



Morphometric Variation as a Proxy for Dispersal in a Highly Dimorphic Reed Bird Specialist from an Isolated and Vulnerable Small Population in SE Spain

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Abstract

In this study, I gathered a comprehensive set of measures in a sample of 63 Bearded reedlings *Panurus biarmicus*, a small and highly dimorphic passerine bird vulnerable in Spain, ringed in the years 2003-2007 and 2009-2010 in an isolated population in "El Hondo Natural Park, SE Spain". Most morphometric parameters were greater in adult males than adult females, irrespective of age groups and they were correlated with weight and size and this implicates that they are size and condition-dependent (most costly to produce) so enhances individual's quality or fitness to the bearer. GLMM's models indicated that selective forces were stronger for wing-length than for tail-length, wing-length dependent by the age of juveniles and sex of males and determined by the weight. This suggests that both traits, especially wing-length, possess great individual fitness that could facilitate for quick movements for dispersal, probably started for juveniles. The earlier studied differences in the wing's shape in this species are probably the proxy factors to enhance dispersal started by juveniles, since they possess shorter drab tails. We need furthermore studies to evaluate if other populations of European plateau are intra and inter-sexual selected and if they are proxies or primers for dispersal and migration of this species.

Keywords: Intra and Inter Sexual Differences; Morphometry; *Panurus biarmicus*; Small Population; Dispersal

Introduction

According to Fisher's hypothesis [1] the exaggerated ornaments of males may deviate from the optimum because of females' preferences. This joint evolution from the optimum is sexual selection [2-4]. If elongated ornaments develop because of females' preferences and bear a relation to survival, the ornament is under natural selection [5,6]. Sexual selection drives in an intra-sexual selection (e.g. sexual selection for traits within individuals of the same sex [7-9]) inter-sexual selection (e.g. sexual selection for traits between individuals of different sex: [10,11]). Extreme ornaments may be seen as phenotypic indicators of quality of the bearer and they are hence costly to produce and it

considers them condition-dependent [12,13]. Morphometry of the ornaments as tail and wing can be subjected to these processes [14-17].

The tail is ornament under sexual and natural selection [14,16] and social selection [18]. Within the natural selection context, tail-length is very useful to develop in reed masses mainly as a balancing organ, playing an important role in habitat selection [15]. The ability to perform brief trips decreases with tail elongation, because the tail length results in a costly ornament [16]. Regarding the wing morphology, aspects such as wing size and wing-shape are also sexually selected [20]. For instance, rounded wing-shapes result in better performance in females, moving around crowded

habitats with more maneuverability than males [20]. Tarsus-length is another morphological parameter sexually selected [21,22].

Amongst the highly dimorphic Eurasian reed-dwelling passerines, the Bearded reedling *Panurus biarmicus* is a medium-small Parrotbill inhabiting scarce and fragmented wetlands from Eurasia [24]. In eastern Mediterranean Spain remains a small breeding population nucleus of 50-75 pp. The main nucleus in south-eastern Spain is located at the southernmost distribution limits in Europa [25,26]. Probably this population is the surplus from a dispersal nucleus of a bigger ancient population of south-eastern France (Poulin *pers com*). Population of this man-made reservoir (pp. 50-70) faces extinction risks mainly because of the poor water quality [26,27]. In this population, high levels of inbreeding may occur, because of isolation degree from source drier and colder areas of centre of Spain, distant 500 km because of mountains barrier-effect that difficulty the short movements of this species in Spain [29] and corroborated by the absence of recaptures among areas [30].

Objectives

Based on the earlier assumptions, I aim to try to assess the following key features in the Bearded reedling: 1.- Are the measuring data subject to measurement errors that might influence its variability?; 2.- Are the morphometric parameters under study size and condition-dependent, costly of produce, that supposes individual's major quality or fitness to the bearer that might facult the capability for dispersal at short-medium distance of the population studied?; 3. Are there age and sex-dependent differences in the average parameters that implicates that they are sexual selected? and 4.- Is there any proxy effect of age and sex in the morphometric parameters that might involve this capability?.

Material and Methods

Study Area

In south-eastern Mediterranean Spain remains a lowlands plateau of about 2000-3000 Ha formed in the past centuries by the calcium-rich sediments of the river Segura on which "El Hondo" was constructed as an inland water reservoir at the beginnings of XX century at 38°16'N 00°41'W in the southwest of Alicante province (38°20'N 0°28'W) in the low limits of the arid semiarid region of middle Alicante province (20.127 Ha) and eastern of Murcia province (37°59'N 1°7'W; 88.600 Ha). This site was categorized as RAMSAR site number 14 as "El Hondo Swamp" in the year 1989 because it holds important numbers of threatened medium birds and supports a rich and complex community

of small size reed birds species. It is a group of eutrophic lagoons surrounding a manmade-construction on the saline and freshwater marshlands. The local climate is temperate, wet and prone to high seasonality with great variability in winter (annual total rainfall is about 250 mm and annual temperature average about 19°C in 1992-2009 [31]), which affects the evolution of some traits of through time in the species under study [31].

