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QUANTITATIVE ANALYSIS OF THE VARIATION OF PLUMAGE COLOURATION IN *Dinopium* FLAMEBACK COMPLEX OF SRI LANKA

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ABSTRACT - *Dinopium benghalense* is one of the five species currently recognized in the old-world woodpecker genus *Dinopium*, which includes six subspecies or races. Sri Lanka had two subspecies of *D. benghalense; D. b. jaffnense* (Golden-back woodpecker) and *D. b. psarodes* (Red-backed Woodpecker). *D. b. jaffenese* is distributed in northern parts while the latter was in southern parts of the island. In the current world checklist of Bird life International, the *D. b. psarodes* has been elevated to a full species level; *D. psarodes* based on its plumage. Many colour variations can be observed within these Sri Lankan forms. Facial patterns and mantle colour are the key identification pointers, though actual intensity of the gold, yellows and red varies individually, making a detailed study of plumage an interesting undertaking for both the amateur birder and for the ornithologists alike. Here we document and validated basic plumage patterns and colour shown by the Sri Lankan *Dinopium* flamebacks. Seventy woodpeckers along a 430 km transect spanning across the island and 55 museum specimens were sampled. We evaluated 21 colour–based characters: Colour analyses were based on Munsell colour charts. We found scarlet, red, orange, golden yellow and olive-yellow forms in *Dinopium* complex in Sri Lanka. A clinal gradation is observed from North to South in these colour patterns.

KEY WORDS : *Dinopium psarodes*, *Dinopium benghalense*, Flameback woodpecker, Plumage cline, Speciation, Sri Lanka

INTRODUCTION

The Black-rumped Flameback, *Dinopium benghalense* Linneus (1758), also known as the Lesser Golden-backed Woodpecker, is distinguished from other species of *Dinopium* by its plain black rump and dark throat. The International Ornithology Committee (IOC; Gill & Donsker 2014) listed six subspecies or races for *Dinopium benghalense*, which are distributed across South Asia. The upper body colour of these six subspecies varies greatly, with the Southern birds having brighter tones than the Northern ones. Compared to the nominate race *D. b. benghalense* (Assam, Northeast India), *D. b. dilutum* (Pakistan, West India) has a pale yellow mantle; *D. b. tehminae* (Southwest India) has more buff on belly and *D. b. puncticolle* (Central and South India) is golden above. The colour of the upper body of the northern Sri Lankan race, *D. b. jaffnense* is olive-yellow, however, the southern Sri Lankan endemic, *D. b. psarodes* has a crimson mantle, back, upper coverts and tertials (Winker *et al.* 1996, Rasmussen & Anderton 2005, Gorman 2014). Clements, on the other hand, recognized only four subspecies (www.birds.cornell.edu/clementschecklist/2014-overview/) and left *D. b. jaffnense* as a synonym in *D. b. puntecolle*. In the current checklist of Bird life International (del Hoyo *et al.* 2014), *D. b. psarodes* has been elevated to a full species level based on the scoring system introduced by Tobias *et al.* (2010) for the European birds. In this paper we adhere to this new classification; Red-backed Flameback (*Dinopium psarodes*; also known as Lesser Sri Lanka Flameback).

Many colour variations can be observed within these Sri Lankan races (Legge 1880,

Wait 1920,1931, Baker 1927, Whister 1944, Philips 1953, Henry 1971, Ali & Ripley 1983, Wijesinghe 1994, Rasmussen & Anderton 2012, Lamfuss, 2013, Gorman 2014). Facial patterns and mantle colour are the key identification pointers, though actual intensity of the gold, yellows and red varies individually, making a detailed study of plumage an interesting undertaking. Freed et al. (2015) have documented a hybrid 'swarm' of *Dinopium* woodpeckers in Sri Lanka. They describe eight hybrid types based on colour using 32 personal field observation data. However such colour observations are subjective and may vary depending on daylight, observed angle, distance, type of equipment used and observer. Here we quantified the plumage colour variations in *Dinopium* woodpeckers using a systematic method, as part of a long-term research programme on hybridization of *Dinopium* flameback woodpeckers in Sri Lanka. To our knowledge, this is the first study to evaluate such variations using systematically samples dataset. Here we document basic plumage patterns and colour shown by the Sri Lankan *Dinopium* flamebacks.

