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The potential value of camera-trap studies for identifying, ageing, sexing and studying the phenology of Bornean *Lophura* pheasants

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The age and sex differences in the plumages of Bornean *Lophura* pheasants are poorly known and limit accurate documentation of the ecology, distribution, phenology and conservation status of these elusive and threatened forest taxa. Remotely triggered camera-traps, however, offer a potentially untapped resource. We studied camera-trap footage (825 still images and 91 videos) and 88 museum specimens of the three species of *Lophura* pheasants from Borneo (*L. bulweri, L. ignita* and *L. pyronota*) to clarify the criteria for identifying, ageing and sexing them. We provide updated descriptions of plumage for each taxon, while accounting for age and sex. We illustrate that every species can be identified, aged and sexed (even from grey-scale records) through a combination of wattle shape, crest size, body and tail colouration, tail:body ratio, contrasting markings on underparts, upperparts and upperwing-coverts, and spur size. Additional clues can be obtained from colour records, such as wattle and leg colouration. Moult phenology of the three species appears similar, with a single complete moult between juvenile and adult plumages which takes place over a lengthy period. In young male *L. bulweri*, however, retrix moult occurs after the body moult, possibly due to the energy cost of moulting its ornamentation. Phenology data indicate that breeding seasons for all three species are either prolonged or dependent on environmental conditions, although very little information was found for *L. pyronota*. Our analyses will improve the identification of Bornean *Lophura* pheasants in camera-trap and field studies.

INTRODUCTION

Camera-trapping is commonly used to monitor species which are otherwise challenging to observe and study (O'Connell *et al.* 2011). The advantage of this technique is that species can be studied without their behaviour being affected by the presence of humans (Silveira *et al.* 2003). Large and medium-sized mammals have been the main focus of camera-trap studies, while data on avian species have often been regarded as 'by-catch' (O'Brien & Kinnaird 2008). However, Winarni *et al.* (2005) in Sumatra, Indonesia, showed that Galliformes can also be monitored efficiently by camera-traps and other studies have confirmed the value of camera-trapping in documenting the ecology, behaviour, distribution and conservation status of large terrestrial birds (Dinata *et al.* 2008, O'Brien & Kinnaird 2008, Fischer *et al.* 2017a,b). However, the correct identification of the species from images, often in grey-scale and partly obscured, is a fundamental requirement of such studies.

Lophura is a widespread galliform genus comprising 11 species, all found in the Oriental region (del Hoyo & Collar 2014). Three of them are found on Borneo: Bulwer's Pheasant *L. bulweri*, Bornean Crested Fireback *L. ignita* and Bornean Crestless Fireback *L. pyronota* (Myers 2010, Phillipps & Phillipps 2014). We follow del Hoyo & Collar (2014) in treating *ignita* and *pyronota* as distinct species. All three species are endemic to Borneo; *bulweri* and *pyronota* are classified as Vulnerable and *ignita* as Near Threatened (IUCN 2017). Few quantitative data have been published on the ecology, demography or behaviour of these species, and there are large gaps in our understanding of their distributions and habitat preferences which potentially hampers our ability to assess accurately their conservation status.

During the early stages of a large-scale study of the distribution of all Bornean Galliformes (Denny *et al.* in prep.), errors in the identification of species in the *Lophura* genus became apparent, especially in respect of camera-trap records. While some of these pheasants have been described as 'unmistakable' (del Hoyo & Collar 2014), many seemingly distinctive features are less conspicuous on camera-trap footage, posing identification challenges including difficulties in estimating body size and proportions, particularly from grey-scale images. In addition, images may be blurred, distant or obscured, with birds sometimes in unfamiliar positions. Furthermore, lack of familiarity with juvenile and immature plumages and moult phenology hampers the documentation of demographic trends. Although habitat and altitudinal information associated with camera-trapping (or field sightings) may provide ecological clues for the identification of Bornean *Lophura* pheasants, these data should be used with caution, as little is known about their habitat use and preferences and the extent of overlap between species (Madge & McGowan 2002, Myers 2010, Table 1).

Here we review an extensive collection of camera-trap images and videos as well as museum specimens of these taxa with the objective of providing an overview of morphological identification features, plumage descriptions, descriptions of moult patterns and new phenological information in order to aid future studies.

METHODS

L. bulweri and *L. pyronota* are monotypic species (del Hoyo & Collar 2014); *L. ignita* is discussed here only to species level as the subspecies *ignita* and *nobilis* appear to differ little in plumage and are poorly understood (Collar & Prys-Jones 2014). Throughout our assessment we used four categories to differentiate each species on the basis of age and sex: 1) juvenile, 2) immature male, 3) adult female and 4) adult male. Juvenile plumage is defined here as the first plumage after the chick stage. We consider an immature male plumage to be intermediate between juvenile and adult plumages after the post-juvenile moult, or a transition from the former to the latter (during moult). We only discuss immature female plumages briefly, owing to challenges in accurately ageing female birds, which requires further study but at present appears to be beyond the scope of camera-trap studies of these species. We used a combination of museum specimens and camera-trap footage to maximise the amount of useful data on plumage, phenology, morphology and moult patterns of the taxa *bulweri*, *ignita* and *pyronota*.

Museum specimens

JHF and SEIJ measured specimens (both skins and mounts) originating from Borneo held at Naturalis Biodiversity Centre, Leiden, Netherlands, and the Natural History Museum, Tring, UK (NHMUK) (Table 2). We allocated specimens into one of

Table 1. Bornean *Lophura* pheasants: presumed habitat use according to Mann (2008), Myers (2010), Fischer *et al.* (2016), del Hoyo *et al.* (2016a), McGowan & Kirwan (2016a) and McGowan *et al.* (2016a).

			Forest type					
Species	**Altitudinal range (m)**	**Tolerance of degraded habitat**	**Lowland dipterocarp**	**Hill dipterocarp**	**Lower montane**	**Alluvial**	**Peat swamp**	**Heath**
L. bulweri	150–1,500	?	✓	✓	✓	✓		
L. ignita	0–1,300	✓	✓	✓		✓		✓
L. pyronota	0–500	?	✓			✓	✓	

the four categories outlined above. We took measurements of body and tail (in cm) and used these to calculate tail:body ratios (%). We also measured spur lengths (both right and left) and crest lengths (in mm). Finally, we noted bill colour. Specimens with spur deformations (one adult male *bulweri*, one adult male *ignita* and two adult male *pyronota*) or wear (two adult male *bulweri*, two adult female *bulweri* and one adult male *pyronota*) were not included in the analyses. We compared biometric variables across the three *Lophura* species using one-way ANOVAs and Tukey-Kramer *post hoc* tests, in which male and female measurements were treated separately. No statistical tests were made on immature or juvenile plumages due to the small sample sizes. All statistics were calculated in Program R 3.3.1 (R Development Core Team 2016) and visualisations were made using the ggplot2 package (Wickham 2009).

