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Original Article

Identification key to species of the flying lizard genus *Draco* Linnaeus, 1758 (Squamata: Agamidae) in Thailand

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ABSTRACT

A species identification key of flying lizards in the genus *Draco* from Thailand was constructed based on 521 preserved specimens from collections during 1967–2012 in the Natural History Museum (THNHM), National Science Museum, Technopolis, Pathum Thani, Thailand. Regardless of sexual characters, four characters were used to identify *Draco* spp. lizards: 1) nostril direction; 2) type of tympanum; 3) pattern of patagium; and 4) snout with or without a series of scales forming a Y-shaped figure. The specimens were identified into nine species—*Draco blanfordii*, *Draco fimbriatus*, *Draco maculatus*, *Draco maximus*, *Draco melanopogon*, *Draco obscurus*, *Draco quinquefasciatus*, *Draco taeniopterus* and *Draco volans*.

Introduction

The agamid lizard genus *Draco* is the most remarkable and successful of the gliding vertebrates and they are well-known as flying lizards due to their ability to glide long distances between trees using a wing-like patagial membrane (patagium), supported by 4–7 elongated ribs or rib-like dermal structures on each side of the body (McGuire, 1998; McGuire and Dudley, 2011; Smith, 1935). Lizard characteristics have been described by Musters (1983) from which the following descriptions have been derived. The body is depressed and the scales on the dorsal body are larger or smaller than the ventral but the ventral usually shows the presence of keeled scales. The snout with or without a series of scales forming a Y-shaped figure (front view) and the direction of nostril may be upward or outward (or obliquely upward). The tympanum can be uncovered, half covered or fully covered with the scales. Each side of the neck has wattle (Fig. 1). All *Draco* species, exhibit sexual dimorphism. The differences between males and females are in their colour and dewlap size; males have brighter and longer dewlaps than those of females. Furthermore, males usually have cervical and caudal crests (Fig. 2). The habitats of *Draco* lizards are large, tall and thick forest with an open area for gliding, trees for climbing and sheltered areas for hiding. The lizards are insectivorous, feeding mostly on small ants and termites (Mori and Hikida, 1994). The *Draco* lizards inhabit primarily Southeast and South Asia including Southern India, the Malay Peninsula, the Philippines and Thailand (Taylor, 1963; Musters, 1983; Honda et al., 1999; Nabhitabhata et al., 2000).

According to the previous studies, the lizard genus *Draco* in Thailand was difficult to identify and so has ended up with variation in the number of species. The key to species has mostly focused on the characters of the male (Taylor, 1963; Musters, 1983). Therefore, the purpose of this study was to revise the identification key to species of the flying lizard genus *Draco* in Thailand regardless of sexual characters. The results from this study will be useful for conservation management as *Draco* lizards in Thailand are on the list of protected species (Wild Fauna and Flora Protection Division, 2008).

Materials and methods

In total, 521 preserved specimens in 70% ethanol from collections made during 1967–2012 at the Natural History Museum (THNHM), National Science Museum, Technopolis, Pathum Thani, Thailand were investigated for qualitative characters used to identify specimens to the species level based on the identification key to species of Taylor (1963) and Musters (1983).

Results

Regardless of sexual characters, four qualitative characters were used to identify the 521 preserved specimens of *Draco* lizards: 1)

