

The size of melanin-based beard ornaments is not related to body condition in the Bearded Reedling *Panurus biarmicus*

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Avian melanin-based plumage ornaments are often considered to be condition-dependent signals exploited in a context of sexual selection. In a highly dimorphic species, the Bearded Reedling *Panurus biarmicus*, the black beard ornaments under the male's eyes play a dual role in both male-male competition and female choice, and also as a sign of dominance status. However, the inter- and intra- consistency of these traits has never been examined in this species. Here I empirically show that different measurements of the same beard trait (beard length, beard width and beard surface area) were highly consistent within the individual given that they were positively correlated in the same individuals in 13 males ringed in the reedbeds of El Hondo Natural Park (SE Iberia). However, the measures of the different beard traits varied greatly between males and there was a broad range of variation between birds. These measurements were not significantly correlated with two measures of body condition (body size index and body weight). This preliminary study does not support the hypothesis that beard ornaments are reliable indicators of individual body condition reflecting phenotypic quality.

Key words: Bearded Reedling, *Panurus biarmicus*, body condition, body size, double measurements, melanin traits.

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Many melanin-based ornaments are considered to act as sexual signals in animals (Andersson 1994) and have been well studied in birds (McGraw 2008). They are thought to signal individual phenotypic quality that can be exploited in male-male competition or in female choice (Jawor & Breitwisch 2003, Guindre-Parker & Love 2014).

For instance, melanin-based plumage ornaments and their association with sexual selection processes have been investigated in the reed-dwelling Bearded Reedling *Panurus biarmicus*. This passerine species has pronounced sexual dimorphism (Robson 2007): adult male plumage characteristics consist of a rufous brown body and a grey head, with two black beards; their under-tail coverts are black and their long tail is brown with white external rectrices

(Cramp & Perrins 1993). Juveniles undergo a complete moult in late May–July (Ginn & Melville 1983), so the secondary sexual characters are only expressed in the adults. Furthermore, no evidence of prenuptial moult is present in this species (Svensson 1992) and the abrasion of plumage traits does not confer on this species any sign of beard formation in adult nuptial plumage, as occurs in other species (Tökölyi *et al.* 2008). Hoi & Griggio (2008) have shown that beard lengths show great individual variation between males and play a dual function in male-male competition and female choice (Hoi & Griggio 2008), as well as a role in dominance status (Hoi & Hoi 2001).

Proxies of body condition can be obtained from estimates of morphology and body mass

(Piersma & Davidson 1991), although these measures are often confused (Green 2001). Although body size is often taken as a reliable measure of body condition, the use of this measure has been criticized (Møller *et al.* 1998, Green 2001, Peig & Green 2010). It may be based on different relationships between body weight and birds' skeletal components (e.g. tarsus or keel length; Senar & Pascual 1997) or as a surrogate of body size in the form of a number of different indices (Schamber *et al.* 2009, Labocha & Hayes 2012). Body weight is taken as an estimator of body mass and a proxy of body condition in multiple field studies because it is strongly associated with the fat reserves that play an important role in key life-history strategies in passerines (Lindström *et al.* 1994, Neto & Gosler 2010, Neto *et al.* 2010, Arizaga & Alonso 2011).

Previous studies of the Bearded Reedling have found no clear relationship between different measures of melanin-based beard traits and estimators of body condition. For example, the black lore area in the beard in juvenile males is not associated with any index of body condition (body mass/tail-length; Surmacki *et al.* 2015), and beard length has been found not to be associated with body mass in studies that examine

the role of the insulin growth factor (IGF-1) with structural pigments (head, flank, back and chin; Mahr *et al.* 2019). In addition, Hoi & Griggio (2008) found no differences in body mass in birds with short or long beards. No other melanin trait has been found to be significantly related to body condition or size in the Bearded Reedling (Hoi & Hoi 2001, Hoi & Griggio 2008, Mahr *et al.* 2020) or in other species (see references in Jawor & Breitwisch 2003).