Camera-trap footage

We collated camera-trap footage from various sources, covering 19 different areas across Borneo (Figure 1, Table 3). The footage was provided by JFB, AJM, ES, TBTB, ORW, AG, JM and SMC, with additional data from Gabriella Fredriksson—a total of 916 files, consisting of 825 still images and 91 videos. Of these files, 374 were colour and 542 grey-scale. All the footage originated from larger biodiversity studies of large to medium-sized mammals (e.g. Wearn *et al.* 2013, Allen *et al.* 2016). Camera-trap records were made between 2009 and 2015, covered every month of the year and encompassed the complete range of Bornean interior forest habitats (e.g. Wearn *et al.* 2013, Fischer *et al.* 2017b) over an altitudinal range of 170–1,500 m. With the gathered data, we covered most of the known distributions of the focal species.

Where possible, we aged and sexed all pheasants in the collated material and evidence of symmetrical moult (i.e. not opportunistic replacement of feathers), when visible, was noted to provide quantitative information on moult phenology. To avoid pseudo-replication, we adopted a conservative approach and treated birds with the same plumage from the same camera-trap locality at each site as one individual, regardless of the time interval, unless several birds were visible in one record or characteristic plumage features (e.g. moulting tail-feathers) enabled identification of specific individuals.

Figure 1. Map of Borneo showing the 19 sites from which camera-trap images of Bornean *Lophura* pheasants were obtained. Size of circle indicates relative number of images; white area = colour footage, grey area = grey-scale footage. Numbers correspond with site reference numbers in Table 3.

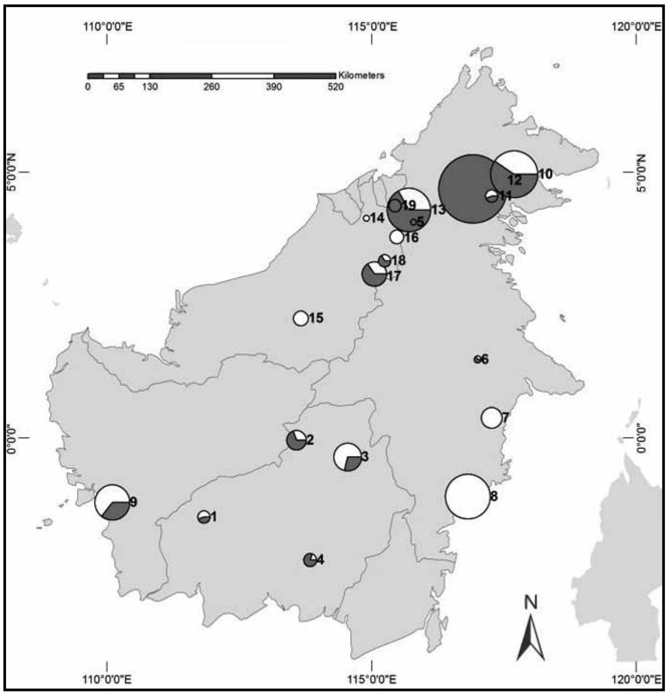


Table 2. Number of Bornean *Lophura* pheasant specimens from Naturalis Biodiversity Centre, Leiden, Netherlands, and Natural History Museum, Tring, UK, used for morphological assessments.

	L. bulweri	*L. ignita*	*L. pyronota*
Juvenile	0	0	1
Immature ♂	2	4	2
Adult ♀	13	19	5
Adult ♂	12	17	13
	27	40	21

Table 3. Origin, number of files and type of camera-trap footage used for assessment.
* indicates video material.

Location	Site	Site ref.	Colour files	Grey-scale files	Total
Indonesia:					
Central Kalimantan	Belantikan	1	5	4	9
	Bukit Batikap Protection Forest	2	7(2*)	16*	23
	Gn Bondang	3	32	13	45
	Sabangau	4	2	8	10
East Kalimantan	Bawan	5	0	2	2
	Berau	6	1	2	3
	Kutai	7	25	0	25
	Sungai Wain	8	119	0	119
West Kalimantan	Gn Palung	9	47*	26*	73*
Malaysia:					
Sabah	Danum	10	53	78	131
	Kalabakan Forest Reserve	11	5	4	9
	Maliau	12	0	276	276
	Ulu Padas	13	37	75	112
Sarawak	Gn Mulu	14	2	0	2
	Hose Mountains	15	13	0	13
	Pulong Tau	16	11	0	11
	Sela'an Linau Forest Management unit	17	12	23	35
	Ulu Baram	18	3	6	9
	Ulu Trusan	19	0	9	9
Total			**374**	**542**	**916**

RESULTS

Museum specimens

Morphological measurements of Bornean *Lophura* pheasants showed clear differences between the species by sex, at least in adult birds (Table 4, Figure 2). Results of one-way ANOVAs revealed significant differences in adult female body length ($f2,32 = 7.46$, $p < 0.05$), tail length ($f2,32 = 42.86$, $p < 0.05$), tail:body ratio ($f2,32 = 10.90$, $p < 0.05$) and spur length ($f2,34 = 67.27$, $p < 0.05$), as well as in adult male body length ($f2,36 = 59.20$, $p < 0.05$), tail length ($f2,36 = 301.06$, $p < 0.05$), tail:body ratio ($f2,36 = 70.04$, $p < 0.05$) and spur length ($f2,35 = 57.90$, $p < 0.05$).