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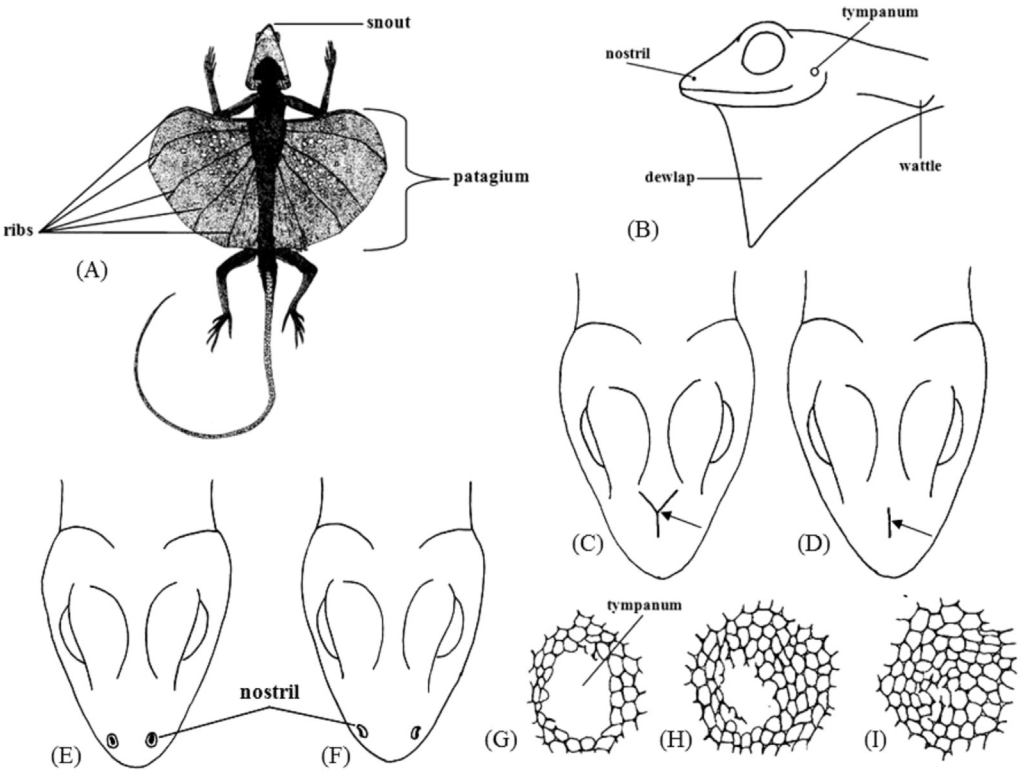

Fig. 1. Key characteristics of *Draco* lizards: (A) ventral view of *Draco* lizards showing the patagium and ribs supporting the patagium; (B) side view of head showing the nostril, tympanum, dewlap and wattle; (C–D) front view showing snout with (C) or without (D) a series of scales forming a Y-shaped figure (arrows); (E–F). direction of the nostril upward and outward (E) or obliquely upward (F); (G–I). type of tympanum, uncovered with scales (G), half covered with scales (H) and fully covered with scales (I) (Figure is modified from Musters (1983) and Shine et al. (1998)).

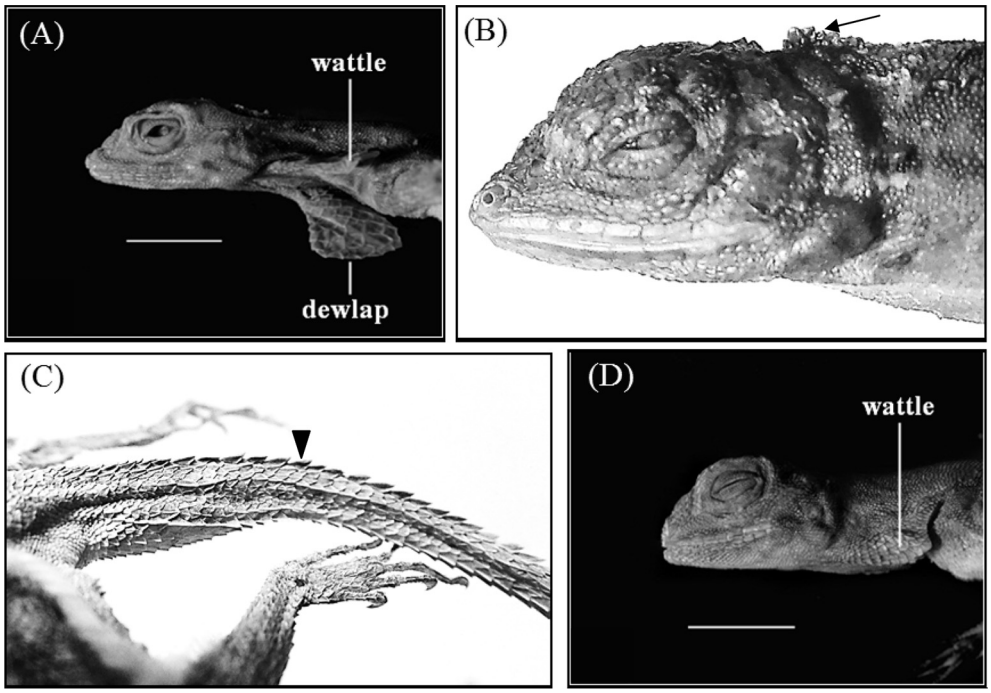

Fig. 2. Male and female of *Draco* lizard showing sexual dimorphic characters: (A–C) male characters; dewlap, wattle, cervical (arrow in B) and caudal crests (arrow head in C); (D) *Draco*'s female; (scale bars = 1 cm).

