

WHAT DO DIFFERENT BILL MEASURES MEASURE AND WHAT IS THE BEST METHOD TO USE IN GRANIVOROUS BIRDS?

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Abstract.-Bill measurement is important in many feeding studies. Traditionally, two alternative bill measures have been proposed: bill length measured from the tip to skull (i.e., total culmen), mainly used in Europe, and bill length measured from the tip to the anterior edge of nostrils, used both in Europe and America. However, the correlation between both measures as well as the analysis of what they are in fact measuring have not been explored yet. The aim of this paper is to test in the Citril Finch (*Serinus citrinella*) whether measurement of bill length from the tip to the anterior edge of nostrils and total culmen are measuring different components of bill length (e.g., ramphotheca vs. premaxilla), and to assess which is the best measure in relation to their measurement error. This is specially relevant in granivorous birds for which total culmen length differs from ramphotheca length. The correlation between bill length to nostrils and total culmen was moderate ($r = 0.75$). Multiple regression of total culmen (dependent variable) on the bill componente included ramphotheca length ($R^2 = 52\%$) and marginally premaxilla length to nostrils (R^2 change = 6%, $P = 0.06$). When using bill length to nostrils as dependent variable it also included ramphotheca length ($R^2 = 60\%$) and premaxilla length to nostrils (R^2 change = 16%, $P < 0.001$). Measurement error was low for bill length to nostrils (ME = 1.6%) but high for total culmen (ME = 26.3%), making the latter measure not reliable. The replicability of total culmen is probably decreased in granivorous birds, compared to other passerines, by the fact that in these species the abrupt edge of the ramphotheca differs from the point at which the culmen meets the skull, which hinders the location of the end of culmen. All of this highly recommends that, specially in granivorous birds, the length of bill should be measured from nostril. Our results also show that both bill length measures are mainly measuring ramphotheca.

¿QUÉ MIDEN LAS DIFERENTES MEDIDAS DEL PICO, Y CUÁL ES EL MÉTODO MÁS ADECUADO PARA GRANÍVORAS?

Sinopsis.-La medida del pico es importante en muchos estudios de alimentación. Tradicionalmente, dos medidas alternativas del pico han sido propuestas: la longitud del pico, medida desde la punta hasta la base del cráneo (i.e., culmen total), principalmente utilizada en Europa, y la longitud del pico, medida desde la punta hasta el margen anterior de la narina, utilizada tanto en Europa como en América. No obstante, la correlación entre ambas medidas así como el análisis de qué están de hecho midiendo éstas aún no han sido explorados. El objetivo de este artículo es poner a prueba, en el verderón serrano (*Serinus citrinella*), si la medida del pico desde la punta hasta el margen anterior de la narina y el culmen total están midiendo diferentes componentes de longitud del pico (e.g., ramfoteca vs. premaxila), y evaluar cuál es la mejor medida en relación con su respectivo error de medida. Esto puede ser especialmente relevante en aves granívoras, ya que el culmen total y la ramfoteca no coinciden. La correlación entre la longitud del pico hasta la narina y el culmen total, fue moderada ($r = 0.75$). La regresión múltiple del culmen total (variable dependiente) con los componentes del pico incluyó la longitud de la ramfoteca ($R^2 = 52\%$) y, marginalmente, la longitud de la premaxila hasta la narina (R^2 cambio = 6%, $P = 0.06$). Cuando se utilizó la longitud del pico hasta la narina como variable dependiente, también incluyó la longitud de la ramfoteca ($R^2 = 60\%$) y la longitud del pico hasta la narina (R^2 change = 16%, $P < 0.001$). El error de medida fu bajo para la longitud del pico hasta la narina (ME = 1.6%) pero alto para el culmen total (ME = 26.3%), haciendo la última medida poco fiable. La repetibilidad de la longitud del pico hasta el cráneo se ve probablemente reducida en aves granívoras, comparado con otros Passeriformes, por el hecho de que en estas especies el margen abrupto de la ramfoteca difiere del punto dónde el pico se une al cráneo, lo cual dificulta la localización del final del culmen. Todo ello hace recomendable que, especial-

mente en aves granívoras, la longitud del pico sea medida desde la narina. Nuestros resultados también muestran que ambas medidas de longitud del pico están midiendo principalmente la ramfoteca.