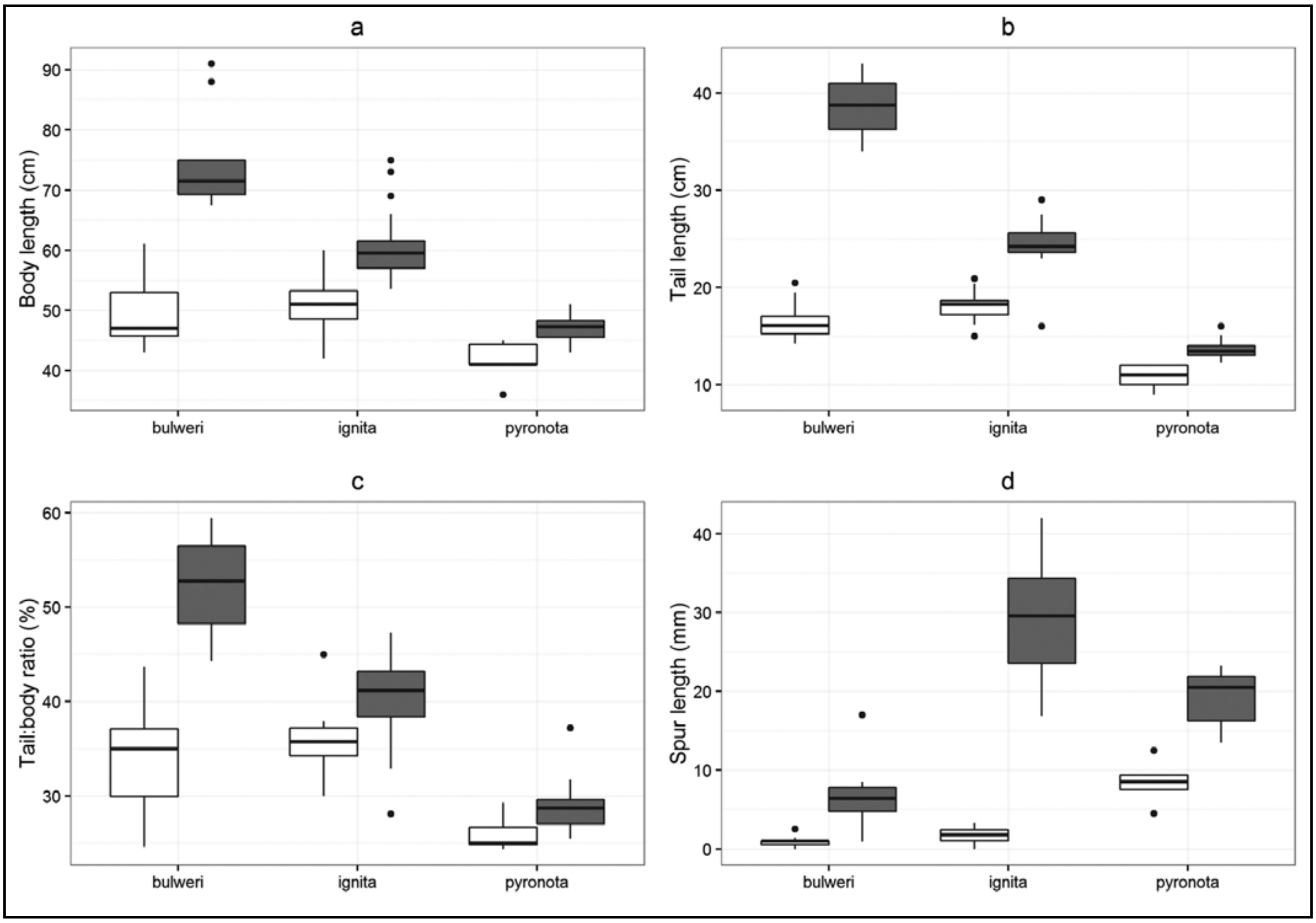
Results from *post hoc* tests also showed that female *pyronota* have the shortest body length ($p < 0.05$), while the body sizes of female *bulweri* and *ignita* are comparable ($p > 0.05$) (Figure 2a). Female *pyronota* also have the shortest tail length, female *bulweri* have medium-length tails and female *ignita* the longest (all $p < 0.05$) (Figure 2b). This results in female *pyronota* also having the lowest tail:body ratio ($p < 0.05$), while this ratio is similar for female *bulweri* and *ignita* ($p > 0.05$) (Figure 2c). Female *pyronota* have the longest spur length ($p < 0.05$), whilst the spur lengths of female *bulweri* and *ignita* are similar ($p > 0.05$) (Figure 2d).

Results from *post hoc* tests showed that male *bulweri* have the longest body, male *ignita* are intermediate in length and male *pyronota* have the shortest body length (all $p < 0.05$) (Figure 2a). The same pattern holds true for male tail length and tail:body ratio (Figure 2b,c). However, male *ignita* have the longest spurs, followed by male *pyronota* while male *bulweri* have the shortest (all $p < 0.05$) (Figure 2d).

Table 4. Bornean *Lophura* pheasants: mean and standard deviation of biometric variables.
[1] = sample size reduced by one due to wear
[2] = sample size reduced by two due to wear
[3] = sample size reduced by one due to deformations
[4] = sample size reduced by two due to deformations

Species	Sex	N	Body length (cm)	Tail length (cm)	Tail:body ratio (%)	Spur length (mm)
L. bulweri	♀	13	49.5 ± 5.8 [2]	16.6 ± 1.94 [2]	34.0 ± 5.97 [2]	0.9 ± 0.64
	♂	12	74.8 ± 8.18 [2]	38.8 ± 2.97 [2]	52.2 ± 5.12 [2]	6.7 ± 4.02 [3]
L. ignita	♀	19	51.0 ± 4.50	18.2 ± 1.41	35.8 ± 3.17	1.7 ± 1.00
	♂	17	61.1 ± 6.21	24.4 ± 2.67	40.1 ± 5.07	29.5 ± 7.04 [3]
L. pyronota	♀	5	41.5 ± 3.56	10.8 ± 1.30	26.0 ± 2.00	8.5 ± 2.90
	♂	13	47.0 ± 2.45 [1]	13.6 ± 1.06 [1]	29.1 ± 3.08 [1]	19.0 ± 3.54 [4]

Figure 2. Boxplots of measurements of Bornean *Lophura* museum specimens.
Plot a = body length (cm), plot b = tail length (cm), plot c = tail:body ratio (%), plot d = spur length (mm).
White box = adult female, grey box = adult male.



Camera-trap footage

A total of 281 individual *Lophura* pheasants were counted on the camera-trap footage. In 280 cases, the species was unambiguously identified. In addition, 99 out of 101 individual *bulweri*, 155 out of 163 individual *ignita* and 16 out of 16 *pyronota* were confidently assigned to one of the four plumage categories (Table 5). Records were limited for juvenile birds of all species and immature birds of some species (Table 5). The paucity of *pyronota* records is notable—the species was only recorded from Bawan, Gn Palung, Gn Mulu and Sabangau (Figure 1)—particularly given the broad geographic distribution of camera-trap localities.

Plumage descriptions

Below, plumage-specific descriptions of each Bornean *Lophura* species are provided, together with notes that may aid identification on camera-trap footage. Throughout this section we refer only to still images, although the same identification features can be used for individuals recorded on video.

