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Cosmetic coloration in Egyptian vultures: Mud bathing as a tool for social communication?

It is well-established that plumage colors are important for avian visual communication and are used to signal social information (Andersson 1994). Most plumage colors are static traits with a relatively fixed information content. Little is known about the ability of birds to modify the expression of plumage colors with exogenous materials after feather development, a phenomenon also known as avian cosmetics (Delhey et al. 2007). Whereas the use of secretions and feather powder are widespread, the use of external sources (mainly red soil) for cosmetics seem restricted to a few groups like cranes and ptarmigans and for camouflage purposes only (reviewed in Delhey et al. 2007). The deliberate staining of feathers in a social signaling context has so far only been described in the Bearded vulture (*Gypaetus barbatus*) (Negro et al. 1999), but the exact function of this behavior is still hypothetical because of the extreme rarity of field data. Hence, we were extremely excited to observe this feather painting behavior in another Old-World scavenger, the Egyptian vulture (*Neophron percnopterus*).

Both vulture species are close relatives, evolutionarily separated from other Old-World vultures and raptors (Lerner and Mindell 2005) and renowned for their remarkable feeding habits, involving the breaking of bones of prey by Bearded vultures (Boudoint 1976), and stone-throwing to break open eggs by Egyptian vultures (Lawick-Goodall and van Lawick 1966). The Egyptian vulture also stands out because of its brightly colored yellow face that is pigmented by carotenoids obtained from eating the excrements of ungulates (Negro et al. 2002).

Egyptian vultures are considered endangered worldwide, but 60 breeding pairs and a total population of about 300 individuals still occur on Fuerteventura (Canary Islands, Spain). Extensive field-work over the past 20 yr has resulted in most birds being individually marked with plastic rings (>85%). Because of this banding, on some days it is possible to identify up to 150 different individuals visiting one of the feeding stations on the island. During monitoring trials at these stations, we noticed that this otherwise mainly white bird showed remarkable individual variation in the amount of rufous coloration on parts of the neck and head. Moreover, whereas some birds are almost completely white, birds with an almost entirely red plumage also commonly appear (Fig. 1). This made us wonder whether the species evolved a feather painting behavior similar to that reported for its close relative.

On 25 August 2016, we presented two bowls to the birds visiting the main feeding station: one with red soil dissolved in water and one containing only water (diameter: 75 cm; depth: 5 cm, distance: 3 m). Almost directly after noticing the mud, an adult female started to scratch this sticky substance with her legs, while carefully looking at the mud 5–10 cm away. At some point, she gently swiped both sides of her head in the mud resulting in the dyeing of head, neck and chest feathers (for examples see Fig. 2 and Video 1, van Overveld 2017*a*). Between 10:00 and 15:00, when the mud dried up, we observed 18 different birds painting themselves with red soil to different degrees (>20% of the birds visiting the feeding station that particular morning, $N = 91$). Meanwhile, only one bird took a bath in the bowl with clear water.

Our observations of multiple birds taking mud baths provide a rare insight into the motivation to paint feathers in a natural context. Indeed, whereas some birds were highly attracted to the mud, others showed very little interest and almost directly turned around to move to the bowl containing water only. Those birds interested differed greatly in the extent they dyed their feathers, with some birds swiping their head very briefly and cautiously (Video 2, van Overveld 2017*b*, see also Video 1, van Overveld 2017*a*), while others took intensive mud baths, almost resembling normal bathing behavior (Video 3, van Overveld 2017*c*). Three birds even returned to take a mud bath twice. Furthermore, mud bathing seems not

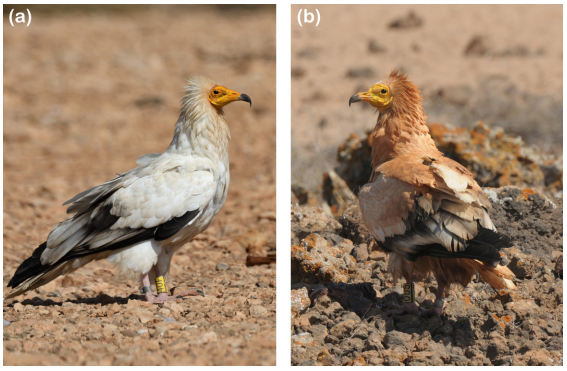

Fig. 1. Plumage color variation of Egyptian vultures on Fuerteventura. (a) A typical white bird (5-yr-old unpaired female, photo taken on 20 September 2016) (b) A bird with a very red plumage caused by extensive mud bathing (14-yr-old breeding male, photo taken on 31 May 2014). This type of plumage variation may occur in both sexes and during all parts of the year. Note that most birds only paint their head, neck and chest feathers (see Fig. 2).

