

2016

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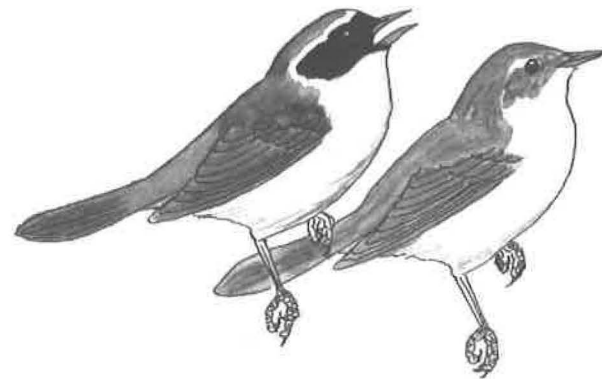
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Recommended Citation

French, Rowan L. K.; Roberto-Charron, Amelie; and Foster, Kenneth R. (2016) "The Accuracy of Wing Chord Ranges in Pyle (1997) as Indicators of Sex in North-Central Alberta Populations of Least Flycatcher, Myrtle Warbler, and Clay-colored Sparrow," *North American Bird Bander*. Vol. 41 : Iss. 3 , Article 3. Available at: <https://digitalcommons.usf.edu/nabb/vol41/iss3/3>

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Common Yellowthroat
by George West

The Accuracy of Wing Chord Ranges in Pyle (1997) as Indicators of Sex in North-Central Alberta Populations of Least Flycatcher, Myrtle Warbler, and Clay-colored Sparrow

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ABSTRACT

Wing chord ranges for several species and sexes in Pyle (1997) are primarily based upon measurements of museum study skins. Intended to encompass North America, these ranges provide the sole means of non-invasively sexing monomorphic birds outside of the breeding season. The validity of such ranges for live, individual populations has been little explored.

*Beaverhill Bird Observatory and Boreal Monitoring Avian Productivity and Survivorship (MAPS) data for sexed, After-Second-Year Least Flycatcher (*Empidonax minimus*), Myrtle Warbler (*Setophaga coronata coronata*), and Clay-colored Sparrow (*Spizella pallida*) individuals were used to determine the accuracy of sexing through wing chord ranges provided in Pyle (1997). Wing chord ranges developed from Alberta data varied by up to 3 mm from those in Pyle (1997). Despite this, wing chord ranges in Pyle (1997) correctly sexed 81.4% of Least Flycatchers, 95.8% of Myrtle Warblers, and 90.2% of Clay-colored Sparrows. Fisher's exact test found a significant relationship between sex classifications based upon wing chord ranges in Pyle (1997) and those based upon breeding or feather characteristics for all three*

species ($P < 0.001$), suggesting consistency between the two methods. However, variations in the reliability of these ranges exist within species. We suggest that banders develop age- and region-specific wing chord ranges to account for geographic variation, or use wing chord ranges in Pyle (1997) only in conjunction with other sexing techniques.

INTRODUCTION

Field studies of migration timing, breeding behaviours, and dispersal rely upon accurate sex determinations in birds (Ellrich et al. 2010, Jahn et al. 2010). In sexually monomorphic species captured outside of the breeding season, sexing is hindered by the absence of breeding characteristics: a cloacal protuberance in males or brood patch in females (Pyle 1997). Prebasic molts occurring in the post-breeding season result in identical or near identical feather appearance in males and females of many passerine species. During the non-breeding season, non-invasive and on-site sex determinations in these species depend upon morphological differences between males and females (Piper and Wiley 1991, Pyle 1997, Ellrich et al. 2010).

As representations of this overall sexual size dimorphism, banders measure wing chord and, less often, tail length (Gosler et al. 1998, Frey et al. 2008). These measurements are compared with ranges in Pyle (1997), which is used extensively in ageing and sexing North American land birds by bird banders (USGS Patuxent Wildlife Research Center: Bird Banding Laboratory 2001). Being shorter-winged, females of many songbird species are sexed at the lower predicted extremes of a species' wing chord range while males are sexed at the highest (Pyle 1997). In species with plumages that appear monomorphic, sex determination is precluded when wing chord and tail length measurements are not long or short enough to differentiate males from females. When captured outside of the breeding season, the sex of these individuals must be classified as "unknown".