Certain (soft) parts are often not well preserved in specimens and can be hard to judge in images (e.g. iris colouration). Plumage descriptions were therefore augmented with data from Madge & McGowan (2002), Myers (2010), del Hoyo & Collar (2014), Phillipps & Phillipps (2014), del Hoyo *et al.* (2016a), McGowan & Kirwan (2016a) and McGowan *et al.* (2016a) where necessary.

Bulwer's Pheasant *Lophura bulweri*

Juvenile

Juveniles (Plate 1) are similar to adult females, but upperwing-coverts have black V-shaped subterminal marks and warm buff tips (McGowan & Kirwan 2016a). It may be possible to determine the sex: depending on the extent of a putative post-juvenile moult (whether or not the juvenile tail is replaced as part of the moult), the presence or absence of vermiculations on rectrices might be correlated with the sex of juveniles (SEIJ pers. obs. 2015), although this requires further investigation. Legs and feet are coral-red and bear no spurs. Iris is red to brown.

Table 5. Bornean *Lophura* pheasants: number of individuals assigned to plumage categories on camera-trap footage.

	L. bulweri	*L. ignita*	*L. pyronota*	*Lophura* sp.
Juvenile	4	2	-	-
Immature ♂	33	17	-	-
Adult ♀	36	60	9	-
Adult ♂	26	76	7	-
Unknown	2	8	-	1
Total	**101**	**163**	**16**	**1**

Plate 1. Juvenile Bulwer's Pheasants *Lophura bulweri* showing buffy tips on the upperwing-coverts, Sela'an Linau Forest Management Unit, Upper Baram, Sarawak, Malaysia, 7 May 2013.

JOHN MATHAI

In colour camera-trap images, adult female *bulweri* (Plate 4) and juvenile *bulweri* (Plate 1) can be distinguished by the warm buff tips on the upperwing-coverts of the latter. These might be difficult to detect in grey-scale images and therefore some camera-trap pictures cannot be aged with certainty.

Immature male

Mean total length 45.5 cm (n = 2). The head is crestless and facial wattles are less extensive than in adult males and have no black tips, making them similar to adult female wattles. The breast and neck have an extensive reddish-maroon hue and there are shining blue feather-fringes on the upperparts. Madge & McGowan (2002) mention narrower blue feather-fringes as a feature of immature males, suggesting that adult males may be crudely identifiable as 'younger' and 'older' age groups. We assume this information is from captive birds as we found no indication of these features on museum specimens. Birds in active moult appear patchy, with a mixture of new adult feathers and old juvenile brown feathers (Plate 2). The tail is straight and dark chestnut rather than the pure white of the adult male (Plate 5). The two specimens assessed have tail lengths of 19 and 20 cm, with a tail:body ratio of 43%. The legs and feet are coral-red and bear small spurs (2 mm and 10 mm respectively) that probably increase in size as a bird ages. Bill colour is dark in both specimens. Iris is red (Plate 2).

Immature male *bulweri* can be recognised in colour camera-trap images by its overall dark plumage with blue feather-fringes, blue facial wattles, coral-red legs and absence of crest (Plate 2), and perhaps most significantly by its chestnut-brown tail. Identification problems may occur in grey-scale images where an immature male *bulweri* (Plate 3) can be mistaken for a female *pyronota* (Plate 12), but the latter has a slightly darker tail and no mottling on the breast.

Adult female

Mean body length 50 cm (n = 11) (Figure 2a). The head is crestless and crown-feathers are dark brown. The cobalt-blue facial wattles are smaller than in adult males and have no black tips, while an inconspicuous red eye-ring is present (McGowan & Kirwan 2016a). The throat is pale brown, while the breast is warm chestnut with fine vermiculations, and the belly and undertail-coverts are dark brown with fewer vermiculations (Madge & McGowan 2002). The upperparts are dull chestnut-brown with fine vermiculations, and primaries and secondaries are darker than the upperparts, with coarser vermiculations (Madge & McGowan 2002). Mean tail length 17 cm (n = 11) and averages 34% of the body length (Figure 2b,c). The legs are coral-red and bear rudimentary or no spurs, a feature inaccurately illustrated in Phillipps & Phillipps (2014). Spurs have a mean length of 1 mm (n = 13) (Figure 2d). Bill colour is somewhat variable, but generally dark. Irides are dark brown to red.

Plate 2. Immature male Bulwer's Pheasant. Note the small facial wattles, the mottled appearance caused by active moult, the blue fringes of the contour feathers, the straight, dark chestnut tail and small spurs on the coral-red legs, Sela'an Linau Forest Management Unit.

JOHN MATHAI

In colour images, adult female *bulweri* can be recognised by the unique combination of a crestless head, cobalt-blue wattles, plain brown plumage and coral-red legs. In grey-scale images, other features can be used: lack of spurs, light and unmarked plumage and the absence of a crest (Plate 4). An adult female *bulweri* can be confused with an adult female *pyronota* (Plate 12), but the latter bears spurs and has an overall darker appearance.

Adult male

Mean body length 75 cm (n = 10) (Figure 2a). The head is crestless with blackish crown and nape feathers; two specimens also show some violet and orange in the crown. The head bears extensive, bright cobalt-blue hammer-shaped wattles with black tips which can be inflated considerably (Plate 5) and an inconspicuous crimson-red eye-ring (McGowan & Kirwan 2016a). The throat and upper breast are glossy dark purple. The lower breast, belly and undertail-coverts are blackish and the lower breast feathers bear blue fringes. The upperparts are blackish and feathers bear shining dark blue, slightly curved spangles, with subterminal maroon iridescence on the mantle (Madge & McGowan 2002). The secondaries are black and the primaries are generally dark brown, although several specimens we examined show distinct cream outer primaries. The long arching tail is conspicuous, pure white and laterally compressed. Mean tail length 39 cm (n = 10) and the tail averages 52% of the total length (Figure 2b,c). The outermost seven pairs of rectrices are mostly stiffened shafts and have few barbs, especially on the outer webs (Madge & McGowan 2002). Legs and feet are coral-red and bear small spurs with a mean length of 7 mm (n = 11) (Figure 2d). The bill is generally dark with a pale tip, but colour appears variable. The irides are red (McGowan & Kirwan 2016a).

In camera-trap images, adult male *bulweri* can be readily recognised by the long arching, pure white tail, although its position can obscure this feature. Other useful identification features (in grey-scale images) are the dark body, small spurs, wattle shape and absence of a crest (Plate 5).

