

SPECIAL REPORT

A review of the occurrence and role of blue facial skin in South-East Asian birds

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Introduction

Tropical rainforests are ecologically complex environments (Laurance & Bierregaard 1997) with diverse foliage structure, micro-habitats and, consequently, light environments. However, how the light in these environments has influenced the evolution of visual communication in tropical animals, particularly birds, has received comparatively little attention and research, even though forests exhibit diverse variations in light conditions across the ultraviolet (UV) and visible spectrum, and this is clearly of importance to animal vision. The diversity of plumage colours and patterns, as well as bare skin colour and display behaviour, in tropical forest birds is testament to the importance of light on their ecology and is a worthy starting point for any attempt to study visual communication in animals.

Endler's (1993) landmark paper was one of the earliest to describe spatio-temporal heterogeneity in light environments across multiple forest sites from the Neotropics to South-East Asia. This study showed four distinct light habitats (forest shade, woodland shade, small gaps and large gaps), each with characteristic ambient light spectra. Such heterogeneity results from the influence of vegetation, the height above the forest floor, the angle of the sun and cloud cover. In rainforest, two major contrasting light environments exist, a canopy rich in UV and blue wavelengths, and an understorey rich in green and orange wavelengths (Gomez & Théry 2004).

Perception of colour patterns in animals against a visual background varies with any ambient light since images of colour patterns as perceived depend on the reflectance of coloured patches in the pattern and spectrum present in ambient light, with clear implications for the evolution of animal vision and visual signals (Théry 2006). Given this, Endler (1993) and many others predicted that the coloration of a forest animal would be an outcome of interactions between ambient light colours in its habitat, as well as (perceived) reflectance colours. Ecologically, this is significant because an animal's coloration should render individuals more conspicuous to conspecifics (e.g. potential mates) and more cryptic to predators, and will depend heavily on the variation of the light during the day. Subsequent studies have provided a growing body

of evidence in support of these predictions (Endler & Théry 1996, Uy & Endler 2004, Gomez & Théry 2004, Théry *et al.* 2008).

Much work has been carried out to understand how light environments in the forest setting drive the evolution and use of visual signals in the communication systems of forest species, especially in tropical rainforests. For example, Endler & Théry (1996) investigated the conditions in lek sites of three Neotropical forest birds and found them to be highly specific to (visible) light environments which offered significant visual contrast with the displaying bird, enhancing the conspicuousness of males to potential mates. Each of the three species in their study had different plumage colours and used differing light conditions offered by specific locations and times. Other studies, e.g. Théry *et al.* (2008), have documented how insects, specifically longhorn beetles, exploit light environments to enhance their conspicuousness to conspecifics within the short period of dusk lighting. As well as studies in the 'visible light environment', the frequency of UV reflectance in bird plumage (Eaton & Lanyon 2003) and experiments on UV-reflecting ornaments in birds highlight the importance of visual UV cues for communication in birds (Hausmann *et al.* 2002).

Although there is growing interest in the use of visually conspicuous signals (perceptible in both visible light and UV wavelengths) in bird communication, the exact functions of many of these signals, especially bright skin coloration, remain poorly understood. Prum & Torres (2003) analysed structural coloration in the skin tissues of many tropical forest species across multiple taxonomic groups, including a number of South-East Asian birds, and noted that structurally coloured skin is prevalent in forest interior birds, especially cuckoos, trogons and many passerines, and is likely to have evolved multiple times in families with forest-dwelling representatives. The use of such visual signals is still poorly understood and, while it is possible that it enhances the conspicuousness of the signaller, more field-based and laboratory studies are needed to clarify this.

