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TECHNICAL NOTES

Effects of experience and a visual aid on ptilochronology

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Abstract Ptilochronology, the study of feather growth bars, has been used to assess nutritional condition, yet the implementation of this technique can be challenging. This study investigated how a magnification aid and level of experience with the technique affected the variability and accuracy of ptilochronology measurements. The average width of growth bars was significantly narrower when made with a magnifying visor as opposed to the unaided eye, suggesting that future ptilochronology studies should incorporate magnification. Measurements were also influenced by the measurer's level of experience, suggesting that a learning curve must be taken into account when analyzing ptilochronology results.

Keywords Ptilochronology · House Sparrow · Magnification · Experience level

Zusammenfassung

Die Auswirkungen von Erfahrung und optischen Hilfsmitteln auf Ptilochronologie

Ptilochronologie, die Studie von Federwachstumsstreifen, wird genutzt, um den Ernährungszustand von Vögeln einzustufen Dennoch ist die Anwendung dieser Methode anspruchsvoll. In dieser Studie untersuchten wir wie die Benutzung eines Vergrößerungsglases und das Ausmaß der Erfahrung mit der Methode die Genauigkeit der ptilochonologischen Messungen beeinflussten. Die mittlere Breite der Wachstumsstreifen war signifikant schmaler, wenn mit Hilfe eines Vergrößerungsglases gemessen wurde, als mit dem bloßen Auge. Dies legt nahe, dass in Zukunft in ptilochonologischen Untersuchungen ein Vergrößerungsgerät eingesetzt werden sollte. Messungen wurden auch beeinflusst von der Menge an Erfahrung der Untersucher, was bedeutet, dass bei der Analyse ptilochonologischer Ergebnisse ein gewisser Lernprozess berücksichtigt werden muss.

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Introduction

Ptilochronology uses the width of feather growth bars to assess the nutritional condition of birds (Grubb 2006). A pair of light and dark bands, known as a growth bar, is formed every 24 h as a feather grows. The width of a bar reflects the growth rate of the feather, which is limited by the availability of nutrients. Ptilochronology has contributed to our understanding of many aspects of ornithology, including territory size, energetic tradeoffs between breeding and molting, and social behavior (Yosef and Grubb 1992; Ogden and Stutchbury 1996; Hogstad 2003).

Although this method has been used frequently, it can be a challenge to implement (e.g., Murphy and King 1991). The visibility of growth bars is not consistent across species or within feathers of the same species (Grubb 2006). This represents an impediment to the widespread application of ptilochronology, particularly for researchers who have not previously used the technique.

We conducted a study with a researcher who had not previously measured growth bars to test whether a magnification aid and level of experience with ptilochronology (i.e., before and after completing a ptilochronology project) could affect measurements of growth bars. We also assessed the effect of increasing experience by examining how the variability of measurements changed as more feathers were examined. Because visual aids and level of experience have not been incorporated in previous ptilochronology projects, our study has the potential to identify factors that could improve future efforts.

Methods

Feathers were collected from House Sparrows (*Passer domesticus*) in Champaign County, Illinois, USA, from September to November of 2011 as part of an ongoing study assessing the effects of urbanization on avian populations. Study sites included two rural farmhouses surrounded by soybean/corn agriculture, two private residences on the periphery of the cities of Champaign and Urbana, and two homes and one nature center within the cities. Sites were visited once monthly on mornings free of precipitation, and mist nets were used to capture birds at feeding stations. Each captured bird was aged and sexed (Pyle 1997), and the outermost right and left tail feathers were pulled (Grubb 2006). We used outer feathers because the majority of ptilochronology studies have done so (Grubb 2006), and following suit would enhance the relevance of our work to the way this technique is typically carried out. House Sparrow feathers were used because the visibility of their growth bars is intermediate among songbirds in our study area (J.D.F., personal observation).

Grubb (2006) advocated recapturing birds and collecting regrown tail feathers for use in ptilochronology studies. However, many studies have used original feathers (e.g., Carlson 1998; Grubb et al. 1998), and growth bars can be more challenging to observe on these than on regrown ones (Grubb 2006). Thus, our use of original feathers reflected conditions present in many ptilochronology studies.