METHODOLOGY

During January to December 2013 we captured a total of 70 flamebacks using mist nets and dip nets along a 432 km transect line extending from the range of *D. psarodes* (Matara District, Southern Province; $06^{0}04.121$N / $79^{0}55.517$E) into the range of *D. b. jaffnense* (Jaffna District, Northern Province; $09^{0}46.298$N / $80^{0}07.397$E). Museum skins were also obtained from the National Museum of Sri Lanka. We examined 55 skins collected during 1904 to 1969 from different collections in the National museum, and from the Legge (1868 to 1877) collection.

We evaluated 21 colour–based characters: colour of the fore head, crown, nape, mustache (malar) band, face region, supercilium, iris, chin, neck (throat), breast, abdomen, scapulas, back (mental), rump, upper tail covers, tail, belly, primaries, secondaries, middle coverts, and upper and lower wing coverts. Percentage red colour in the rump is also measured. Colour analyses were based on Munsell (1976) colour charts. We measured three plumage characters; moustache width (measured ventral to the eye), width of the face region, and the supercilium. All measurements were determined using a caliper (0.01 mm). We visually scored the amount of red and yellow (carotenoid pigments) colour in different parts of the body; crown colour (Black 0, yellow 1, orange 2, red orange 2.5, red 3), mantle colour (yelow1, orange 2, red 3), rump colour (Black 0, yellow 1, orange 2, red 3) and upper coverts (black 0, golden yellow 0.5, yellow 1, orange 2, red orange 2.5, red 3). We also compared these colours in the standard color chart and recorded percentage of RGB values and CMYK values (Munsell 1976).

To summarize patterns of co-variation between plumage variables, we carried out principal components analysis (PCA). The principal axis method was used to extract the components followed by oblique rotation. PCA was done using SPSS (IBM corporation)

TABLE 1: Munsell colour chart values for *Dinopium* flameback plumage colour

Color	Color chart values	
	R,G,B	C,M,Y,K
Yellow	R=255, G=242,B=000	C=0%,M=0%,Y=100%,K=0%
Golden yellow	R=255,G=215, B=000	C=1%,M=13%,Y=100%,K=0%
Orange	R=238,G=118,B=000	C=3%,M=65%,Y=100%,K=0%
Orange-reddish	R=255,G=069, B=000	C=0%,M=87%,Y=100%,K=0%
Red	R=255,G=000,B=000	C=0%,M=99%,Y=100%,K=0%

RGB [red (R), green (G) and blue (B)] and CMYK [cyan (C), magenta (M), yellow (Y) and black (K)]

RESULTS

A total of 70 individuals were sampled across the island that include 41 *D. psarodes*-like red plumage, 17 *D. b. jaffnense*-like yellow plumage and 12 intermediate orange plumage. From the museum collection, we sampled 55 individuals and out of this 25 had red plumage, eight were yellow plumage and 22 had intermediate orange plumage. Plumage characters showed a clinal variation along the line transect from Jaffna to Matara (Fernando and Seneviratne 2014, Fernando *et al.*, manuscript in revision). All individuals captured from Jaffna peninsula had yellowish plumage. All individuals captured from the core of the wet-zone had red

FIGURE 1: Colour variation of sampled *Dinopium* flamebacks in Sri Lanka; **a**. *D. psarodes* - red plumage, **b**. *D. b. jaffnense* - yellow plumage, **c**. Female **d**. Male, **e**. Orange form, **f**. Golden-yellow form, **g**. reddish-orange form, **h**. Olive-yellow form, **i**. Crimson-red form, **j**. Dry-zone male, **k**. Wet-zone male, **l**. reddish rump of a southern Wet-zone bird. (Images a & b courtesy of V. Weeratunga).

plumage. The intermediate plumage colour (orange) was found in varying proportions in the North central dry zone; from the Southern border of Wilpattu National Park (Northwestern Province: 08037.450 N / 80007.675 E) up to Kilinochchi (Northern Province: 09022.583N0, 80025.136E0).