nostril direction; 2) type of tympanum; 3) pattern of patagium; and 4) snout with or without a series of scales forming a Y-shaped figure. The identification resulted in nine species—*Draco blanfordii*, *Draco fimbriatus*, *Draco maculatus*, *Draco maximus*, *Draco melanopogon*, *Draco obscurus*, *Draco quinquefasciatus*, *Draco taeniopterus* and *Draco volans* (see Appendix). The identification key to species of *Draco* lizards in Thailand is detailed below:

1. Nostril directed outward (or obliquely upward) (Fig. 3A).....2
Nostril directed upward (Fig. 3B).....4

2. Tympanum fully covered with scales (Fig. 4A)..... *D. maculatus*
Tympanum uncovered with scales (Fig. 4B).....3

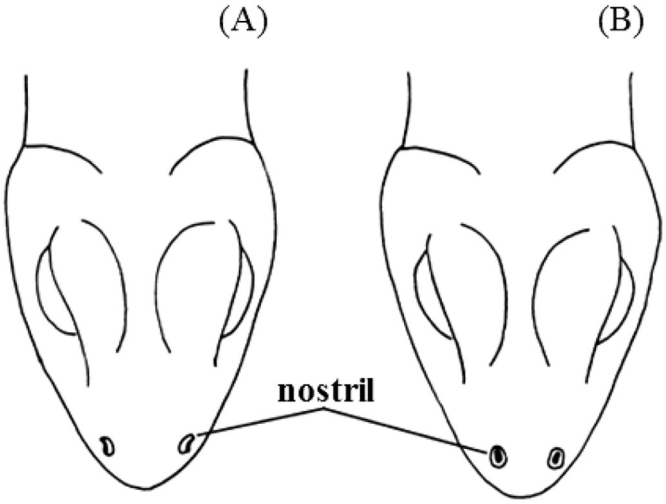

Fig. 3. (A) Nostril directed outward (or obliquely upward); (B) nostril directed upward.

3. Patagium with distinct light lines running longitudinally and distally (Fig. 5A)..... *D. fimbriatus*
Patagium with scattered light blotches (Fig. 5B)..... *D. volans*

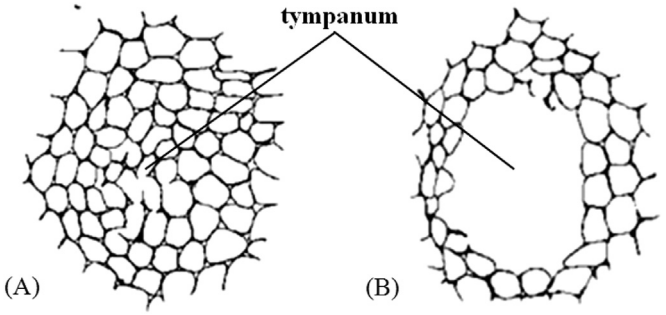

Fig. 4. (A) Tympanum fully covered with scales; (B) tympanum uncovered with scales (Sourced Musters, 1983).

4. Patagium with dark brown appearance (Fig. 6A).....5
Patagium without dark brown appearance (Fig. 6B).....6

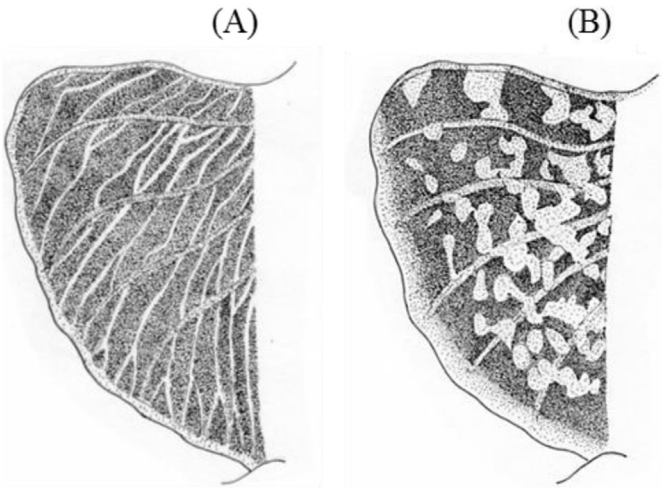

Fig. 5. (A) Patagium of *D. fimbriatus* with distinct light lines running longitudinally and distally; (B). patagium *D. volans* with scattered light blotches.

