

The taxonomic status of Flores Hawk Eagle *Spizaetus floris*

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The Changeable Hawk Eagle *Spizaetus cirrhatus* complex ranges from India (*cirrhatus*) through South-East Asia (mainly *limnaeetus*) to Flores, Sumbawa and Lombok, Indonesia (*floris*). The latter taxon is morphologically very distinct from the widespread *limnaeetus*. It has diagnostic white patches on the upperside of the inner parts of the primaries, a juvenile-like adult plumage, and it is much larger than *limnaeetus*. It is allopatric with *limnaeetus* without any known geographical overlap. The large morphological differences indicate that the two taxa are reproductively isolated. We suggest that *floris* be treated as a distinct species with the English name of Flores Hawk Eagle.

INTRODUCTION

Taxonomic studies within conservation biology have become increasingly important. The IUCN Red List of threatened species (IUCN 2001) is commonly used to help focus conservation priorities on the species at greatest risk of extinction. At present, subspecies are not generally listed (e.g. BirdLife International 2000). In cases where the taxonomic status of rare subspecies has not been sufficiently clarified, there is a risk that potentially valid species could become extinct even before conservation action is initiated.

In Indonesia, the conservation of rainforest raptors has attracted increased attention during recent years. In this region, a number of closely related forest-living hawk eagles *Spizaetus* spp. are found. Changeable Hawk Eagle *S. cirrhatus* comprises a complex of subspecies occurring in two major groups, crested and crestless, but the taxonomic status of the different subspecies has been disputed (del Hoyo *et al.* 1994). Six taxa are normally recognised: two crested taxa comprising *cirrhatus* (India south of Rajasthan and Gangetic plain) and *ceylanensis* (Sri Lanka), and four uncrested taxa comprising *andamanensis* (Andaman islands), *limnaeetus* (north India and Nepal through

Myanmar, southern Indochina, Malay Peninsula to Greater Sundas and southern Philippines), *vanheurni* (Simeulue island west of Sumatra) and *floris* (Lombok, Sumbawa and Flores; Fig. 1).

Amadon (1953) divided the subspecies into two groups: the *cirrhatus* group (*cirrhatus*, *ceylanensis* and *andamanensis*) and the *limnaeetus* group (*limnaeetus*, *vanheurni* and *floris*). B. King (personal communication 1994 to Inskipp *et al.* 1996) suggested that *floris* was a separate species because its adult and juvenile plumages were identical, unlike other subspecies of *S. cirrhatus* which have distinct juvenile and adult plumages. The morphological differences between *floris* and *limnaeetus* are so striking that it seems surprising that these forms have been lumped together. One reason could be that museum specimens of adult *floris* look quite similar to juvenile *limnaeetus* (Fig. 2a), leading to the assumption that all museum specimens are juveniles, wrongly aged by the collectors. This has resulted in incorrect illustrations of adult *floris* in many current handbooks and fieldguides (e.g. Weick 1980, del Hoyo *et al.* 1994, Coates and Bishop 1997, Ferguson-Lees and Christie 2001). These all illustrate adult *floris* with a brown head. The first widely available illustration of an adult *floris* was made by Weick (1980). In his first draft he painted the eagle with a white head based on studies of museum specimens. However, Weick was advised by Amadon and Brown that adult *floris* should have a brown head as in other *Spizaetus* species, so the illustration was incorrectly changed (F. Weick *in litt.* 1999).

Another source of misunderstanding could be that ornithologists visiting the Lesser Sundas might have been confused by the presence of four other sympatric species of eagles with fairly similar juvenile plumages, including white underparts (Short-toed Snake Eagle *Circaetus gallicus*, Bonelli's Eagle *Hieraaetus fasciatus*, Rufous-bellied Eagle *H. kienerii* and White-bellied Sea Eagle *Haliaeetus leucogaster*).

Here we give a detailed description of *floris* based on museum specimens and field studies, focusing on the morphological differences between *floris* and *limnaeetus*, and we comment on the distribution, conservation and taxonomic status of *floris*. Elsewhere we describe the phylogenetic relationships within the *Spizaetus cirrhatus* complex based on analyses of mtDNA sequences (Gamauf *et al.* in prep) and provide

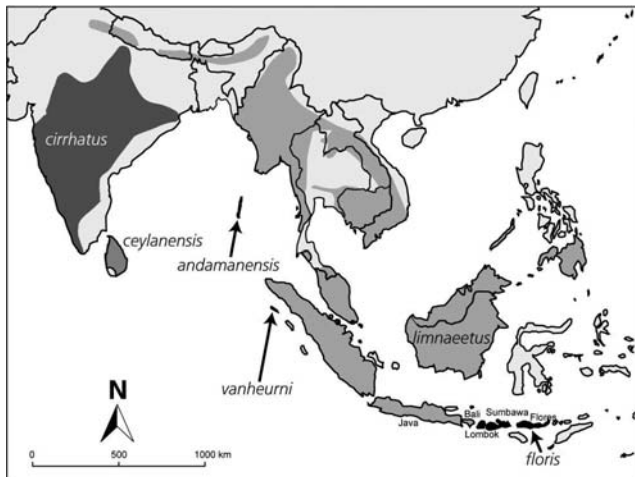


Figure 1. Ranges of taxa in the Changeable Hawk Eagle *Spizaetus cirrhatus* complex.



Plate 1a. Adult *floris* (right), juvenile *limnaeetus* (left).



Plate 1d. Tail of adult *floris* (right) and juvenile *limnaeetus* in moult (left).