Bornean Crested Fireback *Lophura ignita*

Juvenile

Sex may possibly be determined: juvenile males might be darker than juvenile females (McGowan *et al.* 2016a). Juveniles are similar in plumage to adult female *ignita*, but the head lacks the obvious crest and the upperwing-coverts have large black spots (Madge & McGowan 2002).

In camera-trap images, juvenile *ignita* (Plate 6) can be distinguished from adult female *bulweri* (Plate 4) if the black spots on the upperwing-coverts can be seen; otherwise, leg colour, dark chestnut plumage (in colour images) and light markings on the underparts of the juvenile can be used to differentiate it from adult female *bulweri*. Juveniles are often accompanied by adult birds during a period of post-natal care, which obviously makes them easier to identify and potentially provides other identification clues.

Plate 3. Grey-scale image of an immature male Bulwer's Pheasant. Note the similarity to grey-scale image of adult female Bornean Crestless Fireback *L. pyronota* (Plate 12) when the blue edging of feathers cannot be seen. Also note the pale mottling on the breast and mantle caused by old juvenile feathers being actively moulted, and that the tail is lighter in colour than the new, adult-type contour feathers. Compare with Plate 2 and note the different appearance in grey-scale images. Sela'an Linau Forest Management Unit, 6 July 2014.

JOHN MATHAI

Immature male

Mean body length 43 cm (n = 4). At 4–6 months, the plumage of immature *ignita* has been described as a dull version of the adult male (McGowan *et al.* 2016a). The head is crestless and has smaller wattles than adults. Specimens show fine chestnut vermiculations on the mantle. Mean tail length 16 cm (n = 4), which is 37 % of body length and thus shorter than the tail of adult males. Spur length is 3 mm (n = 4) and probably increases as a bird ages. Bill colour is generally pale, but somewhat variable. Iris colour is unknown.

In camera-trap images, immature male *ignita* can be distinguished from adult males by the shorter tail, small wattles, absence of a crest and small spurs, but these features can be hard to detect (Plate 7).

Adult female

Mean body length 51 cm (n = 19) (Figure 2a). The head is dull chestnut and bears an erect, dark chestnut crest consisting of bare-shafted, racket-shaped feathers, mean length 33 mm (n = 19). Facial wattles are dull blue and the throat is whitish. The upper breast is dark chestnut with whitish streaks and the lower breast and belly are dark chestnut with broad white feather-fringes. The vent is dirty white and the undertail-coverts are dark brown. The neck and nape are dark chestnut with whitish streaks. The upperparts are dark chestnut; the wing-coverts and uppertail-coverts bear fine dark vermiculations and the tail is straight, blackish brown and can show chestnut vermiculations along the edges of the rectrices (Madge & McGowan 2002). Mean tail length 18 cm, 36% of the body length (n = 19) (Figure 2b,c). The legs are pale brownish (McGowan *et al.* 2016a) and have no or only rudimentary spurs, which are inaccurately illustrated in Phillipps & Phillipps (2014). Mean spur length is 2 mm (n = 19) (Figure 2d). The bill colour appears variable and the irides are red (McGowan *et al.* 2016a).

In camera-trap images, adult female *ignita* can be recognised by the unique combination of a crest, whitish markings/crescents on the underparts and breast, absence of spurs and a tail darker than the body (Plate 8). These features are generally also visible on grey-scale images (see females in Plate 9).

Adult male

Mean body length 61 cm (n = 17) (Figure 2a). The head is dark blue with an erect, dark blue crest consisting of bare-shafted, racket-shaped feathers, mean length 38 mm (n = 17). The extensive facial wattles are bright cobalt-blue, the throat and upper breast are glossy

Plate 4. Two adult female Bulwer's Pheasants. Note the absence of spurs, lack of crest and unmarked, fairly light plumage. Sela'an Linau Forest Management Unit, 4 July 2014.

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Plate 5. Adult male Bulwer's Pheasant. The long, white, arching tail is particularly obvious in this pose, Maliau Basin, Sabah, Malaysia, 23 August 2010.

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Plate 7. Bornean Crested Firebacks. From left to right: unknown, two immature males, adult male, adult female and a presumed immature male. Note that the immature males (centre) have short tails and small cobalt-blue facial wattles (compare with facial wattles of the adult male in the right background) and lack a crest. Sungai Wain, East Kalimantan, Indonesia, 8 June 2014.

Plate 9. Bornean Crested Fireback. Adult male (centre) with two adult females (left and right). Note the male's obvious crest and the contrast between breast and belly. Berau, East Kalimantan, Indonesia, 6 November 2013.

SUSAN CHEYNE

SUSAN CHEYNE

Plate 6. Bornean Crested Fireback *L. ignita*, juvenile (right foreground), adult female (behind juvenile) and adult male (left-centre foreground). Note that the juvenile lacks a crest, which could cause confusion with an adult female or juvenile Bulwer's Pheasant (Plates 1 & 4). Sungai Wain, East Kalimantan, Indonesia, 2 June 2012.

ALYS GRANDADOS & JEDEDIAH BRODIE

Plate 8. Adult female Bornean Crested Fireback. Note the floppy crest, light markings on the underparts, tail darker than the body, and absence of spurs. Compare with Plate 9 for differences in colour and grey-scale images. Danum Valley, Sabah, Malaysia, 3 August 2013.

dark blue, while the lower breast and belly are coppery-chestnut. The vent and undertail-coverts are blackish, the upperparts are glossy dark blue and the wing-coverts bear iridescent blue feather-fringes. The primaries are dull blackish to pale brown and the lower back is glossy dark maroon, while the rump and uppertail are glossy dark blue. The tail is graduated, becoming more elongated towards the central pair of slightly arched rectrices. The two or three central pairs of rectrices are ochraceous, while the outer five pairs are dark blue to blackish (Madge & McGowan 2002). Mean tail length 24 cm, 40% of body length (n = 17) (Figure 2b,c). The legs and feet vary in colour from whitish to grey-green (McGowan *et al.* 2016a). The spurs are large, mean length 30 mm (n = 16) (Figure 2d). It should be noted that spurs on some specimens were bulbous at the base and probably still developing when collected; we believe these are likely to be young males that had recently attained full adult plumage. The bill is generally pale and irides are red (McGowan *et al.* 2016a).

In camera-trap images, adult male *ignita* can be readily recognised by the crest, pale lower breast, light (or red) belly (which contrasts with the dark upper breast), long spurs and bicoloured arching tail. This combination of features is unique to this species (Plate 9).

