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Cover: Stripe-necked Mongoose *Urva vitticolla* in poster colours, adapted from photograph by Ashni Dhawale, by Pooja Ramdas Patil.

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New localities and sexual dichromatism in Blue-green eyed Spotted Cuscus *Spilocuscus wilsoni* Helgen et Flannery, 2004 (Mammalia: Marsupialia: Phalangeridae) from Biak Island, Indonesia

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Abstract: Spotted cuscuses are medium-sized tree-dwelling mammals native to tropical forests of Australo-Papua that primarily feed on fruits and leaves. They belong to the phalangerid genus *Spilocuscus* (Gray, 1862). The difference in pelage color between male and female *Spilocuscus wilsoni* has not yet been well described morphologically. In the present study, we describe the coat color of four *S. wilsoni* individuals: a male adult, a sub-adult male, a sub-adult female, and a juvenile female. Dorsal, lateral, and ventral body section images were captured on camera, and body weight & length, tail & ear length were measured. The adult male *S. wilsoni* had brown spot and blotch patterns on the dorsal and lateral regions, and the ventral region was plain beige. The sub-adult male had distinct spot patterns without blotches on the dorsal and lateral regions, while the ventral region was plain with a cream base color. The sub-adult female had a mottled pattern that blended with the base color, making a silvery appearance. The female juvenile was spotless throughout, with a foundation hue ranging from creamy to somewhat yellow.

Keywords: Biak Island Spotted Cuscus, coat color, medium-sized tree-dwelling mammal, morphologically describe.

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Author contributions: AMY: field work, conceptualization, and manuscript writing; KAW: conceptualization, manuscript writing, and review; TAW, HI, and BS: review.

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INTRODUCTION

Spotted cuscuses are medium-sized tree-dwelling marsupials that primarily feed on fruits and leaves and are native to tropical forests of Australo-Papua. They belong to the phalangerid genus *Spilocuscus* (Gray, 1862). Previously, Biak Island's Spotted Cuscus was considered belonging to the group *S. maculatus* (Flannery 1995b), but later it was separated as a new species *Spilocuscus wilsoni* Helgen et Flannery, 2004. Among all the species of Spilocuscus, this is the only one that possesses blue-green eyes. *S. wilsoni* is one of the smaller species from genus *Spilocuscus* that coexist with *S. maculatus* on Biak Island.

S. wilsoni is found exclusively on the oceanic islands of Biak-Supiori, located in the northern region of New Guinea. Biak-Supiori Island has an area of 2,497 km^2, located off the coast of Sahul, which has no connection with mainland New Guinea. The endemicity and restricted range of *S. wilsoni* make it 'Critically Endangered' on the IUCN Red List (Aplin & Helgen 2016). The description of *S. wilsoni* was based on two samples; a juvenile male (holotype) and an adult male (paratype) from the Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands (RMNH) (now Naturalis) (Helgen & Flannery 2004). Furthermore, an immature individual of unspecified sex, residing as a domesticated animal within a family setting on Biak, was captured in photograph by Flannery 1992, and constitutes an additional paratype (Helgen & Flannery 2004).

The description of *S. wilsoni* is based on craniodental characters and coat color diagnosis of an adult male (paratype) on dry skin. The adult paratype has a pure white coat dorsally and ventrally, shared only with *S.m. maculatus* of northern New Guinea (Helgen & Flannery 2004). The immature holotype is known to be male, however, there is no information about coat color and body size (Helgen & Flannery 2004).

The pelage color description is essential in the identification of species and individuals. Although the identification of species involved adult individuals, immature individuals also need to be known because the pelage colors of mammals are not necessarily fixed throughout their lifetimes (Caro & Mallarino 2020). Baby marsupials, including cuscus, have pink skin and very little hair, and most weigh less than 0.01% of the mother's weight at birth (Hughes & Hall 1988). The difference in pelage color between male and female *S. wilsoni* has not yet been well described morphologically. We found that sub-adult *S. wilsoni* show sexual dicromatism (mottled in females versus spotted and pale color in males), a limited phenomenon among mammals (Caro 2009) but not unusual among cuscuses (Flannery 1995a,b; Caro 2013).

In this study, we describe the coat color pattern of an adult male, sub-adult male, sub-adult female, and juvenile female of *S. wilsoni*. We also measured the body and marked the location where *S. wilsoni* was found for this distribution data.

