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Melanin-based color variation in the Bearded Vulture suggests a thermoregulatory function

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Abstract

We document a case of intraspecific variation in plumage colouration in Bearded Vultures that may have arisen as a functional response to climate conditions. Two subspecies, *Gypaetus barbatus barbatus* (Eurasia and North Africa populations) and *Gypaetus barbatus meridionalis* (Eastern and Southern Africa), have been described on the basis of plumage colour differences. The plumage of *G. b. barbatus* tends to be darker in comparison with that of *G. b. meridionalis*. The plumage of the two subspecies differ in the feathering of the tarsi (more abundant in *G. b. barbatus*) and presence/absence of dark ear tufts (only present in *G. b. barbatus*, and this being the most useful character to distinguish adult specimens of both subspecies). When exposing skins under the sun or to electric bulbs in a cold room, temperature increases were significantly higher in the black ear tufts than in the frontal region of the head, suggesting that the melanized ear patch of *G. b. barbatus* serves, at least, to heat up the air entering the ear channel and perhaps also the underlying skin. In addition, *G. b. barbatus*, which inhabits mountainous regions with harsh and long winters, would benefit more from feathered tarsi to prevent heat loss through the legs.

Keywords: Bearded Vulture; Climate conditions; *Gypaetus barbatus*; Intraspecific variation; Thermoregulatory role

1. Introduction

Bearded Vultures (*Gypaetus barbatus*) are large scavengers widely distributed in mountains ranges in Eurasia and Africa (Del Hoyo et al., 1994). They can be considered aberrant in relation to the remaining Old World vultures, as they have specialized on eating bones of large and medium-size ungulates (Margalida et al., 2007) which deliberately and repeatedly throw from the air into rocky surfaces (bone-breaking sites or ossuaries) until they become fragmented or disjointed (Boudoint, 1976; Margalida and Bertran, 2001), have feathered heads and because some populations (Crete and Balkans) hunt a relatively large proportion of live prey (i.e., land tortoises, Terrasse, 2001). Bearded Vultures are also peculiar for bathing in red soils for cosmetic purposes (Negro et al., 1999), or for their well developed nest-building abilities (Margalida and Bertran, 2000). Recent molecular phylogenies based on the sequencing of both mitochondrial and nuclear DNA suggest a close relationship of Bearded Vultures, Egyptian Vultures (*Neophron percnopterus*), Palm-nut Vultures (*Gypohierax angolensis*), and an almost extinct Snake-eating Eagle from Madagascar (*Eutriorchis astur*) (Lerner and Mindell, 2005). This mostly African clade, the Gypaetinae, is only distantly related to the clade including the remaining Old World vultures.

Up to five subspecies of Bearded Vultures have been described in the past, but currently only the two subspecies proposed by Hiraldo et al. (1984) are upheld (Fergusson-Lees and Christie, 2001). These two subspecies are based on morphological evidence, including plumage colour and patterns in the adult plumage: *G. b. barbatus*, encompassing all Bearded Vulture populations of Eurasia and North Africa, and *G. b. meridionalis* that includes the Bearded Vultures

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of Eastern and Southern Africa. The main features of *meridionalis*, distinguishing it from the nominate subspecies, are its small size, absence of black ear tufts, absence of black bristles on the chin, interciliar region (crown) of pure white color or only slightly spotted, pectoral band usually absent or incomplete, darker back plumage, and featherless legs (Hiraldo et al., 1984). Size, however, shows gradual geographic variation.

A recent genetic study based on the sequencing of the mitochondrial control region (Godoy et al., 2004) has found a larger genetic distance among extreme populations of *G. b. barbatus* in Eurasia, than between populations of *G. b. barbatus* and *G. b. meridionalis*. The subspecies status of both African and Eurasian populations, and thus the existence of northern and southern independent lineages, is not supported. This finding also suggests that plumage differences have, at most, a shallow genetic origin and that they may represent recent adaptations to different local environments.