Bornean Crestless Fireback *Lophura pyronota*

Juvenile

At present there is no way of determining the sex of juvenile *pyronota*. Juveniles (Plate 10) are similar to adult females, with body feathers

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Plate 10. Mounted specimen of young Bornean Crestless Fireback *L. pyronota* moulting into its subsequent plumage. Note the rusty-buff feather-tips and greenish gloss on breast and upperparts, 5 February 2015.

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Plate 11. Ventral view of Bornean Crestless Firebacks. On the right is an adult female, the left-hand individual is one of two labelled 'male': note the definite colour change between head and neck which caused debate about its age, 21 April 2015.

tipped rusty-buff (del Hoyo *et al.* 2016a). The head has a dark brown crown and small facial wattles and the throat is pale grey. The breast and foreneck are dark brown, with feathers tipped rusty-buff with a greenish gloss. The belly is dull brown, with feathers tipped dull buff. The upperparts are also dark brown with rusty-buff tips, some broad vermiculations and a greenish gloss, while the uppertail-coverts and rump lack rusty-buff tips. Primaries are blackish, as is the tail, with only a faint gloss. The tail of one specimen was 10 cm in length. The dark-grey legs have no spurs and the bill is dark with a pale base. Iris colour is unknown.

Immature male

This plumage has not yet been described. However, two study skins in NHMUK (one with catalogue number 1900.2.14.7, the other unregistered) are labelled as males but are clearly not adult and may be presumed to be immature males. When compared with some female specimens, they appear to be slightly darker underneath with a more distinct colour change between the pale buff neck and head and the darker body (Plate 11).

Adult female

Mean body length 41 cm (n = 5) (Figure 2a). The head is crestless, dark grey with a brown hue and has crimson facial wattles that are less extensive than in the adult male. The throat is pale grey. The breast, belly and undertail-coverts are black with a dark greenish-blue or purple-blue gloss, as are the upperparts, including the rump and uppertail-coverts. The primaries are dark brown. The tail is short, straight and black and can show some gloss. Mean tail length 11 cm, 26% of the body length (n = 5) (Figure 2b,c). The legs are bluish-grey (del Hoyo *et al.* 2016a) and have spurs with a mean length of 8 mm (n = 5) (Figure 2d). The bill is generally dark but appears variable. Iris colour is brown.

In colour camera-trap images, adult female *pyronota* can be recognised by the unique combination of all-dark plumage, lack of crest, scarlet facial wattles and blue-grey legs with long spurs. In grey-scale images, the all-dark plumage, absence of crest and obvious long spurs are features that can be used in identification. If legs or spurs are not visible in the image, this species may be confused with adult female or immature male *bulweri*. Adult female *pyronota* (Plate 12) has plain all-dark plumage, while immature male *bulweri* (Plate 3) has a chestnut tail and some maroon on the breast, which appears slightly contrasting in grey-scale images.

Adult male

Mean body length 47 cm (n = 12) (Figure 2a). The crestless head is black with scarlet facial wattles. The neck is pale grey and not glossy, creating a hooded appearance. The breast, belly and undertail-coverts are blackish with a purple-blue gloss and with broad silvery-white feather-shafts. These are most prominent on the breast, becoming less so on the belly. The mantle is dark grey with broad silvery-white feather-shafts and fine black vermiculations. The wings are glossy grey with more pronounced grey vermiculations and less pronounced white feather-shafts. The primaries are dull brown. The lower back and rump are glossy dark maroon grading into glossy steel-blue uppertail-coverts. The tail is rather short and laterally compressed, with the inner rectrices coloured completely ochraceous-yellow, while the outer rectrices have a blackish base of variable size. Mean tail length 14 cm, 29% of body length (n = 12) (Figure 2b,c). The legs and feet are blue-grey (del Hoyo *et al.* 2016a) with large spurs, mean length 19 mm (n = 11) (Figure 2d). The bill is whitish with a dark base, but this appears variable. The irides are brown (del Hoyo *et al.* 2016a).

In camera-trap images, adult male *pyronota* can be recognised by the broad, silvery-white feather-shafts on the breast and mantle, the hooded appearance and short bicoloured tail (Plate 13).

Moult and breeding phenology

Very little information is available on the life-history of Bornean *Lophura* pheasants, particularly on their moult and breeding

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Plate 12. Adult female Bornean Crestless Fireback. Note the all-dark plumage and lack of crest. Bawan, East Kalimantan, Indonesia, 1 October 2012.

SUSAN CHEYNE

Plate 13. Bornean Crestless Fireback. Adult male (foreground) and presumed adult female (directly behind it). Note the male's pale feather-shafts on breast and mantle, hooded appearance and short pale tail. Also note the difficulty of locating and identifying the second bird. Bawan, East Kalimantan, Indonesia, 20 September 2012.

phenology. Information presented here is intended to form a baseline and in future studies we advocate avoiding age terms that relate to calendar year (e.g. second-year male), as widely used in the literature, for two reasons: 1) they hold limited relevance for tropical taxa that often breed independently of calendar-year seasonality, and 2) knowledge of breeding phenology of these taxa in the wild is virtually non-existent, limiting accuracy. Instead, we suggest using a cycle-based approach to phenology as described in Wolfe *et al.* (2010) and Johnson *et al.* (2011).

Historically, similarities in moult phenology have been used in the interpretation of the taxonomic affinities of subfamilies in the Phasianidae (Beebe 1918, Marien 1951). Moult strategies do not appear to differ significantly between these species. *Lophura* pheasants appear to employ a 'Simple (*syn* Primitive) Basic Strategy' (Howell & Corben 2000), whereby the post-juvenile (*syn* pre-formative) moult is complete, but probably undertaken over a period of up to six months depending on the size of the bird and associated metabolic demands—e.g. see Silver Pheasant *L. nycthemera* (McGowan & Kirwan 2016b) and Swinhoe's Pheasant *L. swinhoii* (McGowan & Kirwan 2016c). Tail moult starts from the outermost rectrix and moves centripetally, a characteristic of the Phasianidae (Beebe 1918). Moult patterns appear consistent across all *Lophura* species (Madge & McGowan 2002). Males in species with large ornamentations, however, may take longer to complete their moult, owing to the energetic demands of moulting such features (e.g. see *L. bulweri* account below). Additionally, the post-juvenile moult in female pheasants appears poorly covered in published literature but is probably similar to that of juvenile males. Our preliminary assessment presented here appears to mirror the moult phenology of the relatively well-studied Common Pheasant *Phasianus colchicus* (Cramp & Simmons 1980).