Removal of tail feathers can incur physiological costs as feathers regenerate and flight performance is temporarily reduced; however, negative survival and reproductive consequences of feather sampling have yet to be documented (McDonald and Griffith 2011). In addition, ptilochronology is a more rigorous measure of nutritional condition than other techniques that do not require feather samples (e.g., body mass indices and blood chemistry; Grubb 2006).

Feathers were mounted on black paper to improve the visibility of the growth bars (Hill and Montgomerie 1994). Bar locations were marked on the paper by making holes with size 1 insect mounting pins (0.37 mm diameter) at the top of the dark band in each bar. The paper was attached to a Styrofoam™ block to make pinning the holes easier (G. Hill, personal communication), and a piece of clear tape was placed between the paper and feather to minimize the size of holes, which improved the precision of measurements. When growth bars were difficult to distinguish, holes were made with the aid of a dimmable lamp on a low light setting. By adjusting the angle of light to feather, bars could be seen more easily.

Digital calipers (Marathon Watch, Richmond Hill, ON, Canada) were used to measure the growth bars to the nearest 0.01 mm. First, the total length of a feather was measured and a point two-thirds from the tip of the calamus was marked (Grubb 2006). Pins were used to mark the growth bar nearest to this point, as well as the next five consecutive bars below and four bars above. The distance between each pair of adjacent holes was measured.

Growth bars of tail feathers from 53 birds were measured with the use of an OptiVisor DA-5 Headband Magnifier with $\times 2.5$ magnification (Donegan Optical, Lenexa, KS, USA). The two tail feathers from the first ten birds were also measured with the unaided eye at the beginning of the study and remeasured with and without the magnifying visor at the end of the study without reference to measurements that had bben previously taken. Measurements were made by one person in her early twenties (L.M.F.) who had good eyesight and no prior experience with ptilochronology.

We tested the effects of the magnifying visor and experience on measurements of growth bar width (two tail feathers from each of ten birds) by comparing measurements made with and without the visor at the beginning and end of the study using PROC Mixed in SAS Enterprise Guide 4.3 (SAS Institute, Cary, NC, USA; Ott and Longnecker 2001). To determine whether the magnifying visor altered the effect of additional experience, we included the interaction between visor use and experience as a term in the model. Left and right feathers from each bird were modeled using a split-plot analytical framework in which individuals were treated as randomized plots and feathers as subplots. The ten growth bars from each feather were modeled as sub-samples. In split-plot analyses, the interaction between plot and subplot (individual by feather) was included as a random term that was used to test whether subplot has an effect on the dependent variable (growth bar width). Interactions among feather, visor, and experience were initially included in the analysis, but were uninformative and consequently removed from the final model.

In an additional analysis, PROC Mixed was used to examine the effect of experience modeled as a discrete variable (i.e., the order in which 98 feathers from 53 birds were measured) on variability of growth bar measurements (i.e., the standard deviation of measurements per feather). The two feathers taken from each bird were treated as

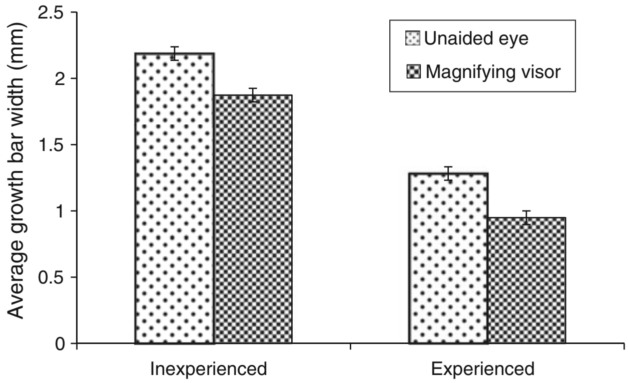

Fig. 1 Mean growth bar width (±SE) of House Sparrow *Passer domesticus* feathers ($n = 20$; two from each of ten individuals) measured with and without a magnifying visor with no prior experience with ptilochronology (*Inexperienced*) and remeasured after examining growth bars from feathers of 53 birds (*Experienced*)