Tropical forests cover lowland and montane South-East Asia and support one of the richest and most endemic avifaunas globally (Sodhi *et al.* 2006). The most species-rich bird communities are

found in lowland rainforests, notably in Sundaic South-East Asia (Peninsular Malaysia, Sumatra and Borneo) where as many as 240 species can occur at a single forest site (Wells 1999). However, habitat loss and degradation is rapid, extensive and now threatens a large proportion of the region's avifauna, especially that in lowland rainforests (Lambert & Collar 2002, Sodhi *et al.* 2006). From an ornithological standpoint, this loss of pristine forest habitat is not only an urgent conservation issue, but also equates to lost opportunities in studying and understanding the diverse and poorly understood behavioural and sensory ecology of the region's many rainforest birds (Lim *et al.* 2008), many of which are now threatened with extinction. In this review, we survey the occurrence of coloured skin patches in Sundaic lowland and montane forest birds in Peninsular Malaysia, Sumatra and Borneo. We focus on species with blue/violet (short wavelength reflecting) bare skin since this is predicted to occur more frequently in habitats (i.e. forest understorey) where blue and UV wavelengths are rare in ambient light (Vorobyev & Osorio 1998). We also discuss the occurrence and frequency of such features in relation to forest environments using field observations of specific forest understorey species.

Occurrence of blue-coloured facial skin in South-East Asian birds

Based on a review of three field guides (MacKinnon & Phillipps 1993, Robson 2000 and Myers 2009) covering Sundaic South-East Asia, we found at least 29 species (approximately 12%) of lowland evergreen forest birds in the region with

Plate 1. The Malaysian Railbabbler *Eupetes macrocerus* is known for its elaborate display involving bowing and calling when its bright blue neck-patches are exposed, Panti Forest, 30 April 2011.



Plate 2. Chestnut-winged Babbler *Stachyris erythroptera*, the (presumed male) bird on the left exposing blue neck skin-patches during display, Upper Pierce reservoir, Singapore, 6 February 2010.

unfeathered facial skin with varying intensities of blue and violet (Table 1), while a smaller proportion of strictly montane species (8% of the total) shared these characteristics (Table 2). Although a number of species possess red facial

Plate 3. Chestnut-rumped Babbler *Stachyris maculata*, a related species that also exposes blue neck skin during display, Panti Forest, Malaysia, 10 June 2009.



Table 1. Lowland forest birds in Sundaic South-East Asia with light blue/blue-violet bare skin.

Family	Species	Bare skin area	Colour	Forest strata
Phasianidae	Crested Fireback <i>Lophura ignita</i>	Face	Blue	Forest floor
	Bulwer's Pheasant <i>Lophura bulweri</i>	Face	Blue	Forest floor
	Great Argus <i>Argusianus argus</i>	Head, neck	Blue	Forest floor
Bucerotidae	Helmeted Hornbill <i>Rhinoplax vigil</i>	Pouch	Light blue	Canopy
	Bushy-crested Hornbill <i>Anorrhinus galeritus</i>	Face	Light blue	Canopy
	White-crowned Hornbill <i>Aceros comatus</i>	Face	Light blue	Canopy
	Wrinkled Hornbill <i>Aceros corrugatus</i>	Face, pouch	Blue	Canopy
	Wreathed Hornbill <i>Aceros undulatus</i>	Pouch	Blue	Canopy
Columbidae	Cinnamon-headed Green Pigeon <i>Treron fulvicollis</i>	Orbital	Blue	Canopy
	Thick-billed Green Pigeon <i>Treron curvirostra</i>	Orbital	Green-blue	Canopy
Meropidae	Red-bearded Bee-eater <i>Nyctornis amictus</i>	Orbital	Blue	Canopy
Cuculidae	Raffles's Malkoha <i>Phaenicophaeus chlorophaeus</i>	Face	Blue	Canopy/understorey
	Red-billed Malkoha <i>Phaenicophaeus javanicus</i>	Face	Blue	Canopy
	Bornean Ground Cuckoo <i>Carpococcyx radiatus</i>	Face, bill	Blue	Forest floor
	Sumatran Ground Cuckoo <i>Carpococcyx viridis</i>	Face, bill	Violet-blue	Forest floor
Picidae	Crimson-winged Woodpecker <i>Picus puniceus</i>	Orbital	Blue	Understorey/canopy
Trogonidae	Red-naped Trogon <i>Harpactes kasumba</i>	Face	Blue	Understorey/canopy
	Diard's Trogon <i>Harpactes diardii</i>	Face	Violet-blue	Understorey/canopy
	Cinnamon-rumped Trogon <i>Harpactes orrhophaeus</i>	Brow	Blue	Understorey
	Scarlet-rumped Trogon <i>Harpactes duvaucelii</i>	Brow	Blue	Canopy
Eupetidae	Malaysian Railbabbler <i>Eupetes macrocerus</i>	Neck	Blue	Forest floor
Monarchidae	Black-naped Monarch <i>Hypothymis azurea</i>	Orbital	Blue	Understorey
	Asian Paradise-flycatcher <i>Terpsiphone paradisi</i>	Orbital	Blue	Understorey/canopy
Timaliidae	Large Wren Babbler <i>Napothera macrodactyla</i>	Brow	Blue	Forest floor/ understorey
	Black-throated Wren Babbler <i>Napothera atrigularis</i>	Brow	Blue	Forest floor/ understorey
	Pin-striped Tit Babbler <i>Macronous gularis</i>	Orbital	Blue	Understorey
	Bold-striped Tit Babbler <i>Macronous bornensis</i>	Orbital	Blue	Understorey
	Fluffy-backed Tit Babbler <i>Macronous ptilosus</i>	Face, neck	Blue	Understorey
	Chestnut-rumped Babbler <i>Stachyris maculata</i>	Face, neck	Blue	Understorey
	Chestnut-winged Babbler <i>Stachyris erythroptera</i>	Face, neck	Blue	Understorey