Bird banding stations are, however, wary of the use of Pyle's wing chord ranges as the sole identifier of sex in birds; as stated by the USGS Patuxent Wildlife Research Center Bird Banding Laboratory (2001),

"most" of the wing chord data presented in Pyle (1997) "need to be tested against birds of known age and sex." Also uncertain is how accurately those ranges in Pyle (1997) apply to individual populations. In particular, live birds might have longer wing chords than reported in Pyle (1997), which represents populations from across North America and incorporates data from museum specimens. These inconsistencies could arise from a combination of specimen shrinkage in study skin preparation and the drying process, age differences, seasonal variations in feather wear, and geographic variation in size (Stewart 1963, Alatalo et al. 1984, Jenni and Winkler 1989, Svensson 1992, Green et al. 2009, Jahn et al. 2010, Zaniewicz 2012). As for the last factor, Bergmann's rule states that animals have larger body sizes at higher latitudes, has been supported in numerous bird species and subspecies (Twedt et al. 1994, Molina et al. 2000, Meiri and Dayan 2003), including the Myrtle Warbler (*Setophaga coronata coronata*), Hubbard 1970). Northern populations with longer distance migrations also tend to show longer wings as an adaptation for more energy efficient flight (Fielder 2005, Nowakowski et al. 2014). Note also that ranges in Pyle (1997) are based on means plus or minus two standard deviations, resulting in capture of 95% of the variation for each sex. Pyle (1997) provides a range of wing chord measures to help account for geographic variation and other factors that impact wing length.

The potential for inaccurate or imprecise sex identifications in the non-breeding season is detrimental to ecological studies that control for or manipulate gender (Ellrich et al. 2010). Wing chord ranges specific to species, sex, age, and region could be used to more frequently and accurately identify sex in monomorphic Least Flycatcher (*Empidonax minimus*) and Clay-colored Sparrow (*Spizella pallida*). These ranges may also help to confer sex identifications on dimorphic species like Myrtle Warbler in the non-breeding season.

METHODS

The study species, Least Flycatcher, Myrtle Warbler, and Clay-colored Sparrow, were selected for their high capture rates in the study areas. The Beaverhill Bird Observatory (BBO) in north-central Alberta (53.494°

N, 112.529° W) and the Boreal Monitoring Avian Productivity and Survivorship (MAPS) program in the Fort McMurray region (56.726° N, 111.380° W) provided raw data collected during the breeding season of May to August.

At the BBO, birds were captured passively using 12 m x 2.8 m mist nets. Data collection occurred from 2000 to 2014 in willow-aspen parkland habitat, and followed Canadian Migration Monitoring Network Protocol (North American Banding Council 2001a,b, Hunsell and Ralph 2005).

Wing chord data collected from 2011 through 2013 were acquired from Boreal MAPS program conducted by Owl Moon Environmental Inc. and The Institute for Bird Populations using standardized Monitoring Avian Productivity and Survivorship (MAPS) protocol (DeSante et al. 2014). The Boreal MAPS program included 35 stations, 26 stations located north of Fort McMurray and nine located in and to the south of the city, with one station being closed due to flooding in 2013. Birds were captured passively using an array of 12 m x 2.6 m mist nets established at each of the stations.