Bulwer's Pheasant *Lophura bulweri*

This species's breeding season is poorly known, but is possibly long, with a single nest found in November and juvenile birds collected in August (McGowan & Kirwan 2016a). In camera-trap footage and specimens, we found juvenile birds in May (3) and November (1) and immature males actively moulting in January (2), March (1), April (2), May (5), July (7) and September (1). Adult females were observed moulting in January (1), February (1), May (1) and June (3). Adult males were observed moulting in January (2), April (1) and May (2). This broadly supports the hypothesis that the breeding season is long or alternatively that it is influenced by specific ecological conditions, as suggested by Phillipps & Phillipps (2014).

Female moult appears to be straightforward, with a single complete moult from juvenile to adult. The duration of this remains unknown and we found no specimens in active moult. Young males have a more complex moult, where the adult body plumage is attained before rectrix moult begins. The tail then moults centripetally after the adult male plumage is attained (see Plates 14 & 15 compared with Plates 2 & 3). The duration of moults and the time between them are unknown. Madge & McGowan (2002) suggest, however, that the 'male achieves adulthood in second year of life'. There does appear to be some delay before the start of rectrix moult in congeners with large tail ornamentations that also 'achieve adulthood in second year of life' (McGowan & Kirwan 2016b,c). It should be noted that these comparative species are allopatric and subject to different environmental conditions from *bulweri*. The energetic demand of growing such large ornamentations offers a possible explanation for this delay and merits further study. Based on camera-trap images, the extent of flight-feather moult may vary, but is still unclear from the information available (e.g. compare Plate 2 and Plate 14).

Bornean Crested Fireback *Lophura ignita*

The breeding biology of *ignita* is virtually unknown, with recently hatched chicks collected in July (McGowan *et al.* 2016a) and observed in camera-trap images in March. In camera-trap footage and specimens, we found older juvenile birds in June (2). Immature

Plate 14. Immature male Bulwer's Pheasant. Note the outermost right rectrix, showing the start of centripetal rectrix moult. Note also that all remiges appear to be retained from the juvenile plumage. Sela'an Linau Forest Management Unit, 31 July 2014.

JOHN MATHAI

Plate 15. Bulwer's Pheasant specimens. From left to right: adult male, immature male in an early stage of rectrix moult, juvenile male in a very early stage of body moult, and adult female. Note centripetal tail moult of the immature male and lack of discernible difference in blue contour feathers, 23 March 2015.

males were observed moulting in March (2), June (8), July (2) and August (1). Adult females were moulting in July (1) and August (1), while adult males were moulting in May (1), July (1), August (2), September (1) and December (1). This suggests a possible breeding season between February and August, with information (albeit limited) from the until-recently conspecific Malay Crested Fireback *L. rufa* suggesting that these species have similar phenologies (del Hoyo *et al.* 2016b).

The post-juvenile moult is probably complete, and McGowan *et al.* (2016a) suggest that males attain a dull adult-type plumage after 4–6 months. It seems unlikely that the female moult is different from the male moult. The moult duration may not be prolonged as in immature male *L. bulweri* due to the smaller size and plumage ornamentations of *ignita* (Cramp & Simmons 1980). After the post-juvenile moult, young females may not be distinguishable from adult females. Other clues, such as the aforementioned spur-length/growth, may offer valuable information for accurate ageing of both sexes.

Bornean Crestless Fireback *Lophura pyronota*

A breeding season from April to June (del Hoyo *et al.* 2016a) has been suggested for this species, although the provenance is unclear due to the paucity of the information available. In camera-trap images and specimens we found only one juvenile (skin of a captive bird). Of the two presumed immature male birds, one was collected in February and one in October.

No comments concerning ageing were found during literature reviews, but McGowan *et al.* (2016b) suggest that young male Malay Crestless Fireback *L. erythrophthalma* attain adult plumage at four months of age. This also suggests a single moult between the juvenile and adult stages in both sexes. However, we consider this tentative, owing to the two specimens of debatable gender labelled as males (Plate 11). If these are indeed young males, two possibilities with regards to moult present themselves: 1) that juveniles are sexually dimorphic and moult as discussed above, or 2) that juveniles are not sexually dimorphic and the first moult leads to an immature-type male that only attains adult plumage after a second moult. The first strategy appears to be the more likely, but it would be premature to draw further conclusions based on the available information.

CONCLUSION

Our study of museum specimens and camera-trap footage provides new insights on Bornean *Lophura* plumage, morphology and life-history, although we accept that our assessment is far from complete. The lack of information on *L. pyronota* is particularly evident. This study illustrates that identification of Bornean *Lophura* pheasants can pose difficulties, but that in most instances individuals can be identified and, to some extent, aged and sexed.

Many gaps and some inconsistencies exist in the published literature on these taxa. Most notable is the lack of data on moult and breeding phenology. Opportunities exist for these gaps to be filled by camera-trap studies, using the information we have presented as a baseline. In addition, we strongly advocate the use of a cycle-based approach to phenology in future studies, using simple and accurate terminologies independent of calendar years (e.g. Wolfe *et al*. 2010, Johnson *et al*. 2011). Improved understanding of the timing and extent of moult and breeding phenology will add to data collected in camera-trap studies. Studies of captive birds could also provide valuable information for ageing and we accordingly encourage aviculturists to document and archive moult timing, moult extent and attained plumages. The majority of juvenile and immature birds observed in camera-trap footage were accompanied by adults, indicating a lengthy period of post-natal care. To this end, camera-trap studies also offer an opportunity to examine the social structure of poorly-known species.

We hope that this paper will aid future identification of Bornean *Lophura* pheasants in camera-trap studies, thereby improving the accuracy of results and, consequently, the knowledge of these poorly understood and threatened species. While our focus has been on the value of identification features for camera-trap studies, the information presented here will also be of use for field studies. Using the characters that we present to identify *Lophura* species in camera-trap footage and in the field could reveal important ecological, behavioural, phenological and distributional data that may have been previously overlooked. Accurate documentation is particularly important given the recent elevation to species rank of both *ignita* and *pyronota*, for which most basic information is unclear or absent. Given the challenges associated with studying many species of Galliformes (Fuller & Garson 2000, Winarni *et al*. 2005), camera-trap studies can undoubtedly provide useful ecological information relevant to conservation management. Galliform camera-trap footage certainly should no longer be treated simply as 'by-catch'.

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REFERENCES

Allen, M. L., Wittmer, H. U., Setiawan, E., Jaffe, S. & Marshall, A. J. (2016) Scent marking in Sunda Clouded Leopards (*Neofelis diardi*): novel observations close a key gap in understanding felid communication behaviours. *Scientific Reports* 6: DOI: 10.1038/srep35433.