5. Patagium with short light lines running longitudinally and distally (Fig. 7A)..... *D. maximus*
Patagium with scattered light spots (Fig. 7B)..... *D. melanopogon*

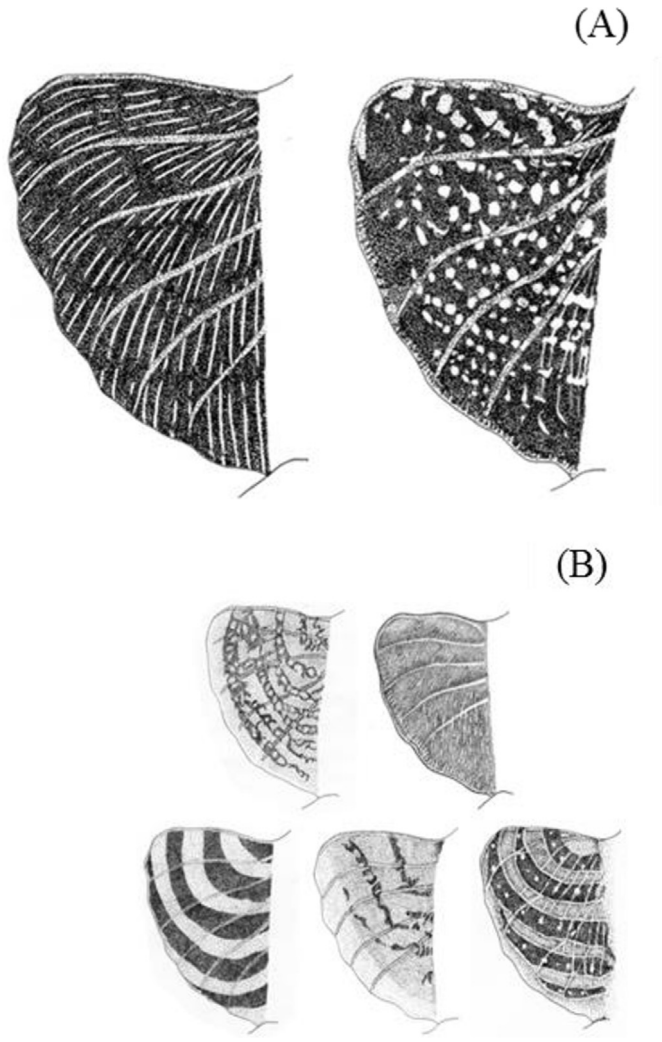

Fig. 6. (A) Patagium with dark brown appearance; (B). patagium without dark brown appearance.

6. Snout with a series of scales forming a Y–shaped figure (Fig. 8A)..... *D. blanfordii*
Snout without a series of scales forming a Y–shaped figure (Fig. 8B)..... 7

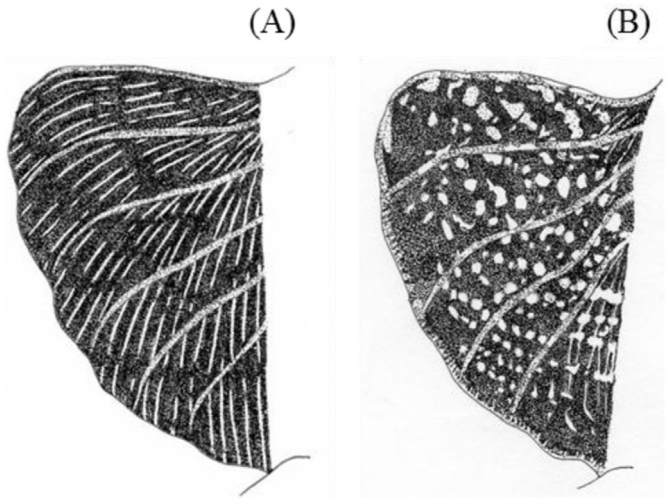

Fig. 7. (A) Patagium of *D. maximus* with short light lines running longitudinally and distally; (B). patagium of *D. melanopogon* with scattered light spots.

7. Tympanum fully covered with scales (Fig. 9A)..... *D. quinquefasciatus*
Tympanum uncovered with scales (Fig. 9B)..... 8

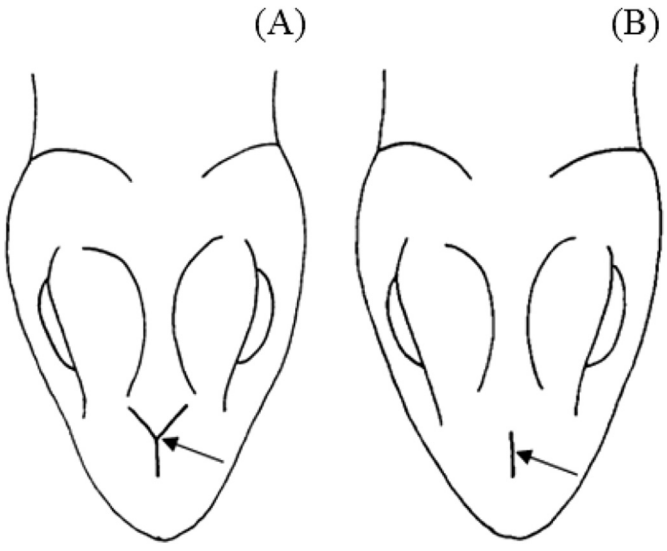

Fig. 8. (A) Snout with a series of scales forming a Y-shaped figure (arrow); (B) snout without a series of scales forming a Y-shaped figure (arrow).

