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CHARACTERISTICS OF HUNTER-HARVESTED MONTEZUMA QUAIL WINGS AND IMPLICATIONS FOR MOLT PHENOLOGY

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ABSTRACT

We obtained 1,899 hunter-harvested Montezuma quail (*Cyrtonyx montezumae*) wings from southeastern Arizona, USA, from the 2008–2009 hunting season. We determined age and sex based on plumage characteristics for 98.2% (1,864) of the original sample. One-way analysis of variance (ANOVA) of wing-chord length found differences ($P < 0.001$) based on sex, but not age, with mean (\pm standard error) male wing chord (113.76 ± 0.15 mm) longer than mean female wing chord (111.03 ± 0.13 mm). Mean male and female wing-chord lengths from our study population were 6.8% and 7.7% shorter, respectively, than previously reported in the literature. We additionally calculated a complete prebasic molt cycle of 177 days based on previously reported preformative molt patterns. The primary benefits of our results are: 1) a more accurate sex-based wing-chord length based on a large sample size, 2) a method to back-calculate molt onset dates for hunter harvested after hatch year Montezuma quail, and 3) a potential means to model the influence of precipitation on population dynamics of Montezuma quail.

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Key words: Arizona, *Cyrtonyx montezumae*, molt phenology, Montezuma quail, wing chord

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Montezuma quail (*Cyrtonyx montezumae*) are found from the southwestern United States southeast to Oaxaca, Mexico along the Sierra Madre Occidental Mountains (Leopold and McCabe 1957, Johnsgard 1973, Stromberg et al. 2020). Reliable population monitoring methods (e.g., whistle counts, covey call count, and roadside counts) for Montezuma quail are limited due to the species' cryptic coloration, its secretive nature (Brown 1979, Harveson 2009, Chavarria et al. 2017, Sanders et al. 2017, Stromberg et al. 2020), and steep topography (Heffelfinger and Olding 2000). A lack of reliable population data both from indices and few field studies have resulted in much of our current knowledge about Montezuma quail being derived from anecdotal evidence or casual field observations (Brown 1979, Chavarria et al. 2017, Stromberg et al. 2020).

The Arizona Game and Fish Department (AZGFD) installed wing barrels to monitor Montezuma quail harvest trends beginning in the 1960s and continuing to the present (Zornes 2009). The hunter-harvested wing dataset represents one of the longest continuous monitoring efforts for Montezuma quail in the United States and has the potential to significantly improve our understanding of Montezuma quail life history and population dynamics. Hunter-harvested wings provide wildlife managers with a valuable, cost-effective tool to estimate population dynamics and annual reproduction indices for multiple game species, such as greater sage-grouse (*Centrocercus urophasianus*; Hoffman 1981, Hagen et al. 2018), sooty grouse (*Dendragopus obscurus*; Hoffman 1981, Zwickel 1982), American woodcock (*Scolopax minor*; Myatt and Krementz 2010), northern bobwhite (*Colinus virginianus*; Haugen 1957, Campbell et al. 1973, Wells and Sexson 1982), and California quail (*Callipepla californica*; Crawford and Oates 1986).

The Montezuma quail is the only North American quail species with sexually dimorphic wing plumage (Leopold and McCabe 1957, Harveson et al. 2007). Accordingly, hunter-harvested wings from this species allow managers and researchers greater insight into population trends based on age and sex, compared to other North American quail (e.g., northern bobwhite, mountain quail [*Oreortyx pictus*], scaled quail [*Callipepla squamata*], California quail, and Gambel's quail [*C. gambelii*]), for which wing surveys and studies are restricted to age-based analyses.

Our study goal was to provide a more robust analysis of Montezuma quail wing morphometrics and molt phenology. Specifically, our study objectives were to: 1) provide updated wing chord estimates based on a large sample size and 2) use molt characteristics (e.g., primary molt) of hunter-harvested Montezuma quail wings across age (e.g., after hatch year [AHY] and hatch year [HY]) and sex (male or female) to better understand molt phenology.