In both the BBO and Boreal MAPS programs, the unflattened wing chord was measured in accordance with North American Banding Council standards (North American Banding Council 2001a, b) and guidelines in Pyle (1997). The sex of each bird was determined through breeding or feather characteristics. Of the individuals measured, only birds aged as After Second Year were included in the analysis, as Second-Year birds average shorter and more worn wings (Alatalo et al. 1984). In addition, band numbers were compared within and between banding stations to ensure that only the first documented record for an individual was included in the analyses. For each of the 26 recaptured birds in the data set, wing chord measurements varied by a maximum of 1 mm, regardless of changes in bander or feather wear. This consistency suggested that the banders' measurements were reliable, and that feather wear had minimal impact on measured wing chord. Similarly, Pearson correlations conducted in Microsoft Excel 14.4.7 for Mac 2011 showed very

weak correlations between feather wear and measured wing chord in After-Second-Year Least Flycatchers (females: $r = 0.0336$; males: $r = -0.0875$) and Clay-colored Sparrows (females: $r = 0.0384$; males: $r = 0.0366$) and weak correlations in After-Second-Year Myrtle Warblers (females: $r = -0.151$; males: $r = -0.278$). Within the After-Second Year age class, birds were, therefore, not excluded from the analysis on the basis of feather wear.

Prior to combining BBO and Boreal MAPS data, a two-tailed t-test with a 95% confidence interval was conducted in SPSS (Statistical Package for the Social Sciences) 22.0 for each sex and species to determine whether differences in wing chord measurements taken in the two regions were statistically significant. No significant difference in wing chord length was indicated ($P > 0.1$) for all but male Least Flycatchers ($P = 0.025$). Based upon these results and to avoid confounding error between sexes of a single species, only Least Flycatcher data from BBO (having the larger sample size) were analyzed for Least Flycatcher: a sample set of 46 male and 166 female birds. BBO and Boreal MAPS data were combined for Myrtle Warbler and Clay-colored Sparrow. This resulted in sample sizes of 73 male and 93 female Myrtle Warblers and 168 male and 71 female Clay-colored Sparrows.

Using these data, the percentage of birds in each sex and species correctly identified as male or female by wing chord ranges in Pyle (1997) was determined. A bird was deemed correctly sexed by Pyle's wing chord ranges if its sex designation corresponded to that based upon breeding or feather characteristics. To test the degree of relationship between the use of breeding or feather characteristics and Pyle's wing ranges to determine sex, two-tailed Fisher's exact tests with Bonferroni corrections were performed.

Wing chord ranges were calculated using two different methods. The first method excluded outliers and did not assume normality, while the second used plus-or-minus two standard deviations from the mean wing chord, as in Pyle (1997). These wing chord ranges were compared with those in Pyle (1997) for consistency.

Frequency distributions and boxplots were used to clarify sex-specific differences in the ranges and distribution of wing chord data. For each species, frequency distributions compare the occurrences of discrete wing chord values between sexes. Boxplots show the most common wing chord lengths for each sex in the form of a median and interquartile range (i.e., IQR: the range of the middle 50% of the data), and identify outliers and extremes. Outliers are defined by $[w < Q_1 - 1.5(IQR)]$ or $[w > Q_3 + 1.5(IQR)]$, where w is a wing chord measurement and Q_1 and Q_3 are the first and third quartiles (25th and 75th percentiles), respectively. Extremes are defined by $[w < Q_1 - 3(IQR)]$ or $(w > Q_3 + 3(IQR))$.

RESULTS

The two methods of constructing wing chord ranges produced similar results for a given sex and species, though variations of 2 to 3 mm were observed for male Least Flycatchers and female Clay-colored Sparrows (Table 1). Ranges also varied by up to 3 mm from those in Pyle (1997). Had only wing chord ranges in Pyle (1997) been used to determine sex, 7.4% of Least Flycatchers (9.0% of females and

2.2% of males), 1.2% of Myrtle Warblers (0% of females and 2.9% of males), and 5.2% of Clay-colored Sparrows (0% of females and 7.4% of males) included in this study would have been classified as the opposite sex to that indicated by breeding characteristics or plumage. These calculations exclude birds with outlier or extreme wing chord measurements (see Fig. 1). Wing chord ranges in Pyle (1997) would have sexed all other, non-outlier birds correctly or classified sex as unknown (Table 2). For each of the three species, Fisher's exact test supported a strong relationship between classifications of male or female based on Pyle's wing ranges and those based on breeding/plumage characteristics ($P < 0.001$).