MATERIAL AND METHODS

This study was conducted from July 2021 to October 2021. Four individuals of *S. wilsoni* from Biak represented the age categories of adult male, sub-adult male, sub-adult female, and juvenile female, one individual, respectively. Information on the origin of the cuscus habitat was obtained directly from a local resident for 1, 2, and 3 and from a keeper in the Biak Bird and Orchid Park for 4 (Figure 1). The subjects were recorded using Canon EOS 750D digital camera with Canon lens EF-S 18–55 mm/F3.5–5.6 (Canon, Tokyo, Japan) in the RAW format. Photographs of the dorsal, lateral, and ventral areas are made in the same frame with a color checker passport. *S. wilsoni* body measurements include weight (W), head-body length (HBL), tail length (TL), and ear length (EL). All length measurements are in centimeters and weight measurements are in grams. This study has received approval from the IPB Animal Ethics Commission (Number 207-2021 IPB).

RESULTS

Adult male

The adult male appears to have a creamy base color and brown spotted and blotched morphs. The spotted and blotched morphs dominate the dorsum and flank, spreading from the head, back, limbs, and half of the tail. The blotch of the head is very dark, and the ears are covered with hair. The muzzle is hairless and darker in color compared to the chin area. The pelage on the foot is darker than the arms. Some ends of the hair strands look blackish and silvery in the dorsum and flank areas, while the ventral area does not. The ventral coat is creamy from the chin and belly to the limbs. This individual has blue-green eyes. The body measurements are as follows: W = 2,480 g; HBL = 46.5 cm; TL = 44 cm; and EL = 2.5 cm. This individual was found in the secondary forest around Warsa village, northern Biak (Image 1).

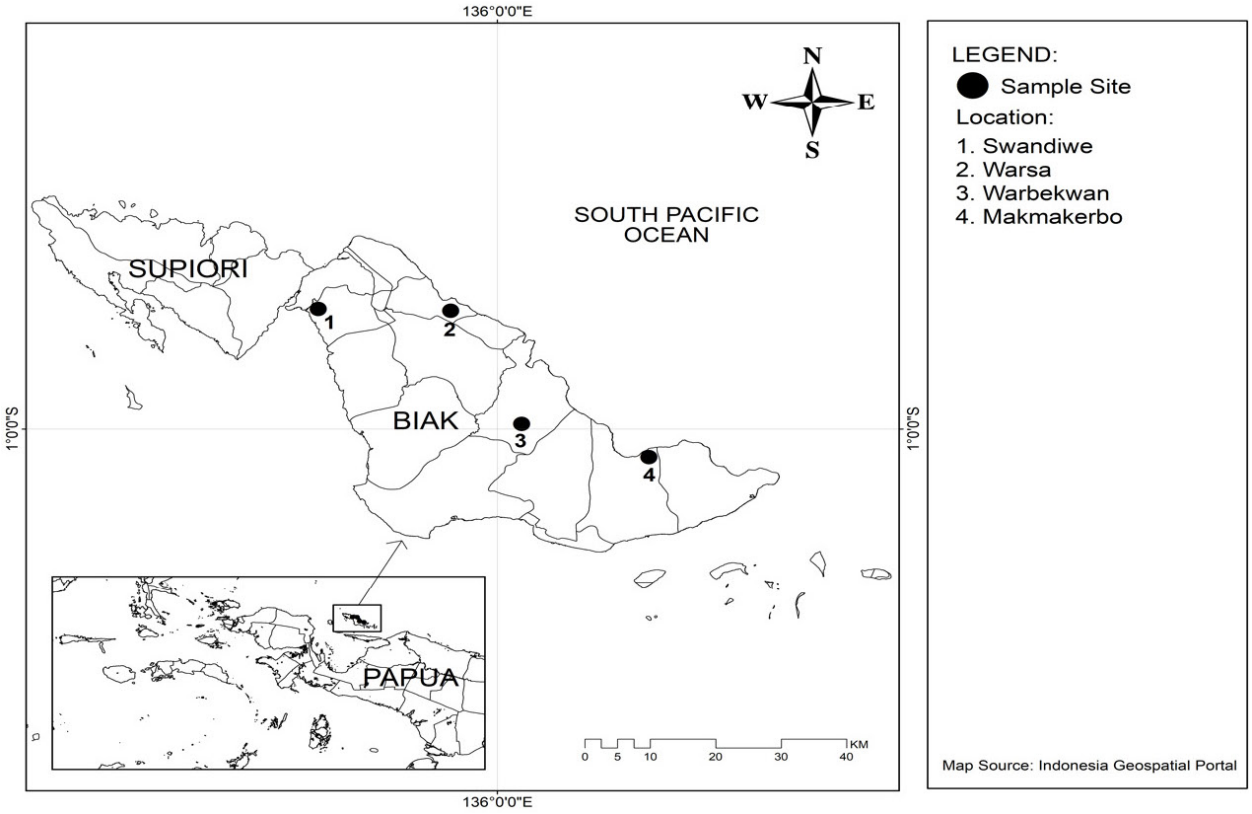

Figure 1. Original habitat of *Spilocuscus wilsoni*.