Data Recording

The first bulk sample of birds (N = 84) was mist-netted inside the core of the Park by the author and these birds were ringed with aluminum rings (Spanish Ministry of Environment- Madrid) and afterwards measured and released by the author in the same site in the years 2003 (N = 29), 2004 (16), 2005 (5), 2006 (10), 2007 (8), 2009 (11) and 2010 (5). The period of ringing and handling covered the breeding (March -October) and non-breeding (November-February) seasons, according to Robson C [24]. Since this first sample contained a non-breeding bird's surplus (N = 21) of unknown origin, the first dataset was reduced to the native sub-sample (N = 63) corresponding to the individuals trapped during the breeding season (2003-2004, N = 34; 2005-2007, N = 17; 2009-2010, N = 12).

The birds were sexed and aged as adults and juveniles according to the plumage key features [24]. I took the following measures following [32]: 1.- Maximum right wing-length (accuracy 0.5 mm); 2.- tail-length (to the base of the under-tail coverts, accuracy 0.5 mm), 3.- left and right tarsus-length (accuracy 0.1 mm). I measured body weight with a 50 g Pesola ® spring balance (accuracy 0.1 g). I estimated the body condition index (BCI) is weight, considered as an index of an individual's quality [33,34,35]. Tarsus-length (averaging the measure of left and right tarsus) was considered as a measure of body size (BSI), because it contains a strong skeletal component and it is a good predictor of body size similarly to keel-length [36,37].

Statistical Procedures

I gave the measurements variability as the percentage of the variation coefficient (CV) [38,39]. This variability was statistically tested by Chi-squared test of all CV's [40]. Repeatability of left and right tarsus was tested according to [41]. All morphological variables meet normality (Kolmogorov-Smirnov test: P = 0.200; N = 63) so parametric tests were used. Pearson's correlation coefficient tested relations between BSI (tarsus-length) and BCI (weight). Means were tested by One-way ANOVA [39]. I expressed means with ± SD. All tests were two-tailed [42].

In order to detect the direction of the selective forces,

I first performed a set of Pearson's correlations among morphological variables with weight and average tarsus-length (Table 1). Second, I used two *Generalized Linear Models* (GLMs), with a linear error distribution, to assess the overall effect of sex (43 males; 20 females) and age (45 adults; 18 juveniles) on tail-length and wing-length. I used both morphological parameters as dependent variables in each model, sex (0 = male; 1 = female) and age (4 = adult; 3 = juvenile) as fixed continuous variables and weight and average tarsus-length included as covariates (Tables 2&3). For analysis, the IBM SPSS.v23 statistical package was used [42].

Results

Morphological Features

The tail-length of the Bearded reedling was on average 77.53 mm \pm 6.04 (range: 67- 90 mm; N= 63) and highly significant variable between sexes within ages ($X^2 = 200$; $P < 0.0001$). Probably due to the low sample sizes, there were

significant age differences in average tail-lengths between sexes, but juvenile females having longer tails than juvenile males (Table 1). Overall mean wing-length (58.14 mm \pm 2.47; range: 53-66; N = 63) shows a very high variability between sexes and ages ($X^2 = 300$; $P < 0.0001$). I found average longer wings in juvenile females than juvenile males (Table 1). Average mean tarsus length (19.64 mm \pm 0.66; range: 18.4- 21.5; N = 63) as highly variable ($X^2 = 200$; $P < 0.0001$) and I found inter- and intra-sexual differences (Table 1). In spite not accounting for reliable fat in this study, average weight (12.55 \pm 0.84; range: 10.0-14.0; N = 63) shows highly significant variability ($X^2 = 300$; $P < 0.0001$). Tarsus-length (BSI) and weight (BC) were not auto-correlated ($r = 0.175$; $P = 0.169$; N = 63) but positively correlated with tail-length and wing-length (Table 2). Repeatability of measures of left-right tarsus-length was high ($R = 0.825$; $F_{1, 62} = 1.212$; $P < 0.0001$). Selective forces were stronger for wing-length than for tail-length according to the *Akaike's Information Criteria* (AIC) of the GLMM's models, since AIC's values for wing-length were minor than for tail-length (Table 3).