FIG. 2. Photo composition showing the painting behavior of an Egyptian vulture in the mud bowl on Fuerteventura. (a) Birds entering the bowl are usually very wary and concentrated and in most occasions first start to carefully scratch the mud with their legs (see text for more details) after which they swipe both parts of the head in the mud (shown in panels (b) and (c). Depending on the intensity of mud bathing the head, neck and chest feathers usually get a very rufous coloration (d), thereby greatly changing the general appearance of the bird.

restricted to certain sex- or age-classes and was performed by both adult males and females (three and five individuals, respectively — one unknown sex), immature birds (age 1–3 yr) of both sexes (four males, two females, one unknown sex) and two recently fledged young.

There is still controversy about whether feather painting plays a role in visual communication (Negro et al. 1999) or primarily functions as protection against bacteria or viruses (Tributsch 2016, see also Arlettaz et al. 2002). Although we acknowledge that sanitary benefits may be an important aspect of feather painting behavior, perhaps even explaining its origin, we nevertheless believe this behavior to also serve a clear visual function, mainly given the great effect on the general appearance of these otherwise white birds (Fig. 1). On the other hand, our field observations do not seem to support a status signaling function as proposed by Negro et al. (1999). We collected an extensive data set on social status of birds visiting the feeding station showing females to be the dominant sex, but with a relatively strong linear dominance hierarchy also being present within each sex (i.e., based on 4,593 displacements between 141 individuals during 400 h of observation, T. van Overveld, *unpublished*). However, no sex-differences in rufous color exist between males and females nor are dominant individuals more rufous than subdominants in either sex.

The observation of multiple birds painting themselves in a group context, sometimes simultaneously and without fighting over this resource, also contradicts previous suggestions that feather painting by Bearded vultures is a secretive behavior used to display knowledge about a precious resource (Negro et al. 1999). In addition, we believe that red mud may be a scarce, but not a limiting, resource. Despite the semi-arid conditions on Fuerteventura, there are several permanent water ponds available on the island and apart from very dry years, most ancient riverbanks ("Barrancos") contain water during most parts of the year. Indeed, even though we performed our experiment during the driest part of the year, many of the birds at the feeding stations showed various degree of recent painting, including birds taking a mud bath in the bowl. The observed interest in the mud may therefore not so much prove its scarcity, but instead, we may have rather facilitated access to this resource, indicating a heterogeneous individual preference for cosmetic use.

The absence of a link with social status, and the relative ease by which birds can modify their feather color, made us hypothesize that mud bathing in this species may not necessarily produce a costly signal. As opposed to Bearded vultures, both color intensity and patterning are also less elaborate and more diverse, which may

point towards a more flexible use of this behavior in Egyptian vultures. Moreover, Bearded vultures are a largely solitary species, while Egyptian vultures roost communally and often aggregate in large numbers at places with an abundance of food. Our feeding station may be visited by 100 birds simultaneously, but competitive displacements are often very subtle and directed to specific birds, suggesting high-levels of individual recognition. Hence, a status-signaling function through feather manipulation may be less relevant in a long-lived species that has the opportunity to update information on the social status of other group members on a regular basis.

At this point, however, it is unclear what other social content, if any, may be signaled through feather painting, especially because we still know very little about Egyptian vulture group dynamics and patterns of social relationship within their society. Observations at the feeding station suggest they have well-developed social cognitive skills as also shown by extensive mutual preening sessions between pairs, even outside the breeding season. Both sexes regularly use objects when participating in affiliative behaviors such as food/present sharing within pairs and males may pick up stones, offer nesting material and pieces of meat to impress females during courtship. One possibility is that feather painting primarily serves a function in pair-bonding and formation or is used to show off during sexual conflicts, but clearly, other potential explanations deserve equal consideration.

To elucidate the exact function of feather painting, an interesting first step would be to explore how the use of red muds is linked to feather wear, preen wax production (stickiness of feathers) and moulting patterns to examine whether birds signal or mask certain aspects of their current physical state. A detailed quantification of seasonal variation within and between individuals in rufous coloration, using photographs and by providing mud at the feeding station, would reveal any association between the use of cosmetics and particular stages of the reproductive cycle and/or to periods of the year during which social encounters occur more frequently. Finally, more targeted experiments, such as reducing or increasing the rufous coloration of specific individuals, combined with observations on the behavioral responses to these color manipulations, are needed to test exactly what specific social content may be signaled.

Our work adds a new and unusual behavior to the already impressive behavioral repertoire of Egyptian vultures and opens exciting new opportunities to test alternative hypotheses for the evolution of avian cosmetics or non-vocal communication in birds in general.

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