Figure 1 shows the plumage colour gradient shown by the individuals of *D. psarodes* and *D. b. jaffenense*. The crown region of all captured birds are red (Figure 1c,d). *Dinopium* flamebacks have plain black nape and upper mantle (Figure 1a,b). Back colour varies according to race (Figure 1 a,b). The back of the flameback has two predominant colour types (Figure 1 a,b): namely crimson-red and golden-yellow representing the two subspecies. However there are intermediate colour forms ranging from olive-yellow (Figure 1h), yellow (Figure 1f), orange-mantle (Figure 1g), orange (Figure 1e) to crimson-red (Figure 1i). In the rump region, black, yellow, orange and red colours are seen in the feather tips (Figure 1e,f,h). Secondaries and coverts show olive-yellow, golden yellow, orange and crimson red (Figure 1h,i). In extreme south the *D. psarodes* has crimson-red shading in the primaries as well (Figure 1 i). Rump also shows a gradation from north to south. The birds in the dry-zone (North) and northern wet-zone have black rump as described in the literature (Figure 1f,g). Birds from the southern most wet-zone had reddish rump (Figure 1l). Similarly, the amount of black and white plumes on the facial region and upper wing coverts showed slight variation with the climate. The dry-zone and intermediate-zone birds of all colour types mostly have broader white supercilium and malar stripe (moustache) (Figure 1a,b,j). Birds in the wet-zone have less white (hence more grey-black) faces (Figure 1c,i,k). Upper wing coverts are dotted with two rows of white spots in dry- and intermediate-zone birds (Figure 1a,b), however the wet-zone birds have less prominent spots in the coverts

FIGURE 2: Variation of back colour in *Dinopium* flamebacks in the national collection (Courtesy of the Department of National Museums, Sri Lanka).

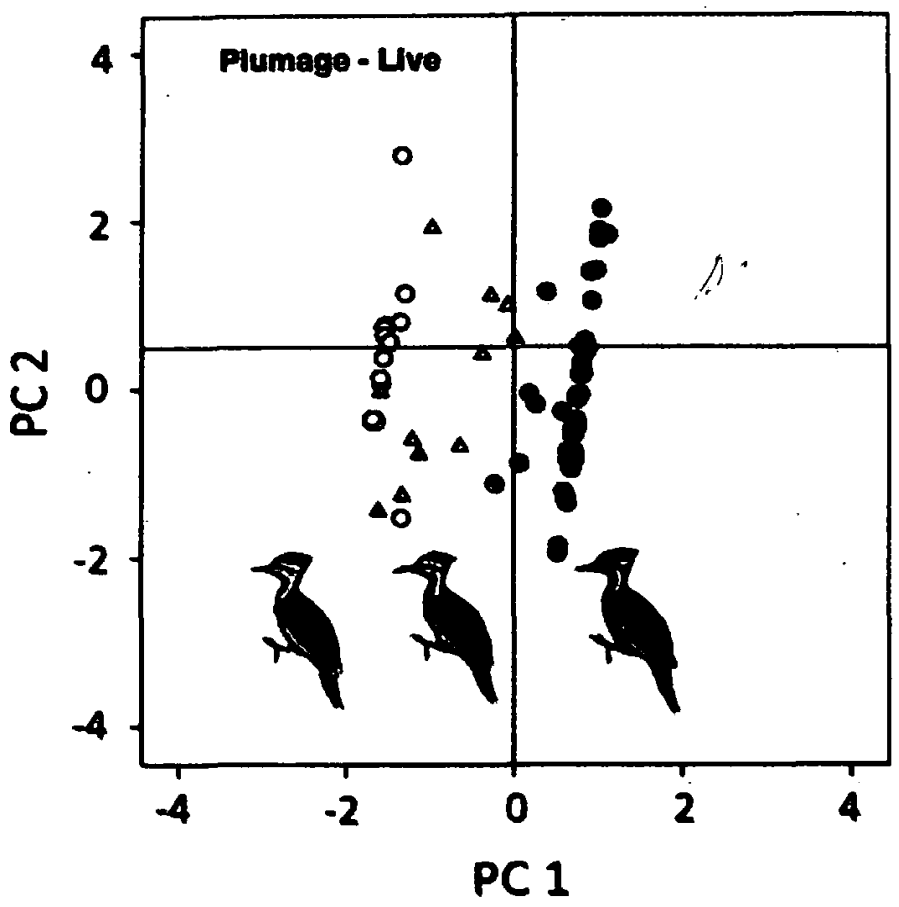

FIGURE 3: Distribution of seven plumage characters, which have showed variation across the known subspecies of *Dinopium* flamebacks in Sri Lanka, in the Principle Axis 1 and 2. The colour of the data point corresponds the back colour of the flameback; Yellow circles, yellow birds; Red circle, red birds; Orange triangles, orange birds (Flameback images are after Winker et al. 1995).