8. Patagium light appearance with thin and black discontinuous transverse bands (Fig. 10A)..... *D. obscurus*
Patagium with 4–5 distinct dark transverse bands alternative to light transverse bands and presence of light spots in the middle of dark bands (Fig. 10B)..... *D. taeniopterus*

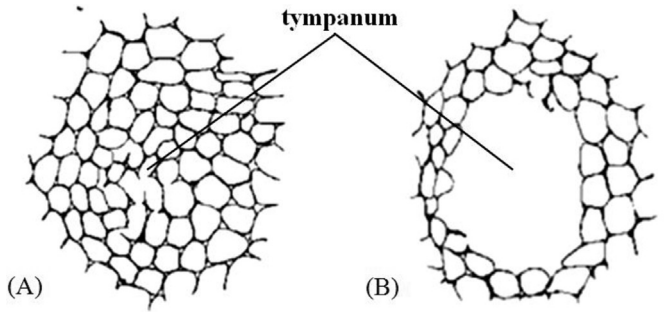

Fig. 9. (A) Tympanum fully covered with scales; (B). Tympanum uncovered with scales (Sourced from Musters (1983)).

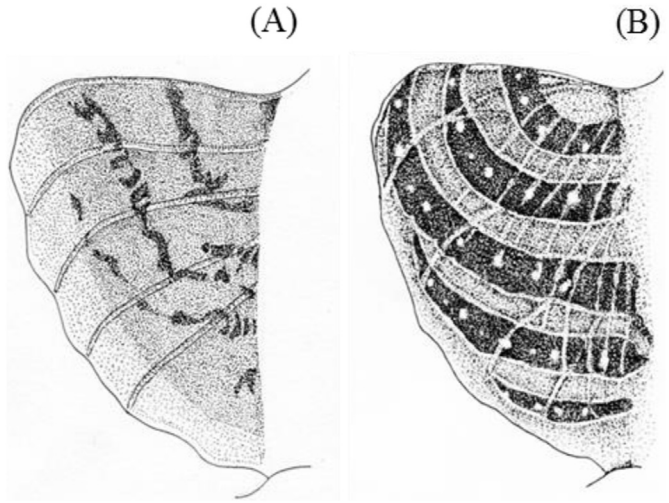

Fig. 10. (A) Patagium of *D. obscurus* with light appearance, thin and black discontinuous transverse bands; (B). Patagium of *D. taeniopterus* with 4–5 distinct dark transverse bands alternative to light transverse bands and presence of light spots in the middle of dark bands.

Discussion

The 521 preserved *Draco* specimens from collections during 1967–2012 were identified into nine species based on the four key characters (nostril direction, type of tympanum, pattern of patagium and snout with or without a series of scales forming a Y-shaped figure). These key characters provide the diagnosis for identification of *Draco* species regardless of sex. The nine species were *D. blanfordii*, *D. fimbriatus*, *D. maculatus*, *D. maximus*, *D. melanopogon*, *D. obscurus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*.

The numbers and species from this study differed from the study of Taylor (1963) who used preserved specimens from museums, field collection and reviews from the literature. Taylor (1963) reported there were 10 species—*D. blanfordii*, *D. fimbriatus*, *Draco formosus*, *Draco haematopogon*, *D. maculatus*, *D. melanopogon*, *Draco punctatus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*. However, Musters (1983) used many *Draco* specimens found in Thailand and a greater number than Taylor (1963). Musters (1983) described *D. formosus* as a synonym of *D. obscurus* as well as *D. punctatus* as a synonym of *D. fimbriatus* due to their morphological variations (Honda et al., 1999). Therefore, the species described by Taylor (1963) were similar to the species in the current study, except for *D. haematopogon*. According to Taylor (1963) *D. haematopogon* was described from studies by Robinson and Kloss (1915) and Smith (1916) who reported that *D. haematopogon* had been found at Koh Pha Ngan, Thailand. However,