Image 1. Adult male of *Spilocuscus wilsoni*. © Yohanita AM, 2021.

Sub-adult male

The sub-adult male appears to have a more dominant creamy base color, and the spotted morph is brown. Spotted morphs spread from the head, back, limbs, and half of the tail but is less than that of adults. The blotch area of the head is brown, the area from the cheeks to the chin is creamy, and the ears are covered with hair. The pelage on the foot is dark. The ventral coat is creamy and a little orange in the chest area. This individual has blue-green eyes. The body measurements are as follows: W = 1,300 g; HBL = 36 cm; TL = 35 cm; and EL = 2 cm. This individual was found in the secondary forest around Makmakerbo Village, eastern Biak (Image 2).

Sub-adult female

The whole body of this sub-adult female is a mixture of creamy, light brown, and dark brown colors. The hair of the head area is a mixture of light brown on the face and dark brown on the head. The ears are covered with brown hair. The hair on the dorsum and flank areas has a mottled pattern of creamy and dark brown, while the tail area is light brown. The ends of the hair strands on the dorsum and flank areas appear silvery-buff hairs. The pelage on the foot is darker than the arms. The creamy-colored ventral area looks like a coat from head to legs. The belly part has an unopened sac. This individual has blue-green eyes. The body measurements are as follows: W = 1,100 g; HBL = 33 cm; TL = 30.7 cm; and EL = 1.5 cm. This individual was found in the secondary forest around Swandiwe Village, western Biak (Image 3).

Juvenile female

The whole body of this juvenile female looks creamy and unspotted (dorsum, flank, and belly visible). The hair on the head is thinner than that on the body. The muzzle is hairless and pink, and the ears are covered with light yellow hair. The dorsum and flank parts, including the legs, are creamy and look a little yellow in the upper back. Some ends of the hair strand on the dorsum and flank areas appear blackish and silvery. The belly part has an unopened sac. This individual has yellow-green

Image 2. Sub-adult male of *Spilocuscus wilsoni*. © Yohanita AM, 2021.

Image 3. Sub-adult female of *Spilocuscus wilsoni*. © Yohanita AM, 2021.

Image 4. Juvenile female of *Spilocuscus wilsoni*. © Yohanita AM, 2021.

Table 1. Differences in pelage coloration and iris color in *Spilocuscus wilsoni* compare to other *Spilocuscus*.

Species	Pelage color		Iris color
	Male	Female	
S. wilsoni	Adult males unspotted are yellowish white (Helgen 2007). Sub-adult has a more dominant creamy base color, and the spotted morph is brown. The adult male has a creamy base color and, more brown blotch that are dominant in the dorsum and flank (present study).	Sub-adult female is red-spotted (ZMB 91706) (Helgen 2007). The juvenile is creamy and unspotted in the entire body (dorsum, flank, and belly visible). Sub-adults have a mottled pattern that looks like a mixture of creamy, light brown, and dark brown colors (present study).	Blue-green (Helgen & Flannery 2004). Yellow-green (juvenile) and blue-green (sub-adult and adult).
S. papuensis	The complete lower surface and base color of the dorsum are creamy in apperance, while the spots covering the back, head, and limbs are dark brown or blackish. Frequently, the upper surface of the body is washed with a yellowish hue and commonly exhibits lighter patches of yellow and brownish speckles, while the tail is typically characterized by gold or red-brown spotting. The markings are more prominent and blotchy in males (Helgen 2007).	The female has the same basic coloration and spot pattern all over the body as the male. However, the spots are smaller and more discrete (Helgen 2007).	Carmine-red (Jentink 1885); as either brown or hazel (Flannery 1994, 1995b; Gray, 1862).
S. maculatus from northern and western New Guinea	Mature males typically have a yellowish-white or orange hue, often featuring substantial orange and white spots or blotches on their mid-back (Helgen 2007).	Mature females exhibit colors ranging from yellowish-white to orange, and some may have yellowish-white coats with orange markings (Helgen 2007).	Brown to hazel (Flannery, 1994, 1995a, 1995b; Gray, 1862).
S. rufoniger	The dorsum of the animal has a creamy base-color with a superimposed pattern of intensely blackish (ranging from jet-black to maroon) spots or blotches on the mid-back and hind legs. The face, head, nape, shoulders, hands, feet, and sometimes the body of the limbs are covered in a vibrant red-orange or golden fur. The tail can be either golden or whitish, and the underside of the throat and chin is typically white fur that often extends as a crescent shape to the cheeks and ears, creating a striking contrast with the intense color of the head (Helgen 2007).	The female displays a coloration identical to that of the male, with the exception of the absence of black spots on the back. Instead, they have a black saddle marking that extends over the mid-back and hind limbs (Helgen 2007).	Brown to hazel (Flannery 1994, 1995a, 1995b; Gray 1862).

