



Short Communication

Sexual Plumage Dichromatism in Two Laughingthrush Species

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ABSTRACT

The plain laughingthrush *Garrulax davidi concolor* (PL) and Elliotts laughingthrush *Trochalopteron elliotii* (EL), are two members of family Leiothrichidae, who are both assumed sexually monomorphic. We employed reflectance spectrometry to determine the plumage coloration in these two species in the hand. PL with dull plumage, the males had brighter head plumage than females, there was no significant difference in coloration of wing and breast plumage between two sexes. EL appeared relatively bright and polychrome plumages, and the males had extremely significantly higher carotenoid chroma than female in grayish-white tail end, however, there was no difference in orange wing patch and yellowish-brown hip plumage between sexes. Both male PL and EL had higher reflectance than female in wavelength ranges 300-700 nm. We argued that the patterns of sexual plumage dimorphism in these two babblers might be selective advantage in reducing nest depredation risk and brood parasitism, and it could be viewed as an indicator to assess the pressure of sexual selection between two sexes.

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Authors' Contribution

PL designed the research, coordinated and drafted the manuscript. HL and JX conducted the field work.

Key words

Sexual dichromatism, *Garrulax*, *Trochalopteron*, Sexual selection, Sexually monomorphic, Natural selection

Many passerine birds were assumed sexually monomorphic, with both male and female expressing similar plumage coloration either bright or dull (Ismar *et al.*, 2014), but in recent years, more and more empirical evidences were provided to testify that the sexual dichromatism in passerine birds is widespread (Badyaev and Hill, 2003; Mays *et al.*, 2006; Matysiokova and Remeš, 2010; Soler and Moreno, 2012; Dunn *et al.*, 2015; Dale *et al.*, 2015). In most cases, sexual dichromatism of plumage coloration originated from carotenoid-based (e.g. yellows, reds, oranges; Hill and McGraw, 2006), melanin-based (e.g. blacks and browns; McGraw *et al.*, 2005; McGraw, 2006; Hill and McGraw, 2006; Hubbard *et al.*, 2010; Ismar *et al.*, 2014) and structural coloration (Hill and McGraw, 2006; Ismar *et al.*, 2014).

Natural and sexual selection were employed to explain sexual difference of plumage coloration (Wallace, 1868; Darwin, 1871; Dale *et al.*, 2015; Dunn *et al.*, 2015). Natural selection favored dichromatism if the nest predation risk favors the duller females than males (Wallace, 1868; Soler and Moreno, 2012) and sexual selection also acted on the evolution of bird coloration in sexual differences (Darwin 1871; Dunn *et al.*, 2015), the sexual dimorphism may be an indicator to assess the strength of sexual selection

and give help to identify phenotypic traits which likely to be the subject of selection (Badyaev and Hill, 2003; Mays *et al.*, 2006), comparative analyses of sexual dimorphism among taxa and species is important to get fully understanding of the influences of natural and sexual selection on the origin and evolution of these differences.

The genus *Garrulax* and *Trochalopteron* within the family Leiothrichidae with at least 40 laughingthrush species in China (Dickinson, 2003). Many occur sympatrically in the mountains of southwest and central China. Babblers in these genus are all appear extremely sexually monomorphic, and could divide into two plumage types, monotonous color and polychrome, the former like the plain laughingthrush *Garrulax davidi* spp. which expresses greyish-brown plumage nearly in whole body, occurs widely in shrub-dominated habitats in both cultivated and uncultivated areas between 800-2600 m a.s.l. in northern China and is the only *Garrulax* species distributed in the Palaearctic region (Lei and Lu, 2006); the latter like the Elliotts laughingthrush *Trochalopteron elliotii*, which has bright orange wing patch, yellowish-brown hip plumage and white tail end, the babbler occurs widely in shrubs and mixed coniferous-deciduous forest at 800-4200 m a.s.l. of southwestern and central China (Lei and Lu, 2006). Both species seemingly sexually monomorphic, and exhibit socially monogamous, open-nesting and biparental care. At Lianhuashan Nature Reserve, southern Gansu Province, central China, they

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are equally prominent in the local passerine breeding community, the two species showed different plumage pattern and coloration, but both are assumed monomorphic. The object of present study is to detect if there are sexual dichromatism in plumage coloration in these two babbler species through reflectance spectrometry.

Materials and methods

We carried out the investigation at Badu village of Lianhuashan National Natural Reserve (34°40'67"N, 103°30'84"E, at 2100 m above sea level), in Gansu Province, central China during the breeding season of the year 2018 and 2019 (April to July). We used mist-net to capture the adults inside their territories after birds paired and colonized, the sex was determined by sexual size dimorphism (Liu and Sun, 2016, 2018).