Table 2. Montane forest birds (occurring above 1,000 m) in Sundaic South-East Asia with blue bare skin.

Family	Species	Bare skin area	Colour	Habitat
Trogonidae	Sumatran Trogon <i>Apalharpactes mackloti</i>	Face	Blue	Understorey/canopy
	Whitehead's Trogon <i>Harpactes whiteheadi</i>	Face	Blue	Understorey/canopy
	Orange-breasted Trogon <i>Harpactes oreskios</i>	Orbital	Blue	Understorey/canopy
	Red-headed Trogon <i>Harpactes erythrocephalus</i>	Face	Blue	Understorey/canopy
Timaliidae	Sunda Laughingthrush <i>Garrulax palliatus</i>	Face	Light blue	Understorey
	Black Laughingthrush <i>Garrulax lugubris</i>	Face	Blue	Understorey
	Bare-headed Laughingthrush <i>Garrulax calvus</i>	Head	Blue	Understorey

skin, this characteristic appears to be taxonomically less widespread, being largely confined to galliformes (e.g. Salvadori's Pheasant *Lophura inornata*), woodpeckers (e.g. Rufous Piculet *Sasia abnormis*), pigeons (e.g. Mountain Imperial Pigeon *Ducula badia*) and some cuckoo species (e.g. Chestnut-breasted Malkoha *Phaenicophaeus curvirostris*). None of the passerine species in the region studied has red facial skin.

Amongst species with blue facial skin, this feature either covers the whole face or is located around the eye, especially the orbital (eye-ring)

region (e.g. Asian Paradise-flycatcher *Terpsiphone paradisi*, Japanese Paradise-flycatcher *T. atrocaudata* [a winter visitor to the area] and *Harpactes* trogons), near the base of the bill (hornbills) and, in some species, the neck and throat region. For example, Malaysian Railbabbler *Eupetes macrocerus* (Plate 1) and three understorey-dwelling babbler—Chestnut-winged Babbler *Stachyris erythroptera* (Plate 2), Chestnut-rumped Babbler *S. maculata* (Plate 3), and Fluffy-backed Tit Babbler *Macronous ptilosus* (Plate 4)—possess some extent of partially concealed blue skin on the



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Plate 4. Fluffy-backed Tit Babbler *Macronous ptilosus* also exposes blue bare skin during display sequences, Pantli Forest, 4 July 2011.

neck which expands and becomes very prominent during vocalisations and possibly courtship display. This feature is especially exaggerated in the Railbabbler where the blue neck skin extends massively during vocalisation (Yong 2005, Bowler 2008, Foley 2011). Both ground-dwelling *Napothera* wren babblers in the region, and some species of understory-dwelling *Stachyris* and *Macronous* babblers, also have varying extents of blue skin on more than one part of the face, usually surrounding the eye, and on the neck (Table 1).