(Figure 1i). The throat is black in all birds (Figure 1c,d,j,k). Bill is blackish, iris chestnut, legs gray in all forms (Figure 1b). *Dinopium* flamebacks are sexually dichromatic; male has red crown and forehead (Figure 1d), female has red crown and a black forehead spotted with white spots (Figure 1c). In all birds, the breast and the belly have dark chevrons, scales and streaks (Figure 1c).

The specimens at the national collection also showed the same gradation that we have observed in live specimens sampled across the north – south gradient of the island (Figure 2). Table 2 and Figure 3 summarize the distribution of plumage characters and the proportion of variance captured by PCs in PCA. The PC1 captured 52.5% of the variation, correlating roughly with all characters that tend to differ between *D. psarodes* and *D. b. jaffnense* (Figure 3). The orange-backed *Dinopium* flamebacks are sandwiched between the red (*psarodes*) and yellow (*jaffnense*) birds (Figure 3).

DISCUSSION

We found crimson-red, red, orange-red, orange, golden yellow and olive-yellow varieties in *Dinopium* allospecies complex in Sri Lanka. Individuals with darker plumage (red) are abundant in the wet-zone. Even in the dry- and intermediate-zones, individuals with darker

TABLE 2: Variation explained and factor loadings of the first two Principle Components (PC) produced in the Principle Component Analysis (PCA) of plumage traits. The loading factors that are contributing heavily towards the PC are in bold text.

	Field samples (N=70)		Museum samples (N=55)		
Variance explained	52.50%	23.72%	38.02%	19.39%	13.64%
Factor loading					
Back colour	**0.981**	-0.099	**0.911**	-0.209	0.080
Rump colour	**0.976**	-0.135	**0.904**	-0.223	-0.020
Secondary's and converts	**0.870**	-0.107	**0.938**	-0.188	-0.119
Supercilium width	-0.222	**0.762**	-0.252	**0.747**	0.134
Face width	0.047	**-0.634**	0.224	0.100	**0.821**
Malar stripe width	-0.036	**0.788**	-0.134	**0.851**	-0.027

plumage (red, orange-red and orange) were mostly found closer to main river systems. Mannar Island of the Northwestern coast, however, seems to be a notable exception. The effect of climate on plumage is not very clear, because the red forms are found well within the Eastern and central dry-zone. The higher the humidity the darker and bigger the individual is (Fernando *et al.* – manuscript in review). The more humid and relatively dark forests of the wet-zone of Sri Lanka might have caused this pattern. Near the mainland India the opposite is true and a similar plumage can be found in both the mainland and the island (Fernando and Seneviratne 2014).

Birds use carotenoid pigments to develop striking red, orange and yellow patches of colour that are used as species recognition cues (Whitfield 1987), signals of quality, to attract mates (Andersson 1994) or to evade predators (Price 2008). To develop carotenoid pigments, birds must acquire pigment precursors from diet and deliver those to feathers for pigmentation (Prum *et al.* 2012). Therefore the diet and the environment could contribute to the unique red colouration of the Sri Lankan endemic flameback. The variation that we report here could also be a result of local adaptations resulting isolation-by-distance, which could cause genetic and phenotypic divergence in *Dinopium* (Fernando and Seneviratne 2014).

We have previously shown that the limited gene flow across climatic (rainfall) gradient might have played a role in the observed pattern and resulted endemicity in this group (de Silva *et al.* 2014). The effect of gene flow from mainland congeners to the endemic taxa is rather limited; therefore the distance and climatic barrier could act as a barrier to gene flow and insulate endemic taxa (de Silva *et al.* 2014). This is probably reflected in the high endemicity of birds seen in Sri Lanka where about one third of resident phenotypes are endemic to the island. The genes entering to the island through recent colonization of mainland forms (yellow forms) could create hybrids in the coastline near mainland (de Silva *et al.* 2014). The fitness of the resulting orange plumage types however, is not known. To further explore these patterns of speciation in flamebacks in Sri Lanka, we are conducting a detailed long-term study using morphometrics, plumage, mating behaviour and genomics of these unique group of birds.