the current study did not find *D. haematopogon* in any preserved specimens in the THNHM collection. Inger (1983) studied *Draco* specimens found in Thailand and reported nine species—*D. blanfordii*, *D. cristatellus*, *D. fimbriatus*, *D. maculatus*, *D. melanopogon*, *D. obscurus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*. However, *D. cristatellus* is a synonym of *D. fimbriatus* (Honda et al., 1999). Furthermore, Musters (1983) used many *Draco* specimens found in Thailand and he reported nine species—*D. blanfordii*, *D. fimbriatus*, *D. haematopogon*, *D. maculatus*, *D. melanopogon*, *D. obscurus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*. When compared with the current study, Musters (1983) did not identify any *D. maximus* but he reported *D. haematopogon* in Thailand by citing the study of Taylor (1963). Nabhitabhata et al. (2000) checked the list of *Draco* species in Thailand and reported there were nine species—*D. blanfordii*, *D. fimbriatus*, *D. haematopogon*, *D. maculatus*, *D. melanopogon*, *D. obscurus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*. The numbers and species were similar to those of Musters (1983). In the current checklist from the database of Uetz and Hallermann (2013), 11 species were identified in Thailand—*D. blanfordii*, *D. cristatellus*, *D. fimbriatus*, *D. formosus*, *D. haematopogon*, *D. maculatus*, *D. maximus*, *D. melanopogon*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*. However, *D. cristatellus* and *D. formosus* are synonyms for *D. fimbriatus* and *D. obscurus*, respectively.

The current study found *D. maximus* in the preserved specimen collection from THNHM; (Numbers 02203, 02204, 02206–02218, 13564–13566 and 13568). These specimens were previously described as *D. blanfordii*. The diagnostic key to discriminate *D. maximus* from *D. blanfordii* identifies *D. maximus* by the presence of a dark brown patagium with short light lines running longitudinally and distally, whereas *D. blanfordii* has a light appearance with oval spots on dark distinct transverse bands in females and light spots and lines on less distinct bands in males (Muster, 1983).

The morphometric and meristic characters were not appropriate for use for identification of the *Draco* species in the field study. However, these characters could be used as an additional or diagnostic tool to support the qualitative characters (Srichairat et al., 2014).

The species identification of the flying lizard genus *Draco* in Thailand was carried out based on the 521 preserved specimens from collections during 1967–2012 in the Thailand Natural History Museum, Bangkok and the National Science Museum, Pathum Thani province, Thailand. Based on four qualitative characters (nostril direction, type of tympanum, pattern of patagium and snout with or without a series of scales forming a Y-shaped figure), the specimens were identified into nine species—*D. blanfordii*, *D. fimbriatus*, *D. maculatus*, *D. maximus*, *D. melanopogon*, *D. obscurus*, *D. quinquefasciatus*, *D. taeniopterus* and *D. volans*.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

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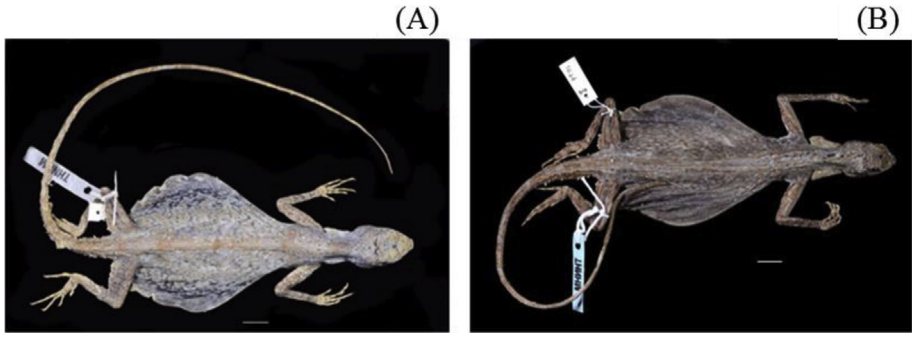
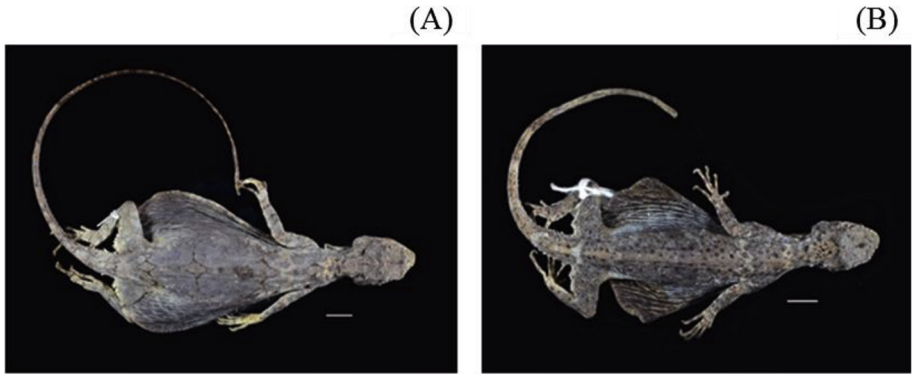
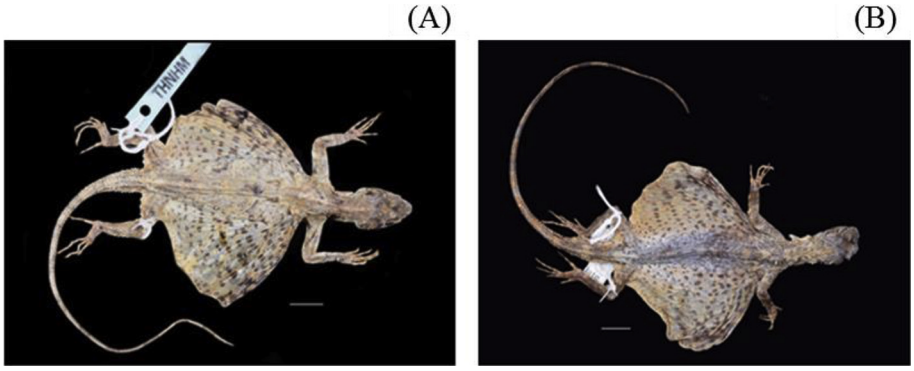
Appendix



