention of providing developmental data is to estimate the age of nestlings subsequently, we recommend that authors provide a specific methodology for how to do so and also provide an evaluation of the accuracy of the proposed methodology.

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Test of the Plumage Characteristics Used to Sex Golden-cheeked Warblers in the First Basic Plumage

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ABSTRACT

While the Golden-cheeked Warbler (Setophaga chrysoparia) *is sexually dimorphic in adult plumage, a large degree of overlap exists within the plumage characteristics used to determine sex for hatching-year Golden-cheeked Warblers in first basic plumage. During the 2009 breeding season, we collected blood samples from 10 hatching-year Golden-cheeked Warblers and compared their actual sex as determined by DNA analysis to their presumed sex as determined by plumage characteristics described in Pyle (1997). For all samples, the DNA analysis confirmed the sex determination based on plumage characteristics. These results provide strong evidence that plumage characteristics alone can be used to reliably determine the sex of Golden-cheeked Warblers in first basic plumage.*

INTRODUCTION

The Golden-cheeked Warbler *(Setophaga chrysoparia) is* a federally endangered migratory passerine. Currently, it is known to breed in the juniper-oak *(Juniperus ashei - Quercus spp.)* woodlands of 25 counties in central Texas (Pulich 1988, Ladd and Gass 1999). In the non-breeding season, this species migrates along the Sierra Madre Oriental of eastern Mexico (Ladd and Gass 1999). It overwinters in the Central American pine-oak *(Pinus* spp.- *Quercus* spp.*)* forest region, which is located throughout the highlands of the Sierra Madre and extends from southern Mexico to northwestern Nicaragua (Ladd and Gass 1999).

The first prebasic, or preformative (Howell et al. 2003), molt of Golden-cheeked Warblers begins within two to three weeks after the young leave the nest and occurs on the breeding grounds (Gass 1996). This molt includes the median and greater secondary coverts (hereafter "greater coverts") and the body feathers (Pyle 1997). While Golden-cheeked Warblers in juvenal plumage cannot be sexed reliably by plumage characteristics, Pyle (1997) describes variation in the amount of black mottling in the chin and throat, the amount of black