Beebe, W. (1918) *A monograph of the pheasants*. London: Witherby.

Collar, N. J. & Prys-Jones, R. P. (2014) *Lophura ignita macartneyi* revisited. *Forktail* 30: 135–138.

Cramp, S. & Simmons, K. E. L. (1980) *The birds of the western Palearctic*, 2. Oxford: Oxford University Press.

Denny, M. J. H., Bernard, H., Brodie, J., Granados, A., Cheyne, S. M., Giordano, A., Hearn, A., Ross, J., Marshall, A. M., Mathai, J., Ross, J., van Berkel, T., Jones, S. E. I., Fischer, J. H., Gardner, P., Goossens, B., Lim H.-Y., Goon, J., Azad, A., Burner, R., Sozer, R., Ridge, S., Wittmer, H. U., Bohm, T., Kretschmar, P., Gaveau, D. & Wearn, O. Modelling habitat occupancy and distribution in Bornean Galliformes. Manuscript in preparation.

Dinata, Y., Nugroho, A., Haidir, I. A. & Linkie, M. (2008) Camera trapping rare and threatened avifauna in west-central Sumatra. *Bird Conserv. Internatn.*18: 30–37.

Fischer, J. H., Boyd, N. S., Maruly, A., van der Kaaden, A., Husson, S. J., & Sihite, J. (2016) An inventory of the avifauna of the Batikap Hill Protection Forest, Central Kalimantan, Indonesia. *Forktail* 32: 26–35.

Fischer, J. H., Debski, I., Taylor, G. A., & Wittmer, H. U. (2017a) Assessing the suitability of non-invasive methods to monitor interspecific interactions and breeding biology of the South Georgian diving petrel (*Pelecanoides georgicus*). *Notornis* 64: 13–20.

Fischer, J. H., Wittmer, H. U., Setiawan, E., Jaffe, S. & Marshall, A. J. (2017b) Incipient loss of a rainforest mutualism? *J. Threat. Taxa* 9: 9734–9737.

Fuller, R. A. & Garson, P. J., eds. (2000) *Pheasants: status survey and conservation action plan 2000–2004*. Gland Switzerland & Cambridge UK: IUCN, World Pheasant Association and WPA/BirdLife/SSC Pheasant Specialist Group.

Howell, S. N. G. & Corben, C. (2000) A commentary on molt and plumage terminology: implications from the Western Gull. *Western Birds* 31: 50–56.

del Hoyo, J., Collar, N., Christie, D. A. & Kirwan, G. M. (2016a) Bornean Crestless Fireback *Lophura pyronota*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/467107 on 18/04/2017.

del Hoyo, J., Collar, N., Christie, D. A. & Kirwan, G. M. (2016b) Malay Crested Fireback *Lophura rufa*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/467108 on 25/08/2017.

del Hoyo, J. & Collar, N. J. (2014) *HBW and BirdLife International illustrated checklist of the birds of the world*, 1. Barcelona: Lynx Edicions.

IUCN (2017) *The IUCN Red List of threatened species*. Version 2017. Accessed at www.iucnredlist.org. on 05/12/2017.

Johnson, E. I., Wolfe, J. D., Brandt Ryder, T. & Pyle, P. (2011) Modifications to a molt-based ageing system proposed by Wolfe *et al*. (2010). *J. Field Orn.* 82: 422–424.

Madge, S. & McGowan, P. (2002) *Pheasants, partridges & grouse*. London: Christopher Helm.

Mann, C. F. (2008) *The birds of Borneo*. Peterborough: British Ornithologists´ Union. BOU Checklist 23.

Marien, D. (1951) Notes on some pheasants from southwestern Asia, with remarks on molt. *Am. Mus. Novit*. 1518: 1–25.

McGowan, P. J. K. & Kirwan, G. M. (2016a) Bulwer's Pheasant *Lophura bulweri*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/53498 on 18/04/2017.

McGowan, P. J. K. & Kirwan, G. M. (2016b) Silver Pheasant *Lophura nycthemera*. In: J del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/53490 on 19/04/2017.

McGowan, P. J. K. & Kirwan, G. M. (2016c) Swinhoe's Pheasant *Lophura swinhoii*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/53493 on 19/04/2017.

McGowan, P. J. K., Kirwan, G. M. & Christie, D. A. (2016a) Bornean Crested Fireback *Lophura ignita*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/53496 on 18/04/2017.

McGowan, P. J. K., Kirwan, G. M. & Christie, D. A. (2016b) Malay Crestless Fireback *Lophura erythrophthalma*. In: J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Accessed at http://www.hbw.com/node/53495 on 01/06/2017.

Myers, S. (2010) *A field guide to the birds of Borneo*. London: New Holland.

O'Brien, T. G. & Kinnaird, M. F. (2008) A picture is worth a thousand words: the application of camera trapping to study birds. *Bird Conserv. Internatn.* 18: 144–162.

O'Connell, A. F., Nichols, J. D. & Karanth, K. U. (2011) *Camera traps in animal ecology: methods and analyses*. New York: Springer.

Phillipps, Q. & Phillipps, K. (2014) *Phillipps' field guide to the birds of Borneo*. Third edition. Oxford: John Beaufoy Publishing.

R Development Core Team (2016) *R: a language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing (version 3.2.4). Accessed at http://www.Rproject.org/.

Silveira, L., Jácomo, A. T. A., Alexandre, J. & Diniz-Filho, F. (2003) Camera trap, line transect census and track surveys: a comparative evaluation. *Biol. Conserv*. 114: 351–355.

Wearn, O. R., Rowcliffe, J. M., Carbone, C., Bernard, H. & Ewers, R. M. (2013) Assessing the status of wild felids in a highly-disturbed commercial forest reserve in Borneo and the implications for camera trap survey design. *PLoS ONE* 8 (11): e77598.

Wickham, H. (2009) *ggplot2: elegant graphics for data analysis.* New York: Springer.

Winarni, N., Carroll, J. P. & O'Brien, T. G. (2005) The application of camera traps to the study of Galliformes in southern Sumatra, Indonesia. Pp.109–121 in: R. A. Fuller & S. J. Browne, eds. *Galliformes 2004. Proceedings of the third International Galliformes Symposium*. Fordingbridge UK: World Pheasant Association.

Wolfe, J. D., Ryder, T. B. & Pyle, P. (2010) Using molt cycles to categorize the age of tropical birds: an integrative new system. *J. Field Orn*. 81: 186–194.

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