For measurement of plumage coloration we used AvaSpec-ULS2048L ultra low straylight fiber optic spectrometer with AvaLight-DHc compact halogen light source and WS-2 white reference tile (Avantes BV, Eerbeek, Netherlands) for reflectance measurements in the hand within wavelength ranged 300-700 nm. The probe was used to provide light and sample reflected light stream, and used to measure body plumage parts which were closed to a black cloth to prevent ambient lights. As the plumage pattern of two species is distinctly different, we selected different body points in the two species to measure the size of head, breast, wing plumage of PL and wing orange patch, hip yellowish-brown patch and tail white end of EL. Each measurement was taken for five times and averaged for each bird. No stretching was done when measuring natural arrangement of feathers. Eighteen males and 15 females of PL and 23 males and 15 females of EL were measured. We obtained reflectance (in %) within the wavelength range 300-700nm by 1-nm increments, calculated total brightness and saturation following the method used by Shawkey *et al.* (2003). We measured carotenoid chroma as $(R_{450} - R_{700})/R_{700}$ (Peter *et al.*, 2004; Hill and McGraw, 2006), where R_{450} is the percent reflectance at 450 nm and R_{700} the percent reflectance at 700 nm. Black was used as control. After each bird was banded with a combination of coloured rings and a unique numbered metal ring on the right leg, the bird was immediately released. To further confirm sex of banded birds, more information on courtship display, sexual dimorphism in singing and copulation behaviour was collected by focal visual observations. All animal procedures were approved by the Institutional Animal Care and Use Committee of the Institute of Zoology, Chinese Academy of Sciences.

All data were normally distributed. One-way ANOVA were used to detect if there were individual reflectance variations across the breeding season in all measured body

plumage parts. The independent sample *t*-tests were used to investigate sex differences in measurements. The result values were presented as Mean \pm SD. All statistical tests were performed with SPSS 16.0 software for windows and all probabilities were two-tailed with alpha levels for statistical significance was set as $P < 0.05$.

Results and discussion

In both of these laughingthrush species, males have relative higher reflectance than females (Fig. 1A). In PL, the male head plumage brightness was significantly higher than females ($t = 5.781$, $P < 0.001$; Table I). We found no other variables significantly different. At wavelength > 400 nm, the males had higher reflectance than females (Fig. 1A). The results indicate sexual dichromatism in head plumage. In male EL, the carotenoid chroma of white patch in tail was extremely significantly higher than that in female ($t = 6.847$, $P < 0.001$; Table I). No significant differences were found in wing orange patch and hip

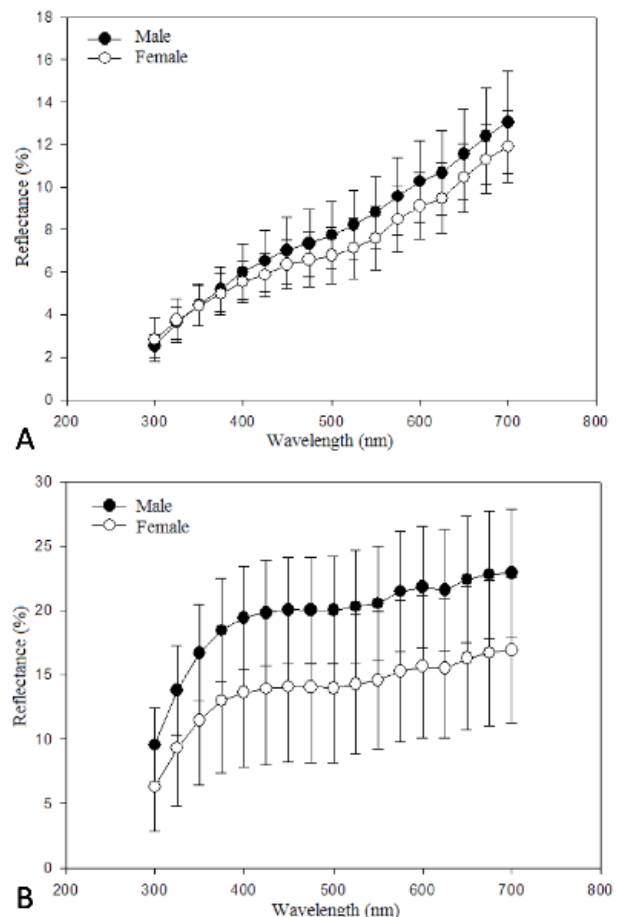


Fig. 1. Mean \pm SD percent reflectance for: A, plain laughingthrush *G. d. concolor*; male ($n = 18$) and female ($n = 15$). B, Elliot's laughingthrush *Trochalopteron elliotii*, male ($n = 23$) and female ($n = 15$).

yellowish-brown feathers. Males had higher reflectance than females at all wavelengths (300-700 nm, Fig. 1B). The results indicated sexual dichromatism in tail white plumage.

