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Short communication

House Sparrows *Passer domesticus* with larger uropygial glands show reduced feather wear

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This study assesses whether uropygial gland size is related to improved feather quality. To address this question, I analysed the relationship between uropygial gland size and feather wear in the House Sparrow *Passer domesticus*. The results show that birds with larger uropygial glands had less worn feathers, suggesting that uropygial gland secretions improve feather resistance to abrasion.

Keywords: feather degradation, feather wear.

Preen oil is an oleaginous secretion that birds spread onto their plumage when preening. It is secreted by the uropygial (or preen) gland, a holocrine complex that is unique to birds and located in the integument of the rump (Clark 2004). The functions of the uropygial gland are still disputed: it may be involved in sexual communication, through pheromone production (Hirao *et al.* 2009), and through coloration of the feathers and skin (review in Delhey *et al.* 2007), as well as in protection against bacteria on the shell surface of eggs (Soler *et al.* 2008). However, the most widely accepted function is maintenance of the plumage. Several studies have shown that feathers deteriorate when the uropygial gland is experimentally removed (Elder 1954, Jacob & Ziswiler 1982, Moyer *et al.* 2003). In addition, preen oil has an antimicrobial activity that inhibits the growth of feather-degrading bacteria (Shawkey *et al.* 2003, Reneerkens *et al.* 2008, Ruiz-Rodríguez *et al.* 2009), as well as having insecticidal effects against chewing lice (order Phthiraptera; Moyer *et al.* 2003, Moreno-Rueda 2010). Moreover, the uropygial gland favours the establishment of feather mites (Acari, suborder Astigmata), which probably improve feather condition by feeding on microbes and dirt trapped in the uropygial secretions (Galván *et al.* 2008). A protective function against feather degradation caused by ultraviolet radiation has also been proposed (Reneerkens & Korsten 2004), but not demonstrated (Surmacki 2008).

Recent studies have emphasized intraspecific variation in uropygial gland size and the associated consequences for bird fitness. The size of the uropygial gland is positively correlated with the quantity of secretion produced (Elder 1954, Martín-Vivaldi *et al.* 2009). Therefore, individuals investing more in the uropygial gland may gain a number of benefits, such as reduced loads of chewing lice and feather-degrading bacteria (Møller *et al.* 2009), increased feather-mite load (Galván *et al.* 2008), or more attractive sexually selected traits, such as larger white wing-bars in House Sparrows *Passer domesticus* (Moreno-Rueda 2010). Moreover, if uropygial oil improves feather flexibility, individuals with larger uropygial glands would suffer less feather wear by abrasion. To test whether birds investing more in uropygial gland size have plumage in better condition, I assessed whether the size of the uropygial gland is correlated with feather wear in the House Sparrow. In a previous study (Moreno-Rueda 2010) I found that uropygial gland size is positively correlated with body condition, and Sparrows with larger uropygial glands showed fewer feather holes (presumably caused by chewing lice). However, the relationship between uropygial gland size and feather wear has not been investigated previously.

METHODS

This study was performed in March 2009 with 28 House Sparrows (14 males and 14 females). The birds were captured in the field in January 2008, when they were yearlings, and kept in an outdoor aviary of 24 m^3, located in Moraleda de Zafayona (southeastern Spain). The birds were supplied with water and food *ad libitum* (commercial mixture of seeds and breeding dough for canaries, sunflower seeds, and wheat), as well as nestboxes and nesting material for breeding, following Moreno-Rueda and Soler (2002). During 2009, the second-year birds all bred. All birds were captured on 20 March and the length, width and depth (from the base of the gland to the base of the papilla) of the uropygial gland were measured (each variable was measured three times) with a digital calliper (Mitutoyo Inc., Kawasaki, Japan; accuracy 0.01 mm). Uropygial gland volume was estimated by multiplying the three measurements (following Galván & Sanz 2006). The repeatability (Lessells & Boag 1987) of this measurement was 0.76. Although this is a gross measurement of size, it has repeatedly proved useful as an index for studying this gland (e.g. Galván *et al.* 2008, Martín-Vivaldi *et al.* 2009,

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Moreno-Rueda 2010). Moreover, the shape of the uropygial gland is similar across individuals, suggesting that this method is useful for measuring uropygial gland size.