STUDY AREA

Wings for our study were harvested in Pima and Santa Cruz counties, Arizona, USA (Arizona Game Management Units 36, 37, and 38) within the Madrean Archipelago ecoregion

(Ruhlman et al. 2012). Elevation of the Madrean Archipelago ecoregion ranges from 600–3,000 m above mean sea level with a mean annual precipitation ranging from 218–1,118 mm from lower to higher elevations (Lowe 1964). Precipitation is bimodal with rainfall from frontal precipitation in winter and monsoonal storms in summer (Crimmins et al. 2011). Desert and semiarid grassland vegetation communities dominated low elevations, with Emory oak (*Quercus emoryii*) and juniper (*Juniperus* spp.) woodland vegetation communities dominant in mid-elevations, and ponderosa pine (*Pinus ponderosa*), Engelmann spruce (*Picea engelmannii*), and Douglas-fir (*Pseudotsuga menziesii*) found at higher elevations (Ruhlman et al. 2012).

METHODS

We obtained 1,899 hunter-harvested Montezuma quail wings from the AZGFD from the 2008–2009 hunting season (23 Nov 2008 to 11 Feb 2009). Hunter-provided wings were in their original submission packet, including date and location of harvest, use of dogs, and number of hunters in each submitting party (Heffelfinger and Olding 2000). We uniquely numbered all wings, recording harvest date and location in a database. We recorded age (e.g., HY or AHY) based on the presence or absence of buff-edged primary coverts, sex based on plumage coloration (Pyle 2008), flattened wing-chord length (mm), and feather molt (p1–p10) for each wing (Pyle 2008, Lyons et al. 2012). We used a 1-way analysis of variance (ANOVA) to test for differences between age and sex classification of mean wing-chord length.

Montezuma quail replace primary feathers sequentially from innermost (p1) to outermost (p10), with HY birds retaining p9 and p10 during their preformative molt (Pyle 2008, Stromberg et al. 2020). We recorded primary-feather molt for each wing and assumed the observed primary-feather molted was lost on the date of reported harvest (Randel et al. 2019).

To estimate preformative molt completion date for hunter-harvested wings, we subtracted the days post-hatching for each primary shed (e.g., p5 = 56, p6 = 77, p7 = 98, p8 = 119) from 135 (Leopold and McCabe 1957), adding the resulting number of days to the date of harvest. No corresponding estimates for prebasic molt duration or primary replacement time were found. To calculate the number of days required to complete the prebasic molt, we added 21 days each for replacement time of p9 and p10, based on preformative primary molt shedding times reported by Leopold and McCabe (1957), resulting in an estimated prebasic primary feather molt cycle of 177 days. We estimated prebasic molt onset by subtracting the assumed primary replacement time (days) of the preformative molt cycle from the date of harvest.

RESULTS

We examined Montezuma quail wings harvested over a 12-week period beginning 23 November 2008. We assigned

age and sex to 1,864 of 1,899 wings with 52.9% aged as AHY and the remaining 47.1% aged as HY. Males were more prevalent than females in our sample and represented 59.4% of all wings. We found a significant effect of sex on mean (\pm standard error [SE]) wing-chord length with male wing-chord length (113.8 ± 0.15 mm) greater than female wing-chord length (111.1 ± 0.13 mm, $F_{(3, 1626)} = 62.04$, $P < 0.001$). We did not find a significant difference in wing-chord length across age classes ($F_{(1, 1647)} = 0.83$, $P = 0.48$).

We detected completed preformative (HY) and prebasic (AHY) molts in all study weeks, with weekly percentages generally increasing for both. We additionally identified shed primary feathers in all weeks for preformative and prebasic molts. Shedding of p5 was restricted to the preformative molt with 17 December 2008 the last harvest date recorded for this primary. We recorded shedding of p6, p7, and p8 in both preformative and prebasic molts. Shedding of p9 and p10 is indicative of AHY individuals and restricted to the prebasic molt; the latest date we recorded for each was 3 February 2009 and 28 January 2009, respectively.

We estimated that the onset of the prebasic molt cycle for our study population ranged from 16 June to 23 October 2008. Our mean prebasic molt onset date was 13 August with no difference in mean prebasic molt onset based on sex (Figure 1).