The pattern of sexual difference in the coloration of feathers in which male PL had with brighter head feathers than female may be correlated with its life history (Dale *et al.*, 2015). In this species, only females incubate the eggs. When female is sitting in the nest darker head reduces the predation risk. For the babbler species in which the female incubate the eggs, the duller plumage of females may have adaptive values for favoring incubation and reducing clutch depredation risk (Ekanayake *et al.*, 2015), both PL and EL are open-nesting. Previous studies suggest females in open-nesting species had more cryptic coloration than females nesting in cavities (Soler and Moreno, 2012; Ekanayake *et al.*, 2015). This implied that natural selection may strongly affect female coloration and drive the evolution of sexual dichromatism (Wallace, 1868; Soler and Moreno, 2012; Ekanayake *et al.*, 2015). In EL, the males tend to have brighter white tail end than females, but in this species, both the male and female incubate the eggs (Jiang *et al.*, 2007). In red-capped plover *Charadrius ruficapillus*, a ground-nesting and biparental incubation shorebird, the male has brighter and redder head plumage which incurred higher clutch depredation than females and attending

nest more at night to reduce nest predation (Ekanayake *et al.*, 2015). If both male and female EL are involved in EL parental care during incubation in turn reduces nest predation risk (Wallace, 1868; Soler and Moreno, 2012; Ekanayake *et al.*, 2015). We need further investigations on the rhythm and duty switching of incubation between sexes. The orange wing patch and yellowish-brown hip feathers indicate carotenoid-based coloration in EL, but we found no significant differences of brightness and saturation in these plumage parts. No individual variations were found in EL, because carotenoid do not appear to influence brightness (Saks *et al.*, 2003; Mays *et al.*, 2006). This is similar to Steere's *Liocichla steerii*, in which the female has bright yellow breast plumage than in males. This was because of difference in the underlying feather microstructure between sexes (Mays *et al.*, 2006), which was supported by previous studies (Mays *et al.*, 2004; Shawkey and Hill, 2005).

In both laughingthrushes, males have relative higher reflectance than females. In local breeding community, the large hawk cuckoo *Hierococcyx sparveroides* and Eurasian cuckoo *Cuculus canorus* are mainly nest parasites. The brood parasitism rate in these two babblers is higher than 10% (our unpubl. data). The duller female coloration might be an anti-parasitism adaptive strategy. This hypothesis needs further experimental studies.

Table I. Average reflectance properties (Mean \pm SD) of body feathers in 18 males and 15 females plain laughingthrushing *Garrulax davidi concolor* and 23 males and 15 females Elliott's laughingthrushing *Trochalopteron elliotii*. The significant difference ($P < 0.05$) is in bold.

Plumage patch		Male	Female	t	P
<i>Garrulax davidi concolor</i>					
Head	Brightness	3.11 \pm 0.41	2.58 \pm 0.29	2.429	0.029
	Saturation	0.17 \pm 0.008	0.17 \pm 0.01	0.096	0.925
	Carotenoid chroma	-0.47 \pm 0.03	-0.48 \pm 0.05	0.729	0.479
Wing	Brightness	0.85 \pm 0.01	0.85 \pm 0.01	-0.701	0.495
	Saturation	0.22 \pm 0.05	0.22 \pm 0.02	-0.252	0.804
	Carotenoid chroma	-0.33 \pm 0.06	-0.37 \pm 0.02	1.787	0.096
Breast	Brightness	0.85 \pm 0.01	0.85 \pm 0.01	-0.684	0.504
	Saturation	0.20 \pm 0.04	0.21 \pm 0.03	-0.399	0.695
	Carotenoid chroma	-0.40 \pm 0.07	-0.39 \pm 0.09	-0.127	0.901
<i>Trochalopteron elliotii</i>					
Wing orange patch	Brightness	0.87 \pm 0.013	0.86 \pm 0.012	1.867	0.07
	Saturation	0.12 \pm 0.036	0.13 \pm 0.035	-0.914	0.367
	Carotenoid chroma	-0.77 \pm 0.102	-0.70 \pm 0.136	-1.769	0.085
Hip yellowish-brown plumage	Brightness	0.84 \pm 0.009	0.85 \pm 0.037	-1.225	0.228
	Saturation	0.12 \pm 0.029	0.10 \pm 0.060	0.965	0.341
	Carotenoid chroma	-0.70 \pm 0.112	-0.72 \pm 0.142	0.520	0.606
Tail white end	Brightness	0.84 \pm 0.006	0.84 \pm 0.007	2.011	0.056
	Saturation	0.20 \pm 0.013	0.20 \pm 0.016	1.975	0.061
	Carotenoid chroma	-0.12 \pm 0.050	-0.17 \pm 0.057	3.043	0.004

Sexual plumage dichromatism is also considered to be correlated with sexual selection (Darwin, 1871; Dunn *et al.*, 2015), which acted on sexual differences, whereas, the natural selection acted on both sexes for the type of colour (Dunn *et al.*, 2015). The difference of plumage coloration between sexes are strongly correlated with morphology, breeding system and life history, such as sexual size dimorphism, parental care, geographical distribution and migration (Dale *et al.*, 2015). Both babblers are socially monogamous, and similar to each other in life history traits, but they express different patterns in plumage and coloration. This may be related to phylogenetic relationship. The two species are evolving in two separate clades (Luo *et al.*, 2009). In addition, we know little about their behaviours and variations of reproductive success. It also needs to be investigated if the plumage coloration is fluctuating with age. There is a lot of work to be done on life to get better understanding of how the natural and sexual selection drives the evolution of plumage coloration in babblers.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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