The most frequently measured wing chords in the sample populations of Myrtle Warblers, Least Flycatchers, and Clay-colored Sparrows, for males and females, respectively, lay within the interquartile ranges of 72-74 mm and 68-71 mm, 63-66 mm and 60-62 mm, and 60-62 mm and 58-60 mm, as indicated by the lower and upper limits of each box (Figs. 1 and 2). Each interquartile range falls within the wing chord ranges in Pyle (1997) for the respective sex and species (Table 1).

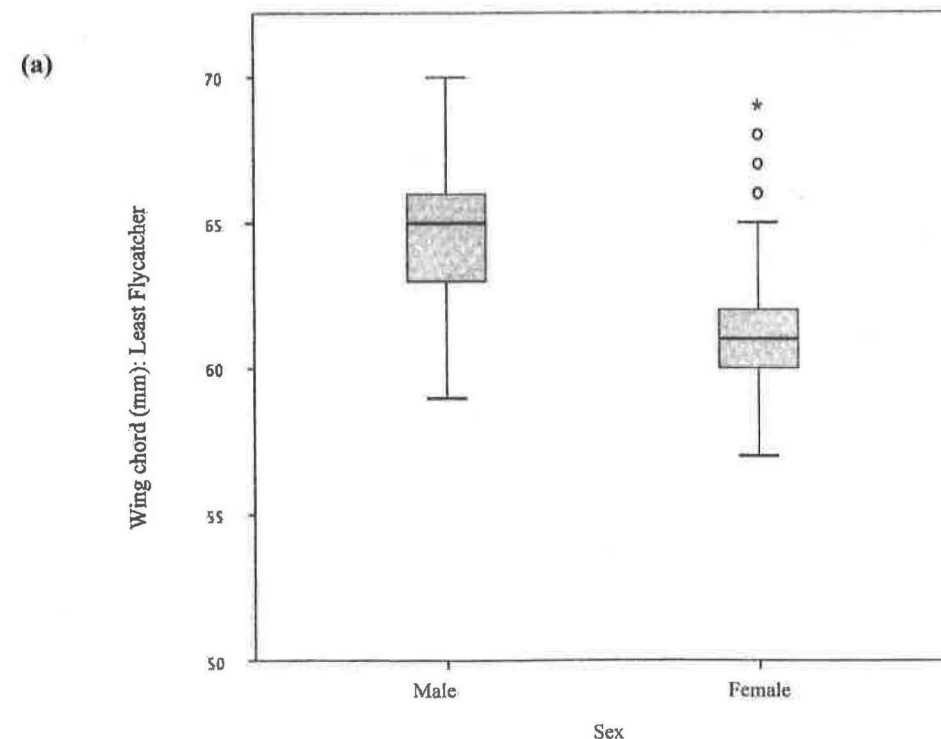
Table 1. Sex-specific wing chord statistics for BBO Least Flycatcher (LEFL), for combined BBO and Boreal MAPS populations of Myrtle Warbler (MYWA) and Clay-colored Sparrow (CCSP), and for ranges in Pyle (1997). "IQR" and "SD" represent the interquartile range and standard deviation, respectively. Ranges for "Alberta" populations of the study species exclude outliers and extremes. Units for all values presented are mm.

		LEFL		MYWA		CCSP	
		Male	Female	Male	Female	Male	Female
IQR		63-66	60-62	72-74	68-71	60-62	58-60
Range	Alberta	59-70	57-65	69-76	65-73	57-65	54-61
	Alberta (mean +/- 2SD)	62-70	57-65	69-77	66-74	57-65	56-62
	Pyle (1997)	60-67	56-63	70-78	65-75	59-67	56-62
Mode		64	60	73, 74	70, 71	60	59
Median		65	61	73	70	61	59
Mean		66	61	73	70	61	59
SD		1.83	1.93	1.93	1.90	2.15	1.45