Outside Sundaic South-East Asia, blue facial skin appears to be less frequent in birds in other parts of the region, and is virtually non-existent in temperate east Asian birds. Other prominent examples from South-East Asia include two species of wattled broadbills (Visayan Wattled Broadbill *Eurylaimus samarensis* and Mindanao Wattled Broadbill *E. steerii*) in the Visayan islands and Mindanao, Philippines, the recently described Bare-faced Bulbul *Pycnonotus hualon* of Lao's limestone forests and the Coral-billed Ground Cuckoo *Carpococcyx renauldi*. A number of other babblers, paradise-flycatchers and monarchs also possess these features.

Behavioural role of blue skin-patches

How these patches of bare coloured skin are used as visual signals by birds in a forest environment has never been studied in tropical South-East Asia. However, tissue analysis suggests that such characters are likely to have evolved many times in different taxonomic groups as an adaptive response to unique light environments in the rainforest understory and forest floor (Prum & Torres 2003), which are characterised by spectra

high in green and orange but low in blue and UV wavelengths. Across the tropics, the occurrence of colourful blue/violet facial skin, especially around the eyes, is strikingly frequent in rainforest birds and is particularly well represented in cuckoos, suboscine passerines (e.g. antbirds, asities, broadbills) and oscine passerines (e.g. batises, monarchs, vangas, babblers) (Prum & Torres 2003).

It is possible that blue facial skin functions as a visual signal in sexual communication for a number of species, possibly as an indicator of fitness as suggested by the use of bare part or skin coloration in other species. Velando *et al.* (2006) noted that the Blue-footed Booby's *Sula nebouxii* foot colour became duller when birds were malnourished, but regained its brightness after feeding, influencing female reproductive investment in the process: if a male's foot colour fades after the laying of the first egg, the female lays a smaller second egg. In the Oriental region, one of the best-known avian courtship displays is that of the Bulwer's Pheasant *Lophura bulweri* of hill and submontane forest in Borneo. During display, the males enlarge their blue facial wattles and spread their white tails to attract females present at the lek (Phillipps & Phillipps 2011).

The Malaysian Railbabbler, a lowland forest specialist of Sumatra, Peninsular Malaysia and submontane parts of Borneo, has an unusual display, the behavioural function of which is still not well understood (Yong 2005). It typically involves the calling bird bowing its head forward and downward each time it sings, exposing a large bright blue patch of skin on the neck which contrasts with the bird's rich chestnut plumage and black facial mask but which is otherwise largely concealed below the feathers (Bowler 2008). The displaying bird also fans its wing- and tail-feathers and points its head upward at a low angle as it sings in the presence of a second individual (pers. obs.). The fact that these displays are not associated with aggressive behaviour suggests that it may be the Railbabbler's courtship display. A very similar display is made in response to taped playback: the calling bird bows and exposes its expanded blue neck skin, suggesting that the display may also be used as a territorial response to intruding conspecifics (Foley 2011). Like the Railbabbler, a number of understory and ground-dwelling babblers also possess varying amounts of blue facial skin, including at least seven lowland forest and three montane species in the region (Tables 1 & 2). Many *Macronous* tit babblers have some blue facial skin around the eye and two of the lowland *Napothera* wren babblers exhibit a small patch of blue skin behind the eye. However, the feature appears to be most common in the closely related *Stachyris* and *Macronous* babblers where it occurs

on the loreal, orbital and neck areas. Chestnut-winged Babbler, a common understorey species, is known to engage in a rather unusual display that enhances the patches of blue skin on its neck. Birds that have been exposed to a playback of their calls have been seen to turn head-on and bow their heads to the ground, while simultaneously exposing a bright blue patch of bare skin on both sides of the neck, suggesting either a territorial or courtship display. Furthermore, paired birds also engage in a similar display where one bird, presumably the male, calls to its mate while constantly exposing the blue skin (Choo 2010). Similarly, pairs or groups of Chestnut-winged Babblers have been observed to perch close together, some members of the group swaying their bodies from side to side, raising their heads forward and upward with regular exposure of the bare blue skin on the neck (Wells 2007).