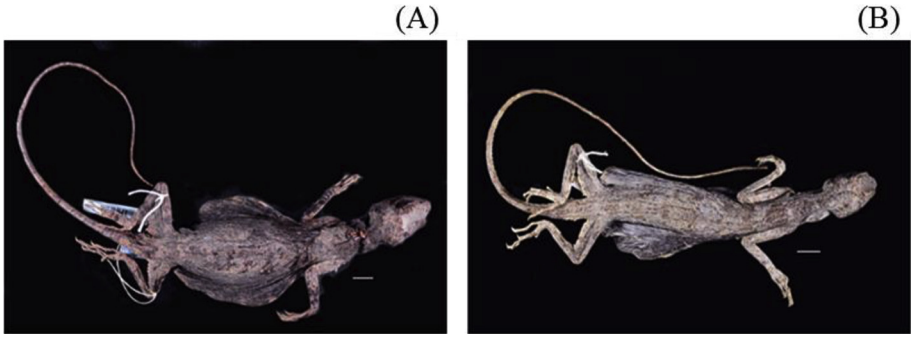
Appendix Fig. 1. *Draco blanfordii*: (A) female; (B) male; (scale bars = 1 cm).



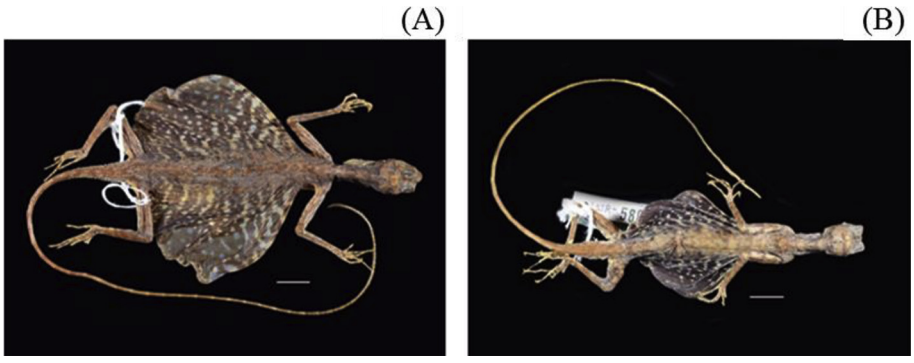
Appendix Fig. 2. *Draco fimbriatus*: (A) female; (B) male; (scale bars = 1 cm).