eyes. The body measurements are as follows: W = 825 g; HBL = 30 cm; TL = 28.5 cm; and EL = 1.5 cm. This individual cuscus was found in the secondary forest around Warbekwan Village, northern Biak (Image 4).

DISCUSSION

Our observation of the coat colors of four individual *S. wilsoni* showed differences in pelage color patterns between males and females. The female had a mottled pattern throughout the dorsal and lateral to ventral edges and appeared to be wearing a coat. The male had a spotted and blotched pattern on the dorsal and lateral areas, while the ventral area was unspotted. We conclude that the sub-adult *S. wilsoni* shows sexual dichromatism (mottled in females versus spotted and pale color in males). Some cuscuses have spots or dorsal stripes; the spotted cuscuses *S. maculatus* and *S. rufoniger* show sexual dichromatism as females lack spots (Flannery 1995a; Helgen & Flannery 2004; Caro 2013), except for *S. papuensis* in which both males and females had spots (Table 1). The spotted cuscus has a unique color, especially in females, and it is recorded that four species inhabit the mainland and islands of Papua. The female *S. maculatus* in the northern islands is plain yellowish-white, while in mainland Papua it is yellowish-white with orange markings from mid-back to the abdomen. Furthermore, the *S. rufoniger* female displays black saddle markings that cover both the mid-back and hind limbs (Helgen 2007).

The sub-adult and adult males in this study showed a brown spotted pattern. Nevertheless, the spots on the sub-adult individual are smaller and more discrete, so the beige base is more dominant. In adults, a blotch on the head extends to the upper back to the forelimbs, and a blotch on the lower back area to the tail and hind limbs; therefore, the brown blotch is more dominant. *S. wilsoni* juvenile female has a plain cream coloration all over the body, and it seems that pale, plain colors are common among juveniles of Spilocuscus. The colors of mammal pelage may not remain constant over their entire lifespan (Caro & Mallarino 2020). Certain pigs and peccaries experience age-related transformation; for example, they are born with spotted and striped coats that eventually become consistent as their young become mobile (Caro et al. 2018).

The immature *S. wilsoni* photographed by Flannery

in 1992 was of unknown sex and was used as additional paratype information (Helgen & Flannery 2004). We saw similar color patterns between the photo and *S. wilsoni* in this study (Image 3), and we conclude that its morphology belongs to the sub-adult female individual. We also found differences in the iris color of juvenile (yellow-green) and sub-adult or adult individuals (blue-green), but this needs further investigation.

Indonesian Abstract: Kuskus bertotol adalah penghuni pohon berukuran sedang berasal dari hutan tropis Australia-Papua yang memakan buah dan daun. Kuskus bertotol termasuk ke dalam famili Phalageridae dan genus Spilocuscus (Gray, 1862). Perbedaan warna rambut antara *S. wilsoni* jantan dan betina belum terdeskripsikan secara morfologi. Pada penelitian ini, kami mendeskripsikan warna rambut dan mengukur bagian tubuh eksternal dari empat individu *S. wilsoni*: jantan dewasa, jantan dewasa muda, betina dewasa muda, dan betina remaja. Pengambilan foto bagian tubuh area dorsal, lateral, dan ventral dilakukan menggunakan kamera. Pengukuran tubuh meliputi bobot, panjang tubuh, panjang telinga, dan panjang ekor. *S. wilsoni* jantan memiliki pola totol dan bercak berwarna coklat di area dorsal dan lateral, sementara area ventral berwarna krem tanpa totol. Individu jantan dewasa muda memiliki pola totol di area dorsal dan lateral, sementara area ventral berwarna krem tanpa totol. Selanjutnya, individu betina dewasa muda memiliki pola perpaduan bintik warna coklat dan krem yang tampak seperti lurik dengan ujung keperakan. Individu betina remaja, satu-satunya yang tidak memiliki totol maupun bercak dan keseluruhan tubuh berwarna krem sampai kuning muda.

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