In the same birds I estimated the wear of the nine primary feathers (excluding the outermost primary) of the left wing using the wear index of Merilä and Hemborg (2000): 1 for fresh feathers, 2 for slightly worn feathers and 3 for heavily worn feathers. The overall wear index was the sum for all feathers (range: 9–27). This index primarily takes into account the degree of wear of the feather tips, presumably caused by abrasion during flight, due to friction arising from airborne particles or other feathers (Schreiber *et al.* 2006), as well as by feather-degrading bacteria (Burtt & Ichida 1999). In addition, I measured the length of the seventh primary (with a ruler, accuracy 0.5 mm) and estimated its mass (digital balance, accuracy 1 mg). The body condition of the birds was estimated as the residuals from the regression of body mass (measured with a digital balance, accuracy 0.1 g) on tarsus-length (measured with a digital calliper, accuracy 0.01 mm; Schulte-Hostedde *et al.* 2005).

All variables followed a normal distribution according to a Lilliefors test, except for uropygial gland size, which was log-transformed (Quinn & Keough 2002). Parametric statistics were used for all the analyses and performed with STATISTICA 7.1 (Statsoft 2005). Means are given with the standard deviation and the raw data are presented in all figures.

RESULTS

No significant differences were found between the sexes in uropygial gland size (females: 120.0 ± 39.33 mm^3; males: 122.2 ± 30.13 mm^3; t_{26} = 0.34, P = 0.73; *t*-test performed with log-transformed data), feather-wear index (females: 11.14 ± 3.88; males: 8.93 ± 4.01; t_{26} = 1.49, P = 0.15) or feather mass (females: 156.4 ± 12.68 mg; males: 167.3 ± 18.61 mg; t_{26} = 1.80, P = 0.08). Feather mass was negatively correlated with feather wear (r = −0.50, P < 0.01; Fig. 1). The relationship between feather mass and feather wear remained significant after controlling for sex (β = −0.45, $F_{1,25}$ = 6.21, P = 0.02; effect of sex: $F_{1,25}$ = 0.49, P = 0.49). Feather mass was positively correlated with feather length (r = 0.50, P < 0.01); however, the relationship between feather mass and wear remained significant after controlling for feather length ($F_{1,24}$ = 7.39, P = 0.01; effect of length on wear: $F_{1,24}$ = 1.15, P = 0.29; effect of sex: $F_{1,24}$ = 1.16, P = 0.29).

The feather-wear index was not correlated with body condition (r = 0.05, P = 0.79). However, the feather-wear index was correlated with uropygial gland size, birds with larger glands having feathers with less wear (r = −0.53, P < 0.01; Fig. 2). This correlation remained significant when two possible outliers (birds with the largest uropygial glands) were removed (r = −0.42, P = 0.03). The relationship between feather wear and uropygial gland size remained significant after controlling for sex (β = −0.51, $F_{1,25}$ = 9.81, P = 0.004; effect of sex: $F_{1,25}$ = 2.26, P = 0.14). There was a tendency for individuals with larger glands to have heavier feathers (r = 0.35, P = 0.06).

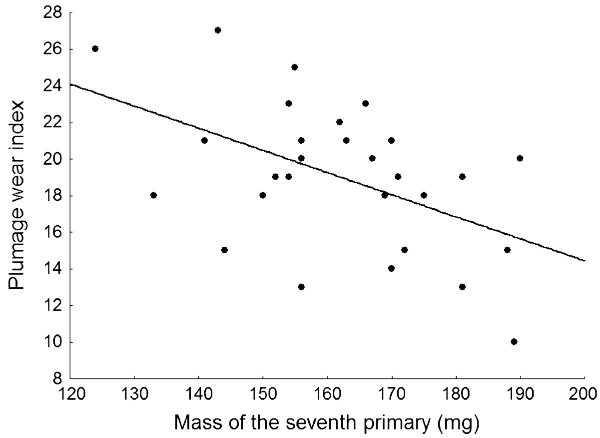

Figure 1. Relationship between the plumage-wear index and the mass of the seventh primary of 14 male and 14 female House Sparrows.