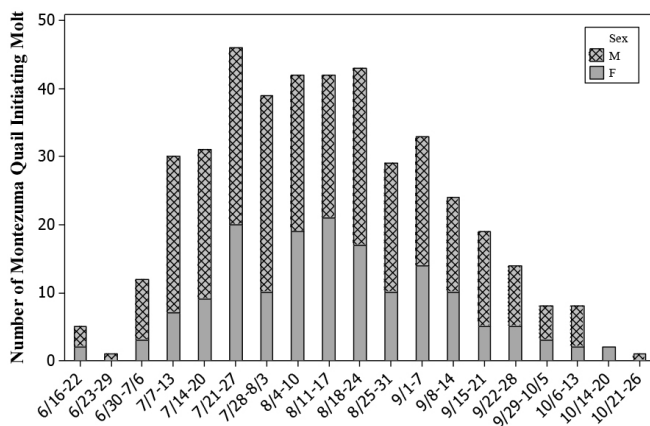


Fig. 1. Estimated onset of prebasic molt of male (cross-hatched) and female Montezuma quail based on hunter-harvested wings from the 2008–2009 Arizona, USA hunting season.

DISCUSSION

Our mean male wing-chord length (113.8 ± 4.0 mm) was 5.2% and 7.7% shorter than previously reported by Johnsgard (1973) and Stromberg et al. (2020), respectively. Our mean female wing-chord length (111.1 ± 3.5 mm) was 7.4% and 6.8% shorter than previously reported by Johnsgard (1973) and Stromberg et al. (2020), respectively. Eitnjar and Becherer (2016) reported a mean wing-chord length of 129 mm, 12.7% larger than our pooled mean wing-chord length of 112.6 ± 0.1 mm. Our smaller mean wing-chord length for both male and female Montezuma quail is likely attributable to the

larger sample size in our study than those previously reporting Montezuma quail wing-chord lengths. An alternate possible explanation for the decreased wing-chord length of our samples is climate-driven changes in morphology; investigating this explanation is beyond the scope of our single-season study. Decreases in fat-free mass and wing-chord length have been correlated to migratory species in western Pennsylvania, USA (Van Burskirk et al. 2010), common nightingale (*Luscinia megarhynchos*) in Europe (Remacha et al. 2020), and tree swallow (*Tachycineta bicolor*; Paquette et al. 2014). Further research of long-term wing datasets would be required to determine whether such a pattern is present in Montezuma quail and whether alternate hypotheses could be developed to explain the potential decrease in wing-chord length.

In our study of hunter-harvested Montezuma quail wings, we found evidence of primary feather molt (p5–p10) from November 2008 to February 2009. Molt phenology of Montezuma quail is currently assumed complete by November annually (Pyle 2008, Stromberg et al. 2020). Our findings are inconsistent with Stromberg et al. (2000) and Pyle (2008) but do coincide with the findings of Swarth (1909), who estimated prebasic molt initiation to be October or November. By using the harvest date, primary feather shed, and assumed replacement time, we suggest both preformative and prebasic molt may not be completed until late April of the subsequent year.

The preformative molt cycle for North American quail species has been extensively studied, specifically as a method for aging HY individuals (Stoddard 1931, Leopold 1939, Wallmo 1954, Johnsgard 1973, Calkins et al. 2020). By comparison the prebasic molt cycle of North American quail has lacked as intensive study, and as such molt and replacement timing of p9 and p10 is understudied or underreported for most North American quail species. We estimated that the complete prebasic molt timing for Montezuma quail was 177 days, with the onset of molt occurring as early as mid-June and as late as the third week in October. Our estimate of 177 days should be used as an approximation, and future research related to replacement and regeneration times of p9 and p10 in Montezuma quail should be conducted under control conditions to refine prebasic molt phenology for this species. Our use of 1,864 Montezuma quail wings to evaluate the effect of age and sex on wing morphometrics and molt phenology is, to our knowledge, the largest sample size obtained for this species.

Montezuma quail are 1 of 4 sexually dimorphic North American quail species; the others are northern bobwhite, California quail, and Gambel's quail. While these 4 quail species can readily be sexed when a live or whole specimen is present, Montezuma quail are the only species where sex can be assigned based on wing plumage characteristics alone. The ability to identify sex based on wing plumage alone presents unique research opportunities for Montezuma quail. In addition to assessment of the effect of age and sex on molt phenology, hunter-harvested wings can be used to derive more meaningful population demographic and reproduction estimates based on environmental variables such as timing and intensity of monsoon.

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