Bill length is an important measure in many feeding studies (Davis 1954, Packard 1967, Gosler 1987, Matthysen 1989). Three main alternative field bill measures have been proposed: (1) length of bill from nostril (Baldwin et al. 1931: 16); (2) Total culmen, measured from the bill tip to the skull (Sagarra 1917: 7, Baldwin et al. 1931: 13); and (3) Exposed culmen, measured from the bill tip to the forehead feathers (Baldwin et al. 1931: 1,1). Worn-off or damaged forehead feathers make measurement of exposed culmen not easily defined and not replicable (Baldwin et al. 1931, Winker 1998); this measure is excluded from any further discussion. The two remaining measures are widely used, but curiously, while in America the traditional bill length measurement has been length of bill from nostril (Baldwin et al. 1931, Pyle et al. 1987 [note that this author names this measure "culmen"], Winker 1998), in Europe it has been total culmen (Sagarra 1917, Svensson 1975, Spencer 1984, Ceballos et al. 1984). Earlier European handbooks only described total culmen, even advising against the measurement from nostrils because it could be "highly dangerous" (Spencer 1984). Nowadays, the use of the length of bill from nostril has increased in Europe, and now both measurements are commonly taken by European ornithologists (Svensson 1992) and both appear in European reference books (Cramp and Perrins 1994).

Both bill measures, either from nostril or total culmen, have been assumed to measure the ramphotheca since they vary seasonally and are subjected to wear and tear (Gosler 1987, Matthysen 1989). However, the relationship between them, and the extent to which they reflect horny or skeletal measures, has not yet been tested. In granivorous birds (e.g., Fringillidae, Emberizidae, Ploceidae) the pattern is additionally complicated by the presence of an integument between the horny covering of the bill (ramphotheca) and the forehead of the bird (E. Moreno, pers.comm.) (Fig. 1), so that the abrupt edge of the ramphotheca differs from the point at which the culmen meets the skull. This makes the measurement of total culmen in these species probably less accurate, but also allows to differentiate between culmen and ramphotheca. The aim of this paper is to test in a granivorous bird, the Citril Finch (*Serinus citrinella*), whether measurement of bill length from the tip to either the anterior edge of nostrils or to skull (i.e., total culmen) are measuring different components of bill length (e.g., ramphotheca vs. premaxilla), and to assess which is the best measure in relation to their measurement error.

MATERIAL AND METHODS

We obtained external ramphothecal and skeletal measurements of the bill of 36 Citril Finches from the Barcelona Zoology Museum. For five of the birds some measurements could not be obtained; this is the reason

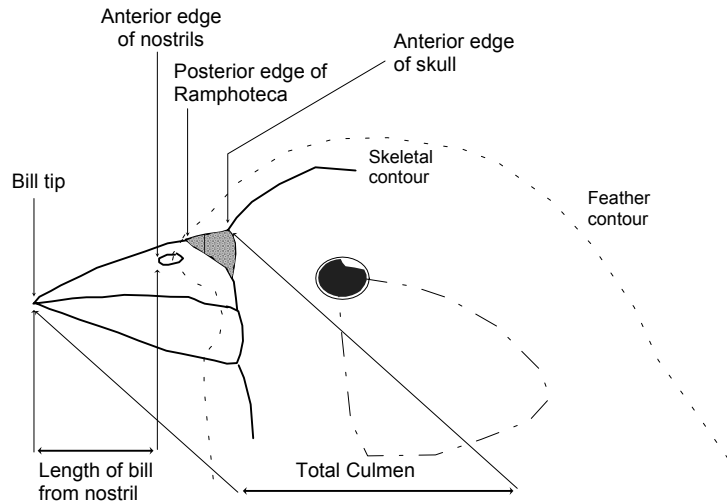


FIGURE 1. Lateral view of the head of the Citril Finch illustrating the field bill measurement landmarks. Both the feather and the skeletal contours are shown.

for sample size differences among analyses. The birds had been collected in Catalonia from 1992 to 1998. External ramphothecal bill measures were taken with a digital caliper to an accuracy of 0.1 mm by a single observer (JP) from fresh specimens as soon as they arrived at the Museum. They included (1) length of bill from nostril, measured from the anterior end of the maxilla (hereafter bill tip) in a straight line to the anterior edge of the nostril (Baldwin et al. 1931: 16); (2) Total culmen, measured from the bill tip in a straight line to the notch on the forehead where the base of the culmen meets the skull; and (3) Ramphotheca length, measured from the bill tip to the abrupt edge where the horny covering of the bill meets the integument (Fig. 1).

The sex of about half of the birds ($n = 15$) could not be identified, either because birds were still showing a high proportion of juvenal plumage or they were in bad plumage condition. The remaining sexed birds were mainly males (70%). All of this precluded any analysis by sex. Nevertheless, since we are investigating for a relationship between different measurements taken from each bird, any sex difference in bill proportions only makes our analyses more conservative.

Skeletal mensures were also taken by a single observer (JP) with a digital caliper to an accuracy of 0.1 mm. They included (1) total premaxilla length, measured from the tip of the premaxilla to skull and (2) premaxilla length to nostrils, measured from the tip of the premaxilla to the anterior edge of the nostrils (Fig. 2). The skeletons were prepared by maceration.