It is therefore not surprising that the Fluffy-backed Tit Babbler, an understorey babbler sympatric with Chestnut-winged Babbler in lowland forests, shares a superficially similar display. An understorey specialist confined to lowland evergreen and swampy forests in the Thai-Malay Peninsula, Sumatra and Borneo, the Fluffy-backed Tit Babbler skulks in thick vegetation, usually in pairs or small family groups (Wells 2007). Pairs often perch low, well concealed in the understorey, and engage in a display where one bird erects its crown feathers, producing a series of harsh scratchy notes and exposing the bright blue skin along the neck each time it does so. This behaviour may last for 10–20 minutes before the birds are flushed or move on to forage elsewhere. A similar display is seen in the Pin-striped Tit

Babbler *Macronous gularis* but, interestingly, this species show pinkish rather than blue neck skin when calling (pers. obs.) (Plate 5).

It is interesting to note that four sympatric forest understorey birds, one of which— Malaysian Railbabbler—is not closely related to the other three (Jönsson *et al.* 2007), have evolved displays that involve exhibition of bright blue neck skins-patches, made prominent when the bird is calling. Whilst it remains unknown if these characters are also strongly UV-reflecting features, patches of blue skin clearly have significance as a display feature given the light conditions of the understorey (Gomez & Théry 2004) and the visual contrast it offers against generally brownish-coloured understorey birds. On the other hand, these features may have additional roles as adaptations to forest understorey conditions. For example, it has been suggested that Neotropical antbirds, which are ecologically similar to Asia's babblers, have bare skin around the eye as an adaptation to enhance birds' hunting capabilities when foraging in dense vegetation by improving eye movement (Skutch 1996).

Nearly all of what is known about the role of blue facial skin and associated behaviour is based on casual observations of a few common species. Most other species with similar features, including nearly all trogons and many cuckoo species, have never been studied. This further underscores the paucity of life history and behavioural ecology knowledge of most South-East Asian birds (Sodhi *et al.* 2006). Given the diversity of species, colours and ornaments in tropical species, particularly in South-East Asia, there must also be a diversity of communication systems that have never been studied before, as well as other aspects of behavioural ecology. In fact, recent studies, whether experimental work or structural analyses of bird pigmentation, reveal a diversity of visual communication mechanisms in birds that stretches across the visible and UV spectra.

Conservation implications for South-East Asian forest birds

From a conservation perspective, the rapid degradation and loss of bird-rich rainforests in Sundaic South-East Asia mean that effective conservation intervention at a species, community or ecosystem level will need to take into consideration aspects of behavioural and sensory ecology (Lim *et al.* 2008). Most single-species studies of birds consider population dynamics and attempt to predict population trends over various time-scales while overlooking diverse aspects of the organism's life history, including its communication and sensory systems. It is possible

Plate 5. Pin-striped Tit Babbler *Macronous gularis* showing pinkish rather than blue neck skin when calling, Bukit Batok Nature Park, Singapore, 23 March 2012.





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Plate 6. In common with other South-East Asian phasianids, the Crested Fireback *Lophura ignita* sports blue facial skin. Taman Nagara National Park, Pahang, Peninsular Malaysia, 15 February 2010.

Plate 7. Many Asian trogons have blue orbital rings; this Scarlet-rumped Trogon *Harpactes duvaucelii* also has a blue bill and eyebrow. Panty Forest, 28 March 2010.



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Plate 8. A number of cuckoo species, including the Raffles's Malkoha *Phaenicophaeus chlorophaeus*, also sport blue facial skin. Panty Forest, 4 May 2007.



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that many forest birds, especially understorey species, may not be able to survive in disturbed habitats due to changes in light conditions and sensory settings which interrupt or disrupt visual or vocal communication mechanisms, reducing their ability to find mates and breed successfully.

Using Neotropical studies as examples, Stratford & Robinson (2005) suggest that the specialised adaptations of understorey rainforest birds to generally low light conditions may be a reason why many understorey insectivores are reluctant to cross forest gaps or do not survive for long in fragmented landscapes, although specific underlying physiologies remain unknown. From a South-East Asian perspective, it is clear that there are numerous areas that conservation ecologists will have to look into in the future to understand how visual communication systems in birds can potentially be impacted by habitat change before it becomes clearer why certain species are not able to persist in degraded forest fragments.

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