In this preliminary study from a small sample of Bearded Reedling males ringed in a south-western Mediterranean wetland in 2007 and 2009–2010, I examine the following hypothesis: 1) whether or not duplicated field measurements of three beard traits (length, width and surface area) are significantly related, and whether or not intra-male individual variation exists between them; 2) whether or not within-individual variation is relatively small compared to the variation of measurements observed in between-male average measurements; and 3) whether or not between-individual variation in these traits is significantly associated with two measures of body condition (body size, BSI, and body weight, BC), which would suggest that they could act as an indicator of phenotypic quality (Senar *et al.* 2008, Parejo *et al.* 2011).



Figure 1. Beard measures (L = beard length; W = beard width) from Bearded Reedling males. Photo: I. García Peiró. *Mesures del bigoti (L = longitud del bigoti; W = amplada del bigoti) preses en els mascles de mallerenga de bigotis.*

Material and methods

The field study was conducted in El Hondo Natural Park, a reedy reservoir (2,400) situated in the fragmented lowlands of southern Alicante province (SE Spain) (38°16'N 00°41'W). The study site is the most southerly point in the European range of the Bearded Reedling (Gosler & Mogyorósi 1997). This study area had a population of about 40 pairs in the earlier 2000s (López *et al.* 2007) but is currently threatened by extinction (Belenguer *et al.* 2016). Thirteen males were ringed with aluminium rings (Spanish Ministry of Environment-Madrid), measured and released by the author at the same ringing site in February–June 2007 (N = 3), 2009 (N = 7), and 2010 (N = 3). Because beard size in Bearded Reedlings is a static trait, that is, it does not change in size in the same moult period, I assumed that the capture month did not influence beard size. Ringing and recapture took place during the breeding season (Cramp & Perrins 1993). The age of the birds was assessed and the lengths of both the left and right tarsi (accuracy 0.1 mm) were measured following Svensson (1992). In addition, two non-blinded measures of each right- and left-hand beard were taken using Camlab® with-dial callipers (accuracy 0.1 mm): (1) beard-length (L) was measured from the base of the eye to the tip of the beard (accuracy 0.1 mm), (2) beard-width (W) was measured as the lateral stripe from the base of the eye up to the beak touching the skull (accuracy of 0.1 mm), representing the widest part of the beard (Fig. 1). To examine intra-males consistency, for each male the left- and right-hand beards were measured twice in the field to obtain four measurements per beard trait per male.

Since beards have a right-angled triangle form, the two measures were then transformed into a measurement of the beard surface area (mm²) by multiplying their length (L) by their width (W) divided by two (Fig. 1). Body weight was measured with a 50 g Pesola® spring balance (accuracy 0.1 g). Inter-male consistency was expressed as the standard error (SE) of the average values of each beard trait.

I estimated the BSI through residuals of a linear regression of body weight against the averaged left-right tarsus length (Weight = 0.79*Tarsus-length - 3.11; F_{1,13} = 7.02; P = 0.02; r² = 0.39). I considered body weight as a

measure of body mass and hence of condition (Piersma & Davidson 1991, Schamber *et al.* 2009, Labocha & Hayes 2012).

Pearson's correlations (SPSS 2005) were used to examine the associations between (1) different field measurements of the same beard trait and (2) between average beard size characteristics (e.g. beard length, width and surface area) and two measures of body condition (body size index, BSI, and body mass, BC). Bonferroni's corrections for Pearson's correlations were not applied because of the low number of correlations (N < 20) (Armstrong 2014). Statistical analyses were performed using SPSS v.23 software (SPSS 2015). The normality of all variables used in this study were tested using the Kolmogorov-Smirnov Tests (P ≈ 0.2) (SPSS 2015).

Results

Inter and intra-annual variations

The original sample was homogeneous given that I found no differences between BSI and BC between months and years (Two-way ANOVA, BSI: F_{6,13} = 2.03, P = 0.21; BC: F_{6,13} = 0.61; P = 0.72) and so it was unnecessary to correct the indices for time periods.