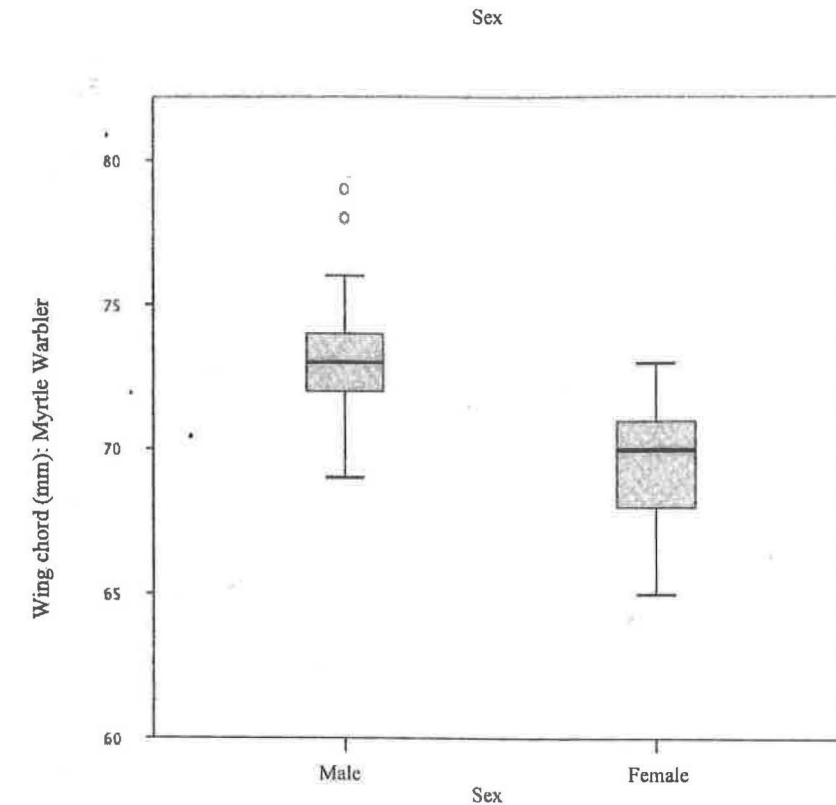
Table 2. Percent of Myrtle Warbler (MYWA), Least Flycatcher (LEFL), and Clay-colored Sparrow (CCSP) individuals correctly sexed using wing chord ranges in Pyle (1997). "Definitively sexed" birds are those with wings sufficiently long or short enough to fall within a species' exclusively male or female wing chord range in Pyle (1997). Values for the "% correctly sexed" and "total number definitively sexed" categories for each sex and species do not include birds that wing chord ranges in Pyle (1997) would have sexed as "unknown." Birds with outlier or extreme wing chords were excluded from all counts.

Species	Sex	Total number definitively sexed	% Correctly sexed	Total number unknown
MYWA	Female	42	100.0	51
	Male	6	66.7	64
	Total	48	95.8	115
LEFL	Female	47	70.2	109
	Male	34	97.1	12
	Total	81	81.4	121
CCSP	Female	27	100.0	44
	Male	95	87.4	67
	Total	122	90.2	111