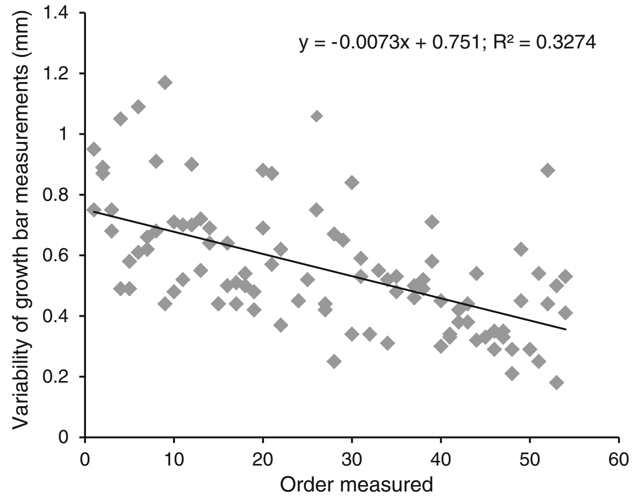

Fig. 2 Standard deviation of growth bar measurements per tail feather of House Sparrows ($n = 98$ feathers from 53 individuals) relative to the order in which the feathers were measured. An ordinary least-squares regression line is shown with the line equation and R^2

subsamples. A second-order polynomial term was included in the model to test whether variability stabilized during the study.

Results

Average growth bar widths were significantly narrower when measured with the magnifying visor compared to the unaided eye ($F = 48.11$, $df = 1$ and 777, $P < 0.001$; Fig. 1). Bar widths were also narrower when measurements were taken at the end of the study as opposed to the beginning ($F = 385.07$, $df = 1$ and 777, $P < 0.001$; Fig. 1). The interaction between use of the visor and the timing of measurements was not significant ($F = 0.05$, $df = 1$ and 777, $P = 0.8303$; Fig. 1), suggesting that use of the visor consistently changed results over the course of the study. There was no significant difference between measurements taken from right and left feathers ($F = 0.22$, $df = 1$ and 9, $P = 0.6500$). Variability in growth bar measurements declined linearly over time from the beginning to the end of the study ($F = 47.33$, $df = 1$, $P < 0.0001$) and had not stabilized after feathers from 53 birds were measured, as indicated by the nonsignificant second-order polynomial (Fig. 2; $F = 2.22$, $df = 1$, $P = 0.1393$).

Discussion

Growth bar measurements were influenced by the magnifying visor and experience with ptilochronology. The average width of measurements made with the visor was shorter than those taken with the unaided eye, irrespective of experience level. We suggest that the magnification aid enhanced the ability to measure difficult-to-see growth bars that were otherwise overlooked, which improved the accuracy of the measurements taken. Some instances of missed bars were obvious, as one bar measurement was substantially longer than the others on a feather, but the variability in bar lengths meant that many initially unseen bars were only identified by remeasuring feathers with the magnification aid or after gaining additional experience. However, one person with no prior experience with ptilochronology took measurements in this study, and it is possible that other researchers, particularly those with extensive experience, may not benefit from the use of a magnification aid.

Level of experience also affected growth bar measurements. Average growth bar width was narrower when measured after gaining more experience with the technique, regardless of whether or not the magnifying visor was used. This suggests that a magnification aid cannot compensate for improvements in accuracy gained with experience. Variability of measurements taken per feather also decreased as more feathers were examined, and had not stabilized even after over 2,000 growth bars were measured, which implies that the precision of measurements steadily improved with more experience.

We propose that because growth bars are challenging to locate on the feathers of some species (Grubb 2006), it will take a great deal of practice to become proficient at ptilochronology, even with a magnification aid. This learning curve, which has not been addressed in previous studies, should be factored into future ptilochronology projects by regressing the average width and variability of growth bars per feather against the order in which feathers are measured. When values have stabilized, future measurements are likely to be more accurate and precise. Feathers measured prior to the stabilization of average width and variability should be re-examined.

Ptilochronology is a widely applied and useful technique for assessing avian condition (Grubb 2006), but to maximize the utility of this tool, factors that could influence growth bar measurements should be taken into account in future studies. Incorporating a visual aid and modeling the effect of increasing experience on measurements are two methods that could improve the reliability of ptilochronology research by reducing the number of growth bars that are overlooked and improving the precision of measurements taken.

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