Table 1. Pearson's correlations between first and second measurements per beard trait (left and right) and per average beard trait in Bearded Reedling males. *Correlacions de Pearson entre la primera i la segona mesura per tret de barba (esquerra i dreta) i per característica mitjana de barba entre els mascles de la mallerenga de bigotis.*

Trait	First vs Second measure	
	r	p
Length		
Left beard	0.83	0.000
Right beard	0.87	0.000
Average beard	0.93	0.000
Width		
Left beard	0.65	0.017
Right beard	0.54	0.056
Average beard	0.58	0.036
Surface		
Left beard	0.64	0.018
Right beard	0.90	0.000
Average beard	0.81	0.001

Table 2. Summary of field measurements of beard traits in Bearded Reedlings (N = 13). Values are the means of the double measure of both left-hand and right-hand sides.
Resum de les mesures de camp dels trets dels bigotis de la mallerenga de bigotis (N = 13). Els valors són mitjanes de dobles mesures per a cada costat esquerra i dreta.

Variable	Left side		Right side		Both	
	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range
Beard-length (mm)	15.44 ± 0.58	12.50 – 18.55	15.74 ± 0.63	11.70 – 19.40	15.59 ± 0.59	12.10 – 18.83
Beard-width (mm)	6.04 ± 0.15	5.15 – 6.95	6.28 ± 0.15	5.00 – 7.15	6.16 ± 0.13	5.08 – 7.05
Beard-surface (mm)	92.96 ± 3.43	76.18 – 113.16	99.07 ± 5.17	73.13 – 134.83	96.01 ± 4.10	75.71 – 120.09

Intra- and inter-male variation in beard measurements

For each beard (left and right) and each beard trait (length, width and surface area) there was a high positive correlation between the first and second measurement (Table 1); the only exception was the duplicated measurements of non-significant values of the right-hand beard width, so this measure should be taken with caution (Table 1). This implies that the measurement errors of a given beard trait within individual males is relatively small compared to the great variation in measurements observed between males given the mean standard errors and broad range of measures obtained (Table 2).

Beard traits and measures of condition and size.

In terms of individual variation in average beard length, width and surface area, and in body condition, the results show that no significant correlation exists between average beard traits and either BSI or BC (Table 3).

Discussion

When measuring a trait, several sources of error

may affect the feasibility of a trait measurement. These sources of error can be due to the observer who conducts the field study. I observed significant positive associations within individual males, which indicates that measurements were consistent in individual birds. However, I was unable to find any relationship between average beard measurements and BSI and BC. Given the broad range of variation in the average measures (Table 2), it is clear that individual variability between males was higher than within males.

One possible explanation for the lack of any relationship between beard traits and condition-related traits is that the morphological measurements were not measured accurately. The observer who took the measurements is left-handed and so during the beard measurement birds were always held in the left hand such that the two measurements of the right-hand beard were followed by two measurements of the left-hand beard. Because the head of the captured bird did not remain still, it is to be expected that two consecutive measurements of the same beard trait (length, width or surface area) of the same beard (left-hand or right-hand) could differ due to differences in handling (Busse & Cofta 2000).

Despite the methodological constraints during handling regarding differences in trait consistency, at least two arguments can be

Table 3. Pearson's pairwise correlations between average beard traits and two measures of body condition (BSI, BC) in Bearded Reedling males.
Correlacions de Pearson entre els trets mitjans dels bigotis i dues mesures de l'estat corporal (BSI, BC) entre els mascles de la mallerenga de bigotis.

Variable	BSI		BC	
	r	p	r	p
Beard length (mm)	- 0.45	0.125	-0.20	0.322
Beard width (mm)	- 0.02	0.939	-0.22	0.471
Beard surface (mm ²)	- 0.44	0.130	-0.31	0.301

offered. First, from a methodological point of view, the measurements of beard length were more accurate than the measurements of beard surface area. Second, for a fixed spatial position of an external observer, the direction the bill points will determine the width of the observed beard. For instance, beard widths will be thinner when the bill is pointing towards the external observer, whereas similar observed beard lengths will be obtained for bills pointing in any direction. This provides support for the hypothesis that beard length in particular is a reliable static melanin-based measure that can be exploited in conspecific interactions, including male-male competition and female choice (Hoi & Griggio 2012). A further repeatability analysis with at least two blinded measurements in the same individual could shed light on whether or not biometric measurements of the beard traits are consistent enough for use in this context.