TRAIT	MEAN \pm SD	N	RANGE	% CV	F	d.f	P	F	d.f	P
Wing-length (mm)					INTER-SEXUAL			INTRA-SEXUAL		
Adult Male	59.91 \pm 1.69	32	56-66	2,82	23.24	1.45	< 0.001	61.93	1.45	< 0.001
Adult Female	57.31 \pm 1.49	13	54-59	2.6						
Juvenile Male	55.50 \pm 1.28	11	53-58.5	2.31	0.156	1.18	0.699	4.107	1.18	0.058
Juvenile Female	55.78 \pm 1.79	7	53-59	3.21						
Weight (gr)										
Adult Male	12.90 \pm 0.72	32	11,3-14,3	5.58	1.79	1.45	0.189	15.65	1.41	< 0.0001
Adult Female	12.56 \pm 0.87	13	10.8-14.1	6.93						
Juvenile Male	11.94 \pm 0.65	11	10.9-13	5.44	0.41	1,18	0.843	2.76	1.18	0.114
Juvenile Female	11.87 \pm 0.91	7	10.4-13.2	7.67						
Mean Tarsus (mm)										
Adult Male	19.96 \pm 0.59	32	18.9-21.5	2.96	28.19	1,45	< 0.0001	28.19	1.45	< 0.0001
Adult Female	19.00 \pm 0.41	13	18.4-19.6	2.16						
Juvenile Male	19.74 \pm 0.49	11	18.8-20.7	2.48	6.43	1,18	0.022	6.43	1.18	0.022
Juvenile Female	19.17 \pm 0.42	7	18.7-20.7	2.19						
Tail-length (mm)										
Adult Male	82.30 \pm 3.63	32	74-90	4.41	52.99	1.45	< 0.0001	52.99	1.45	< 0.0001
Adult Female	73.96 \pm 3.05	13	69-80.5	4.12						
Juvenile Male	70.82 \pm 3.92	11	67-78.5	5.54	1.42	1.18	0.251	1.42	1.18	0.251
Juvenile Female	72.93 \pm 3.22	7	70-79	4.42						

Table 1: Morphometry of the bearded reedling in SE Spain in relation to sex and age. Patterns of variation is expressed by the variation coefficient between sexes and ages. One-way ANOVA F's values, degrees of freedom and probability level for differences in the average values between ages within sexes between ages (intra-sexual) and within ages between sexes (inter- sexual) classes are given.

Variable	r	BSI		BCI		
		p	N	r	P	N
Wing-length (mm)	0.385	0.002	63	0.611	< 0.0001	63
Tail-Length (mm)	0.476	< 0.0001	63	0.559	< 0.0001	63

Table 2: Pearson's correlations between and average left-right tarsus-length as body size index (BSI) and weight as body condition index (BCI) as relative to the morphometry of the Bearded reedling.

WING-LENGTH					
	b	SE	Wald Chi-squared	df	p
INTERCEPT	42.37	7.06	36.07	1	< 0.0001
AGE	-2.57	0.48	28.75	1	< 0.0001
SEX	1.28	0.51	6.21	1	0.013
WEIGHT	0.92	0.28	11.01	1	0.001
TARSUS-LENGTH	0.21	0.4	0.27	1	0.604
AIC	242.11				
Deviance	142.27				
TAIL-LENGTH					
	b	SE	Wald Chi-squared	df	p
INTERCEPT	27.6	18.26	2.29	1	0.131
AGE	-6.3	1.19	28.01	1	< 0.0001
SEX	-3.22	1.28	6.38	1	0.012
WEIGHT	1.54	0.69	4.94	1	0.026
TARSUS-LENGTH	1.71	0.99	2.97	1	0.085
AIC	356.74				
Deviance	877.66				

Table 3: Generalized Linear Models (GLM's) to the dependent variables (wing-length and tail-length) and sex and age as fixed factors and weight and average tarsus as covariates. Akaike's value (AIC) and Deviance for each one of the models is indicated. Both models are represented by main effects, without interactions.

Discussion

Despite all measured morphological parameters showed high variability that might be due to biases of the measurer also noted in other traits measured in this species [43]. I claim to standardize and to take repeated measures of a same trait during field procedures (see [43]) although however measures of left-right tarsus-length were highly repeatable. This study reveals that the main morphometric parameters of the Bearded reedling were inter and intra-sexually selected in a small and isolated Mediterranean population. In captivity experiments, they show tail is inter-sexually selected after artificial elongation because females preferred longer tail males [14]. The tail trait serves as a signal of maneuverability [44] or for escaping abilities in cluttered habitats being a drag for speed accomplished by short and slow flights [4,6]. Wing-length serves as an optimal

organ to enhance speed ability, for long-faster trips [20]. All these features allow Bearded reedlings to perform for large movements as is shown elsewhere [45,46].

This study finds that a flight-lift component (wing-length) and a flight-drag component (tail-length) are both dependent and directly related to condition and size. Then, they are indicators of an individual's quality or fitness. Experiments by Malzer I, et al. [47] in this species corroborate some of these findings since tail-length is positively correlated with levels of IGF-1, a hormone related with the link between condition and the expression of elaborated traits, and also positively related with body weight. Some migrating marsh passerines do not show differences between sexes in some morphometrics and body condition during the molt [48] so is suggested that strong physiological changes during the breeding period could drive in age and sex differences in

morphological parameters that are more susceptible during molt because of energetic demands.

Conclusion

This study reinforces the idea [50] that birds carrying bigger morphometric parameters (e.g wing-shapes and tail-lengths) are better predictors for dispersal ability. This is a key factor jointly with seasonality, heavily given in the population of Bearded reedlings in “El Hondo”, the key drivers for dispersal, especially in harsh and cold years [31]. Further, we need studies to explain if such morphological variability occurs in other areas of Spain to elucidate what are the causes and consequences of being fitness signals suitable for enhancing short- medium movements [45,46,51].

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