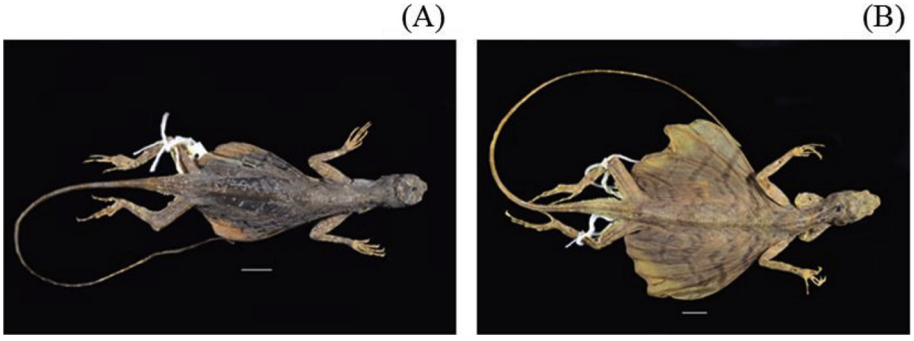
Appendix Fig. 3. *Draco maculatus*: (A) female; (B) male; (scale bars = 1 cm).



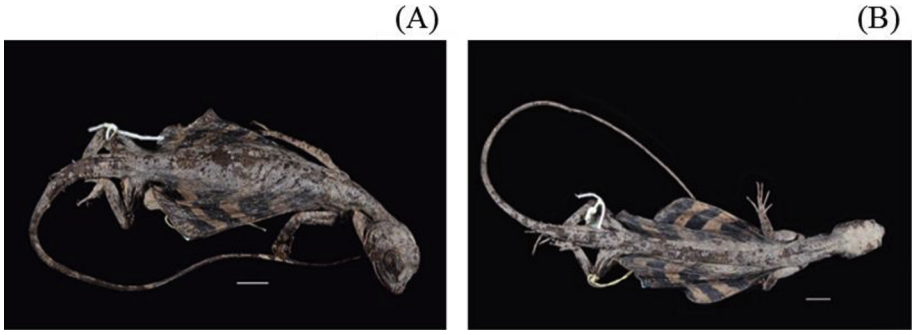
Appendix Fig. 4. *Draco maximus*: (A) female; (B) male; (scale bars = 1 cm).



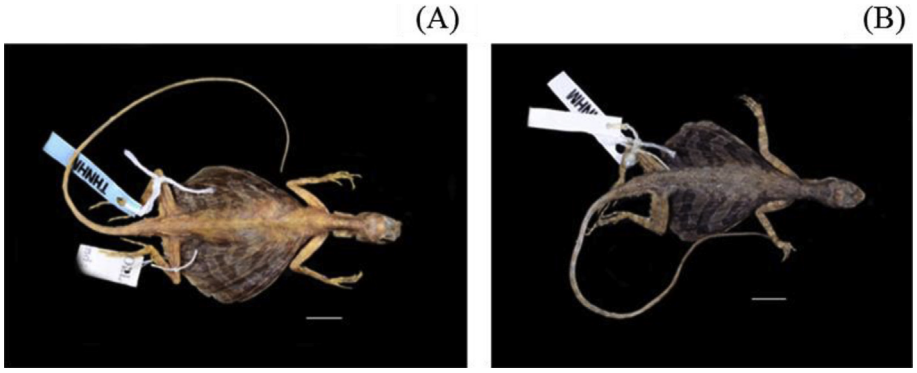
Appendix Fig. 5. *Draco melanopogon*: (A) female; (B) male; (scale bars = 1 cm).



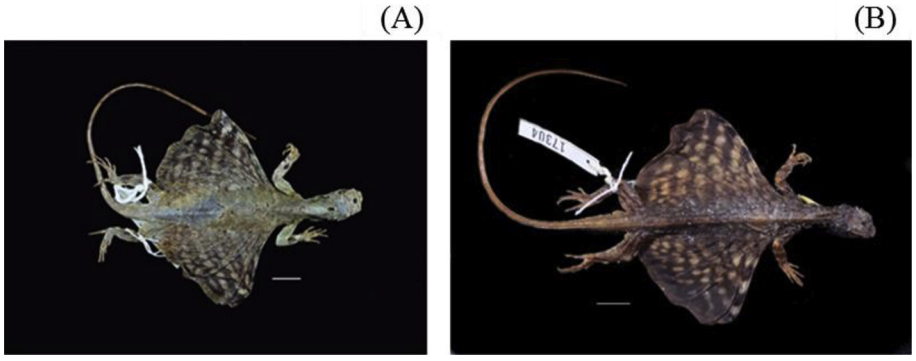
Appendix Fig. 6. *Draco obscurus*: (A) female; (B) male; (scale bars = 1 cm).



Appendix Fig. 7. *Draco quinquefasciatus*: (A) female; (B) male; (scale bars = 1 cm).



Appendix Fig. 8. *Draco taeniopterus*: (A) female; (B) male; (scale bars = 1 cm).



Appendix Fig. 9. *Draco volans*: (A) female; (B) male; (scale bars = 1 cm).

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