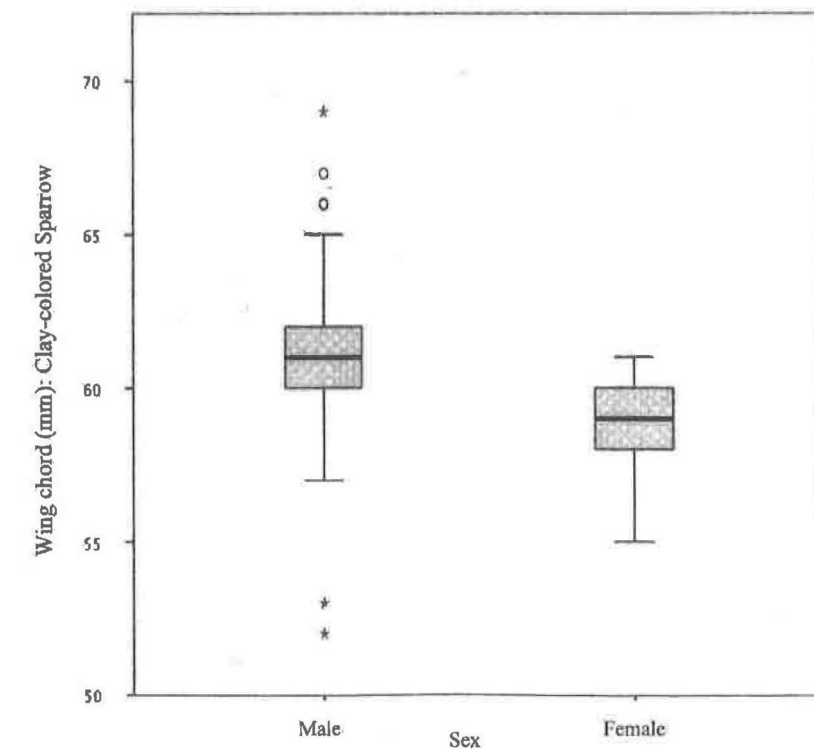
Fig. 1. Wing chord length (± 1 mm) by sex for **a** Least Flycatchers, **b** Myrtle Warblers, and **c** Clay-colored Sparrows. The bolded horizontal line within each box denotes the median of the sample, while the t-bars indicate the range to the exclusion of outlier points. Outliers are shown as open dots, and extremes, as asterisks.



(b)



(c)