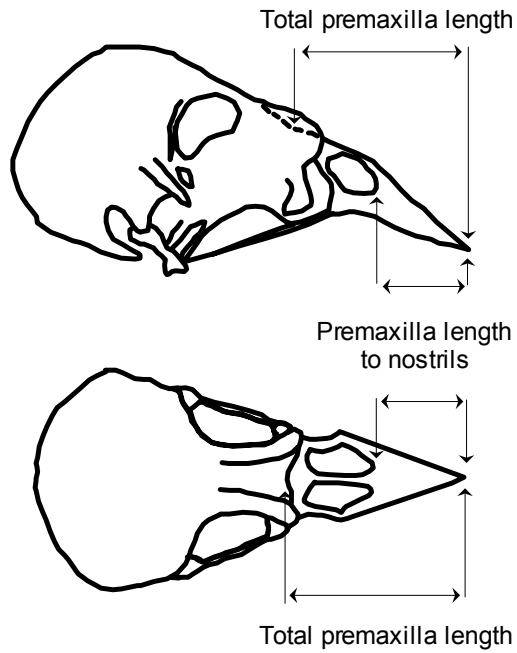


FIGURE 2. Lateral (a) and dorsal (b) view of the Citril Finch skull illustrating the premaxilla measurement landmarks.

Percent measurement error (% ME) was calculated for each character (skeletal and external) from the mean squares of single classification ANOVA on two repeated measures per individual (Bailey and Byrnes 1990).

Stepwise multiple regression analysis were performed between each one of the two traditional field bill measures and the measures of the bony and horny components of the bill (total premaxilla length, premaxilla length to nostrils and ramphotheca length).

RESULTS

Measurement error accounted for less than 6% of total variance for all the measures except for total culmen and total premaxilla length, which had a low replicability (Table 1).

Correlations between internal and external bill measures are shown in Table 2. Stepwise multiple regression of the length of total culmen (as dependent variable) on ramphotheca, total premaxilla and premaxilla to nostrils lengths (as independent variables) included ramphotheca length ($R^2 = 52\%$, $P < 0.001$, $n = 31$) and premaxilla length to nostrils (R^2 change = 6% , $P = 0.06$).

TABLE 1. Percent Measurement Error (following (Bailey and Byrnes 1990)), mean measurement error \pm SE (mm) and sample size (n) of external ramphothecal and skeletal measurements of the bill.

Measurement length	% ME	Mean error \pm SE	n
Total culmen	26.3	0.21 \pm 0.050	36
Bill length from nostril	1.6	0.05 \pm 0.008	35
Ramphotheca	5.9	0.14 \pm 0.023	34
Total premaxilla	9.1	0.09 \pm 0.017	35
Premaxilla to nostril	5.1	0.06 \pm 0.009	35

Stepwise multiple regression of the length of bill from nostril (as dependent variable) on ramphotheca, total premaxilla and premaxilla to nostrils lengths (as independent variables) included ramphotheca length ($R^2 = 60\%$, $P < 0.001$, $n = 31$) and premaxilla length to nostrils (R^2 change = 16%, $P < 0.001$).

DISCUSSION

Our results show that, at least in the Citril Finch, the traditional European bill measurement to skull (total culmen) has a high measurement error (26%), while the traditional American bill measurement to nostril has a low measurement error (2%). The replicability of total culmen is probably decreased in granivorous birds, compared to other passerines, by the fact that in these species the abrupt edge of the ramphotheca differs from the point at which the culmen meets the skull, which hinders the location of the end of culmen (E. Moreno, pers. comm.). All of this highly recommends that, specially in granivorous birds, the length of bill should be measured from nostril.

Multiple regression analysis of length of bill from nostril in relation to the different bone and horny components shows that this measurement is mainly related to ramphotheca length (60%), and to a lesser extent, to premaxilla length to nostrils (16%). A similar trend is found when using total culmen (to skull). This confirms our earlier suggestion (Pascual and Senar 1996) that bill length was probably a measurement of ramphotheca, since although we did not measure this component, we found in the Serin (*Serinus serinus*) a moderate correlation between length of bill from nostril and length of premaxilla from nostrils ($R^2 = 25\%$).

TABLE 2. Correlations (r), in the Citril Finch, between external ramphothecal and skeletal measurements of the bill ($n = 31$). * = $P < 0.01$; ** = $P < 0.001$.

	Total Premaxilla	Ramphotheca	Bill length from nostril	Total culmen
Premaxilla to nostrils	0.77**	0.48*	0.72**	0.56*
Total premaxilla		0.35	0.53*	0.45*
Ramphotheca			0.77**	0.72**
Bill length from nostril				0.75**

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