Eurasian Bearded Vultures live in high mountains with harsh and long winters. They have feathered tarsi, thicker plumage overall and larger size (Delibes et al., 1984), and thus we concur with these authors that the differences with the African birds living in more temperate mountain ranges can be explained as thermoregulatory adaptations to cold weather in a classical example of Bergmann's rule. Delibes et al. (1984), however, failed to provide insights into the possible adaptive value of the differences in plumage traits. They suggested instead that the different patterns could simply be incidental by-products of genes involved in different physiological processes (Mayr, 1963). Black is produced by melanin (McGraw, 2006) and represents the most heat-absorbing colour (Hamilton and Heppner, 1967; Heppner, 1970; Lustick, 1971; Ward et al., 2007), and several authors evidenced that large dark-plumaged birds face important thermoregulatory constraints in torrid environments (Walsberg, 1982; Cloudsley-Thompson, 1999; Ward et al., 2002; Negro et al., 2006). Noting that the main plumage differences among African and Eurasian morphs are in the degree of melanization, we here hypothesize that black colour markings, and particularly the ear tufts and the frontal patch diagnostic of Eurasian birds, improve heat absorption. This would be advantageous for individuals inhabiting high mountains in the northern hemisphere, which could have favoured the appearance of that trait only in those areas.

Although the most common selective pressures invoked to explain intraspecific colour variation deal with sexual selection, the pressures that natural selection exerts on plumage colouration has received relatively less attention (Bortolotti, 2006). Our aim in this paper is to document a case of intraspecific variation in plumage colouration that may have arisen as a functional response to climate conditions. Numerous avian subspecies have been described on the basis of plumage colour differences, but in most cases these differences remain only as diagnostic characters for taxonomy. Here we aimed at describing taxonomic diagnostic traits while giving reasons that explain why they could have evolved through their adaptive function.

2. Material and methods

We have re-analysed plumage patterns described in Delibes et al. (1984), who examined numerous specimens in museums all across Europe belonging to the two currently recognized subspecies (see Appendix): (a) *Gypaetus barbatus barbatus*, including specimens from Central Asia, India, Caucasus–Persia, Balkans, Alps, Sardinia, Iberian Peninsula, North Africa and Yemen; and (b) *Gypaetus barbatus meridionalis*, including specimens from Ethiopia and South Africa.

Plumage traits and levels of variation (Fig. 1) were those described by Delibes et al. (1984): (a) *central portion of the crown* (all white, dirty white or slightly marked with black, black and white; (b) *black tuft in the ear* (well developed, visible but little-developed, absent); (c) *density of black bristles on the chin* in a 30×30 mm area on each individual (0, 1–8 bristles, 9–19, and >20 bristles); (d) *pectoral band* (complete or almost complete, traces of pectoral band or intermediate and absent).

The temperature of different feather tracts in the head ("b" and "e", Fig. 1) of a stuffed Bearded Vulture of the *barbatus* subspecies was registered with an electronic thermometer (precision of ±0.1 °C) incorporating a flexible wire probe that could be placed between head feathers over the skin. Temperature was measured on a summer day in the morning (air temperature 28 °C). In parallel, we measured the temperature in a control sample that consisted in a synthetic white cotton ball. Measurements were taken in a shaded area and also exposing the stuffed skin to the sun different lengths of time (5 and 10 min). The specimen was an adult (i.e., bird in definitive plumage) from the Pyrenees (Spain–France) deposited in the vertebrate collection of the Estación Biológica de Doñana (Sevilla).

In addition to the temperature measures taken in the outdoor, we used a similar procedure but under laboratory conditions inside a cold-storage room with the skins of another two adult birds with definitive plumage collected in the Pyrenees and deposited in the collection of the National Museum of Natural Sciences (Madrid). This way we were able to record the increase

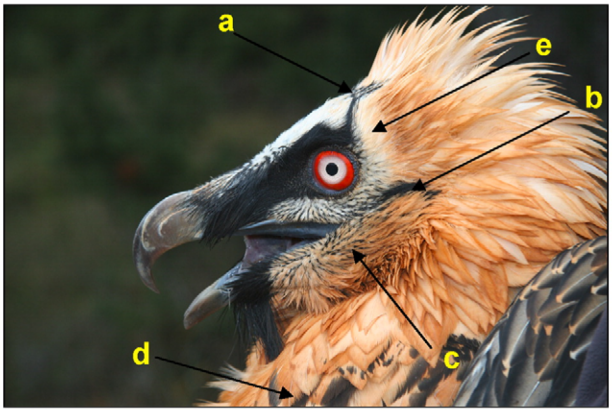

Fig. 1. Detail of the different feather tracts in the head and body of a *Gypaetus barbatus barbatus* in which plumage traits and levels of variation were analyzed (see Materials and methods) and temperature was measured: control (i.e., white cotton ball) b) ear tufts e) frontal region.