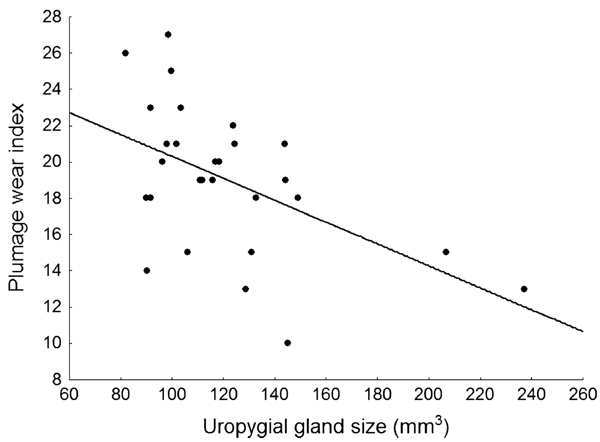

Figure 2. Relationship between the plumage-wear index and uropygial gland size in 14 male and 14 female House Sparrows.

DISCUSSION

Previous studies have demonstrated that uropygial oil helps maintain plumage in optimal condition because when the gland is removed, the plumage deteriorates (Elder 1954, Jacob & Ziswiler 1982, Moyer *et al.* 2003).

The present study adds to those findings by demonstrating that intraspecific variation in uropygial gland size is correlated with intraspecific variation in feather wear. That feather mass was correlated with the feather-wear index suggests that this index reliably indicated plumage attrition. It should also be noted that uropygial gland size is positively correlated with the volume of preen secretion produced (Elder 1954, Martín-Vivaldi *et al.* 2009). Therefore, the findings here suggest that individuals with a larger uropygial gland maintain their plumage in better condition (i.e. show less wear). Nonetheless, it should be noted that this study is correlational and thus the cause cannot be established unequivocally.

The present study may explain why plumage spottiness is negatively correlated with uropygial gland size in Barn Owls *Tyto alba* (Roulin 2007). Because melanin-pigmented feathers usually suffer less wear (e.g. Bonser 1995, Gunderson *et al.* 2008, Mahler *et al.* 2010), Barn Owls with more spots have more resistant plumage, which needs less care, and thus less investment in the uropygial gland. Goshawks *Accipiter gentilis* prefer to prey on species with smaller uropygial glands, possibly because these species have plumage in worse condition due to wear, and thus reduced flight capability (Møller *et al.* 2010).

Feather wear has various negative consequences for birds, for example by reducing the insulation of plumage through the loss of feather mass and fine structure, as well as increasing the energy expenditure required for flight by reducing the aerodynamic efficiency of the feathers. Feather shortening, a consequence of abrasion (Francis & Wood 1989), decreased flight ability in Starlings *Sturnus vulgaris* (Swaddle *et al.* 1996). In Rock Doves *Columba livia*, plumage deterioration caused by chewing lice negatively affected the capacity for thermoregulation (Booth *et al.* 1993) and survival (Clayton *et al.* 1999). In Barn Swallows *Hirundo rustica*, feather holes affect flight capacity, increasing time in flapping flight (Barbosa *et al.* 2002), decreasing survival (Pap *et al.* 2005), and delaying arrival in spring (Møller *et al.* 2004) as well as the onset of breeding (Pap *et al.* 2005). In sum, feather wear is costly for birds, and thus individuals would benefit from investing in the uropygial gland to reduce such costs. However, investment in the uropygial gland is constrained because the development of the uropygial gland itself infers a cost. Secretions from the uropygial gland consist of diverse waxes and oils (Haribal *et al.* 2005) that are energetically costly to produce, and the development of the uropygial gland is inhibited when birds are stimulated to produce an immune response (Piault *et al.* 2008).

Recent studies have shown that the uropygial gland has many functions in birds, including plumage maintenance, protection against parasites and sexual communication. More importantly, recent studies have shown that intraspecific variation in uropygial gland size covaries with characteristics such as plumage coloration (Galván & Sanz 2006, Roulin 2007, Moreno-Rueda 2010), the load of feather mites, bacteria and chewing lice (Galván *et al.* 2008, Møller *et al.* 2009, Moreno-Rueda 2010), and plumage quality (this study). These correlations between uropygial gland size and different traits probably have fitness consequences, which remain to be completely elucidated. The findings here show for the first time a relationship between uropygial gland size and plumage wear, suggesting that uropygial gland size is correlated with a decrease in feather wear by combating ectoparasites and/or improving feather integrity.

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