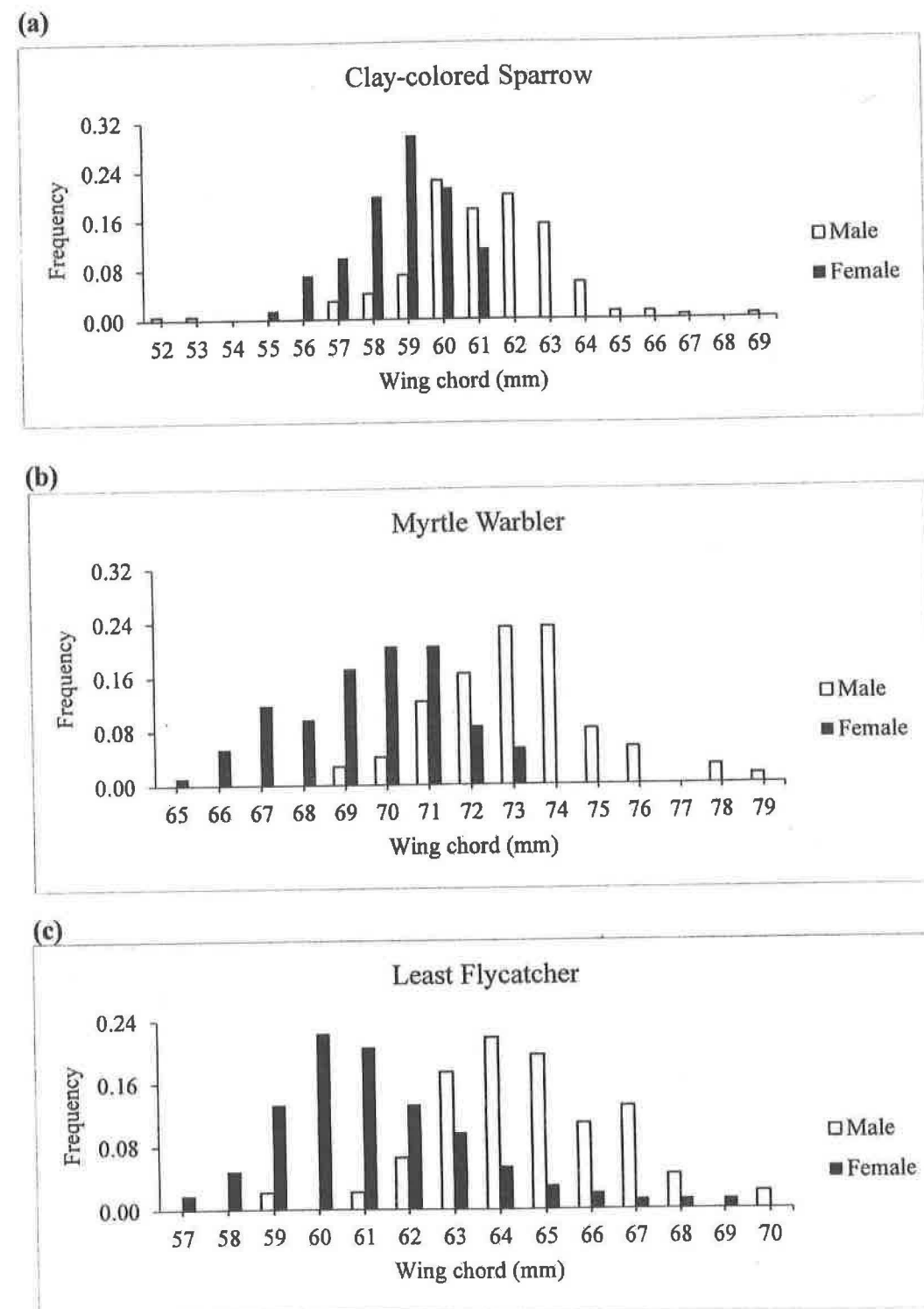


Fig. 2. Frequencies of measured wing chords (± 1 mm) for north-central Alberta **a** Clay-colored Sparrows, **b** Myrtle Warblers, and **c** Least Flycatchers, for each of females (black bars) and males (white bars). Percent frequencies were calculated as the number of individuals of a single sex with a given wing chord divided by the total number of individuals of that sex in the sample.

DISCUSSION

Contrary to the hypothesis, BBO and Boreal MAPS wing chord data from After-Second-Year Least Flycatcher, Myrtle Warbler, and Clay-colored Sparrow individuals captured during the breeding season do not appear to average consistently larger values than those values in Pyle (1997). All interquartile ranges developed from BBO and Boreal MAPS data fall within the wing chord ranges in Pyle (1997) for the respective sex and species. Similarly, Fisher's exact test identified a strong relationship ($P < 0.001$) between definitive sex identifications based upon Pyle's wing chord ranges and those based upon feather or breeding characteristics. These results indicate that wing chord ranges in Pyle (1997) are accurate for at least the middle 50% of north-central Alberta–Least Flycatcher, Clay-colored Sparrow, and Myrtle Warbler individuals. This outcome is likely a result of Pyle's measurement of a variety of both museum specimens and live birds from populations across North America and in various seasons (Pyle 1997), thereby mitigating the effects of specimen shrinkage, primary feather wear, and latitude.

At their upper and lower limits, however, sex-specific wing chord ranges in Pyle (1997) should be used with caution. North-central Alberta wing chord ranges developed using each of two methods varied from corresponding ranges in Pyle (1997) by up to 3 mm. Use of Pyle's wing ranges to determine sex also produced percent inaccuracies greater than 5% for female Least Flycatchers and male Clay-colored Sparrows: a higher level of uncertainty than considered acceptable by the Bird Banding Laboratory and Canadian Wildlife Service (Pyle 1997). Region-specific wing chord ranges like those developed in this study could improve the accuracy of sex classifications for specific populations and age cohorts. Previous studies of Northern Waterthrush (*Parkesia noveboracensis*) (Molina et al. 2000), American Robin (*Turdus migratorius*) (Aldrich and James 1991), and Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) (Twedt et al. 1994) have found that wing chord measurements are longer in northerly and westerly regions, are related to geographic trends in temperature and July absolute humidity (Aldrich and James 1991), and can be used to distinguish between geographically distant populations (Molina et al. 2000).