Melanin-based colouration, the commonest pigment in animal coloration in many different taxa, is often associated with other phenotypic traits such as behaviour, physiology and morphology (Jawor & Breitwisch 2003, Hill & Macgregor 2006, Meunier *et al.* 2011). In addition, experimental studies have concluded that melanin ornaments are less sensitive to environmental stress associated with endoparasitic infection (McGraw & Hill 2000) or to nutritional conditions during moult (McGraw *et al.* 2002), and studies have failed to detect any significant condition-dependence in melanin ornament expression (McGraw 2008). Other studies with modest sample sizes have failed to detect any significant positive association between melanin-dependent traits and body condition (Senar *et al.* 2003, Heigy *et al.* 2019). Nevertheless, some studies have detected a significant relationship between melanin-based traits and body condition (Meunier *et al.* 2011, Guindre-Parker & Love 2014). This thus indicates that relationships between melanin-based colouration traits and body condition are species- or trait-specific.

In the case of Bearded Reedlings, the results of the current study are consistent with the conclusions of a previous study of this species (Mahr *et al.* 2020) and there is no evidence of any positive association between beard size in this bird and body condition. Previous studies have suggested that melanin-based ornaments such as beard size might reflect the hormonal status

and/or competitive ability of males (e.g. McGraw 2008, Hoi & Griggio 2008, 2011). Further study of other populations using the same or different measurement techniques (Zuk & Decruyenaere 1994, Figuerola *et al.* 1999, Figuerola & Senar 2000, del Val *et al.* 2009, Galván & Sanz 2010, Williams *et al.* 2020) might help confirm or reject this hypothesis.

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Resum

La mida dels ornaments de la barba melànica i la condició corporal no es troben associats en la mallerenga de bigotis *Panurus biarmicus*

Els ornaments basats en melanines dels ocells sovint es consideren senyals dependents de la condició física, usats en el marc de selecció sexual. En una espècie altament dimòrfica, la mallerenga de bigotis *Panurus biarmicus*, el negre dels bigotis exhibit sota dels ulls té una funció dual dins de la competència entre mascles i/o l'elecció per part les femelles i també com a senyal de dominància. No obstant això, la inter- i intraconsistència d'aquests trets no ha estat explorada en aquesta espècie. En aquest estudi es mostra empíricament que diferents mesures d'un mateix tret (longitud, amplada i superfície de les bigoteres) són altament consistents dins del mateix individu i van estar positivament correlacionades en dues mesures dels mateixos trets de 13 mascles anellats als canyissars del Parc Natural del Fondo (SE d'Ibèria) durant els anys 2007, 2009 i 2010. El valor mitjà de les diferents mesures de les bigoteres va ser altament variable entre mascles, donat la gran quantitat de variació entre elles, i no van estar significativament correlacionades amb dues mesures de condició (índex de mida corporal i pes). Aquest estudi preliminar no dona suport a la hipòtesi que els ornaments melànics de les bigoteres siguin indicadors de la condició individual que reflecteix qualitat fenotípica.

Resumen

El tamaño de los ornamentos de barba melánica no están asociados con la condición corporal en el bigotudo *Panurus biarmicus*

Los ornamentos de las aves basados en melaninas a menudo se consideran señales dependientes de la condición, explotadas en el marco de selección sexual. En una especie altamente dimórfica, el bigotudo *Panurus biarmicus*, el negro de los bigotes exhibido debajo de los ojos juega una función dual dentro de la competición entre machos y/o elección por parte las hembras y también de estatus de dominancia. Sin embargo, la inter- e intra-consistencia de estos rasgos no ha sido explorada en esta especie. En este estudio se muestra empíricamente que diferentes medidas de un mismo rasgo (longitud de las bigoterías, anchura y superficie) fueron altamente consistentes dentro del mismo individuo dado que estuvieron positivamente correlacionadas entre 13 machos anillados en los carrizales del Parque Natural de El Hondo (SE Iberia) en los años 2007, 2009 y 2010. Sin embargo, las diferentes medidas de los rasgos de bigoterías en promedio fueron altamente variables entre machos, dado el amplio rango de variación entre ellas y no estuvieron significativamente correlacionadas con dos medidas de condición (índice de tamaño corporal y peso). Este estudio preliminar no apoya la hipótesis que los ornamentos melánicos de las bigoterías sean indicadoras de la condición individual que refleje calidad fenotípica.

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