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REFERENCES

Andersson, M. (1994). *Sexual selection*. Princeton University Press, Princeton, NJ, USA.

Ali, S. and S.D. Ripley (1983). *Hand book of birds of India and Pakistan, together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. Oxford University Press, London.

Baker, E.C.S. (1927). *The fauna of British India including Ceylon and Burma*, Vol, 4, Taylor and Francis, London.

de Silva, K.M., P.S. Dodangoda and S.S. Seneviratne (2014). A peculiar biogeographic history for a flameback woodpecker revealed through high throughput sequencing. *51st meeting of the Association of Tropical Biology and Conservation*, Cairns, Queensland, Australia.

del Hoyo, J., N.J. Collar, D.A. Christie, A. Elliott and L.D.C. Fishpool (2014).

HBW and BirdLife International Illustrated Checklist of the Birds of the World. Lynx Edicions, Barcelone, Spain.

Fernando S.P. and S.S. Seneviratne (2014). Local adaptations and distance away from the Indian mainland had contributed towards endemism in Dinopium Flamebacks in Sri Lanka. *4th Student Conference on Conservation Science*, Bangalore, India (available online: http://www.sccs-bng.org/2014/abstracts/158)

Freed, L.A., D. Warakagoda, R.L. Cann, U. Sirivardana and U. Hettige (2015). A hybrid swarm of *Dinopium* woodpeckers in Sri Lanka. *Wilson Journal of Ornithology* **127:**13-20.

Gill, F. and D. Donsker (2014). IOC World Bird List (Version 4.4). doi : 10.14344/IOC.ML.4.4.

Gorman, G. (2014). *Woodpeckers of the world: the complete guide*, Christopher Helm, London.

Henry, G.M. (1971). *A Guide to the Birds of Ceylon*, 2nd ed, Oxford University Press, London.

Lamsfuss, G. (2013). Some comments on the Ceylon golden-back and red backed woodpeckers, *Ceylon Birds Club Notes*, May:106-116.

Legge, W.V. (1880). *A history of the birds of Ceylon*. Tisara Prakasakayo, Dehiwala, Sri Lanka.

Munsell (1976). Munsell book of color. Munsell color company. Munsell/Macbeth/ kollmorgan corp.

Price, T. (2008). *Speciation in birds*. Roberts & Company, Greenwood Village, CO, USA.

Philips, W.W.A. (1953). Nests and eggs of Ceylon birds (Picidae and capitonidae). *Ceylon journal of Science*, Vol. XXV.

Prum, R.O., A.M. LaFountain, J. Berro, M.C. Stoddard and H.A. Frank (2012). Molecular diversity, metabolic transformation, and evolution of carotenoid feather pigments in cotingas (Aves: Cotingidae). *Journal of Comparative Physiology* B, **182:** 1095-1116.

Rasmussen, P.C. and J.C. Anderton (2012). *Birds of South Asia, The Ripley Guide*. Smithsonian National Museum of Natural History, Washington D.C. and Michigan State University and Lynx Edicions. Barcelona, Spain.

The Clements Checklist of Birds of the World. Online available: www.birds.cornell.edu/clementschecklist/2014-overview

Tobias, J.A., N. Seddon, C.N. Spottiswoode, J.D. Pilgrim, L.D.C Fishpool and N.J. Collar (2010). Quantitative criteria for species delimitation. *Ibis*. **152:**724–746.

Wait, W.E. (1931). *Manual of the Birds of Ceylon*, 2nd ed. Dulau & Co. Ltd. London.

Whister, H. (1944). The avifaunal survey of Ceylon conducted jointly by the British and Colombo Museums. *Spolia Zeylanica*. **23**

Whitfield, D.P. (1987). Plumage variability, status signaling and individual recognition in avian flocks. *Trends in Ecology and Evolution*. **2:**13-18.

Wijesinghe, D.P. (1995). Distribution of woodpeckers in Sri Lanka, *Ceylon Birds Club Notes*, June:58-64.

Winkler, H., D.A. Christie and D. Nurney (1995). *Woodpeckers: An Identification Guide to the Woodpeckers of the World*. Houghton Mifflin Company, New York, USA.

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