This suggests that the latitude, longitude, and climate of the breeding site should be considered when constructing wing chord ranges. As with ranges in Pyle (1997), geographically specific wing chord ranges would be best able to classify sex when used in conjunction with feather appearance, breeding characteristics, or other morphometric features (Freeman and Jackson 1990, Frey et al. 2008).

When developing wing chord ranges, the statistical distribution of the data should also be considered. While this study's two methods of wing chord range construction produced generally consistent results, discrepancies of 2 to 3 mm for male Least Flycatchers and female Clay-colored Sparrows are likely due to small sample sizes and deviations from normality. To ensure the most accurate representation of wing chord variation for a specific population, we suggest that future studies use the plus-or-minus two standard deviations method (intended to capture the middle 95% of wing chords) only if the assumption of normality holds.

Age-related variation in wing chord length was controlled by excluding Second-Year birds, in which greater wear of juvenal primary feathers is expected to result in apparently shorter wing chords (Alatalo et al. 1984). Nevertheless, it remains possible that worn primaries on After-Second-Year birds reduced measured wing chord length in some individuals. Females, in particular, are prone to feather wear during the breeding season, though feather quality naturally degrades over time in both sexes of the studied species (Merilä and Hemborg 2000, Vágási et al. 2011). Differences in molt location and timing across the three species may have produced different degrees of feather wear (Pyle, pers. comm., 18 Jan 2016). Clay-colored Sparrows and Myrtle Warblers undergo molts of primary feathers on the summer grounds and have more worn feathers during the subsequent breeding season than do Least Flycatchers, which molt on wintering grounds (Pyle 1997). These differences in feather wear may help to explain why wing chords were shorter than expected in male Myrtle Warblers and Clay-colored Sparrows, but not in male Least Flycatchers. However, Pearson correlations showed only weak relationship between primary feather wear and wing chord.

Contrary to the prediction that higher degrees of feather wear could be related to shorter wing measurements, correlation coefficients for Clay-colored Sparrows and female Least Flycatchers were positive. Note also that wing chord measurements for recaptured birds varied by a maximum of 1 mm, even as feather wear increased. Thus, it is unlikely that the inclusion of birds with primary feather wear values of three and four significantly affected wing chord ranges for this study's three species.

Future studies could address the broader accuracy of wing chord ranges presented in Pyle (1997) and in this study for populations in different geographic areas. Of particular interest are analyses of geographic variation in wing chord in sedentary bird species with isolated breeding populations, as these species tend to most strongly adhere to Bergmann's Rule (Wright 1946, Meiri and Dayan 2003). Variation in wing morphometrics relative to geographic subspecies boundaries and hybrid zones could also be investigated, particularly in relation to applications in sexing and identification of subspecies.

ACKNOWLEDGMENTS

We thank Christine Godwin, Peter Pyle, the MAPS program at The Institute for Bird Populations, and BBO and OMEI (Owl Moon Environmental Inc.) staff past and present for securing funding for the Beaverhill Bird Observatory and Boreal MAPS programs and collecting the wing chord data. For their support of the BBO, we thank Nature Canada, TD (Toronto-Dominion Bank) Friends of the Environment, Alberta Conservation Association, Mountain Equipment Co-op, Alberta EcoTrust, the Alberta Gaming and Liquor Commission, and Shell Fuelling Change. We also recognize funding received in support of the Boreal MAPS in the Oil Sands Program provided by Syncrude Canada Ltd., Hammerstone Corporation, Canadian Natural Resources Ltd., Cenovus Energy, ConocoPhillips Canada, Devon Energy, Husky Oil Operations Ltd., Imperial Oil Ltd., Suncor Energy, and TOTAL E&P Canada. Peter Pyle and Christine Godwin also provided valuable comments in reviews of earlier drafts. Lastly, R.L.K. French appreciates the feedback and support provided by International Baccalaureate (IB) extended essay supervisor, Dale

Skoreyko; IB coordinator, Laurel Usher; and family in the initial research and drafting processes.

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