Plate 1b. Head of *floris*.



Plate 1e. Tail of juvenile *floris*.



Plate 1c. Wing-patch of adult *floris*.



Plate 1f. Tail of adult *floris*.



Plate 2a. Ventral side of adult *floris* (right), juvenile *limnaetus* (middle) and adult *limnaetus* (left).



Plate 2d. Primaries of adult *limnaetus*.



Plate 2b. Dorsal side of the same birds.



Plate 2e. Variation in *limnaetus*, dorsal side. The two birds to left are juveniles.



Plate 2c. Primaries of adult *floris*.



Plate 2f. Ventral side of the same birds.

a detailed description of the distribution and population status of *floris* (Prawiradilaga *et al.* in prep).

METHODS

We studied four specimens of *floris* and 155 of *limnaeetus* at the National Museum of Natural History (Naturalis) in Leiden (formerly Rijksmuseum van Natuurlijke Historie, RMNH). One skin of a juvenile *floris* was studied in Bogor Museum (MZB). This individual we confidently identified as being juvenile because of a note on the label recording the lack of ossification of sternal foramina (*Foramina im Brustbein noch nicht verknöchert*: Rensch 1931). In addition we studied photos of two specimens of *floris* from the American Museum of Natural History (AMNH), including the holotype. We suggest that the holotype is a juvenile, because its tail pattern was similar to that of the Bogor specimen. Wing length was measured with the wing flattened and stretched (maximum wing chord). A list of the specimens of *floris* examined is given in Table 1.

A total of 609 hours of field observations were carried out in Lombok, Sumbawa and Flores on 98 days in August–October 2002, December 2002–February 2003 and June–July 2003. Altogether 42 individuals of *floris* were observed, most of which were adult birds of territorial pairs. During studies on Java, a considerable number of *limnaeetus* were observed in the field, as well as in captivity.

RESULTS

Morphological differences between *floris* and *limnaeetus*

The head of *floris* is white in both adults and juveniles, sometimes with fine brownish streaks on the crown (Plate 1a,b). The mantle and back are dark brown. The inner vanes of the tertials are pure white. On the inner parts of the outer primaries, the outer vanes are white, forming a large and well-defined white patch on the upperside of the wing (Plate 1c). In some individuals, this patch is less conspicuous and more greyish, but still contrasts with the dark colour of the rest of the upperwing. The tail is brown with six dark bars, the outermost broader than the others (c.44 mm compared to 14 mm). The distance between the two outermost dark bars is slightly larger than between the other bars (23 and 14 mm respectively, Plate 1d). The inner part of the tail and the uppertail-coverts are white, producing a distinctive white patch (Plate 2b). The entire underside, including the thighs and legs, are pure white. One individual (AMNH 534895), described by Hartert (1898) as an adult, has some very faint pale rufous-brown bars on the breast, sides of the breast and thighs (Plate 1f).

In *limnaeetus* two distinct colour morphs are described, one being completely dark (del Hoyo *et al.* 1994). In the Philippines, Gamauf *et al.* (1998) found that 50% of 34 individuals were light morphs, 38% were dark morphs, and 12% were intermediate with a grey-brown breast. Among 155 skins from Indonesia,

Table 1. Measurements of *Spizaetus floris*.

Specimen	Locality	Sex	Age	Wing (mm)	Tail (mm)
AMNH 534895	Flores	Male	Adult	430	
AMNH 534896	Flores	Male	Juvenile	450	296
RMNH 81112	Flores	Female	Adult	456	274
RMNH cat. no. 1	Flores		Adult	441	255
RMNH cat. no. 2	Flores			462	277
RMNH 66257	Flores		Adult	450	272
MZB 11948	Sumbawa	Male	Juvenile	438	281

Table 2. Comparison of adult plumage of *Spizaetus floris* and *S. cirrhatus limnaeetus*.

Characters	<i>Spizaetus floris</i>	<i>S. cirrhatus limnaeetus</i>
Morphs	Light	Light, dark and intermediate
Head	White, sometimes with fine brownish streaks on crown	Brown
Mantle and back	Blackish-brown	Umber-brown with paler edges
Primaries	Inner parts of the outer feathers are white, forming a white patch on the upperwing	Brown (no wing patch)
Inner webs of tertials	Pure white	Brown
Breast and belly	Pure white, sometimes with very faint pale rufous-brown bars	White with bold dark brown streaks
Thighs and legs	Pure white, sometimes with very faint pale rufous-brown bars	Buff with fine white bars
Tail	Brown with six dark bars. Distance between the outermost dark bars is only a little larger than between the other bars	Brown with 4–5 dark bars. Distance between the outermost dark bars is much larger than between the other bars

we found that 51% were light morphs, 48% dark and 1% were intermediate. Figs. 3e and 3f show some of the variation in *limnaeetus* from Indonesia.

In light morphs of adult *limnaeetus*, the mantle, back, upperwing-coverts and secondaries are umber-brown with paler edges. The paler-fringed secondary coverts form a narrow band. In contrast to the dark upperparts, the head and neck are pale with numerous fine but distinct streaks, occasionally brownish. The nape feathers are prominent although there is no crest. The chin and throat are white, usually with a black median stripe and lateral stripes. The long tail is concolorous with the upperparts. There is a wide dark subterminal bar, followed by 3–4 narrower dark brown bars towards the base. The distance between the two outer bars is much larger than between the other bars (Plates 1d, 2a,b). The breast and belly are white with bold, dark brown streaks. The long and powerful feathered legs and the undertail-coverts are buff with fine

Table 3. Comparison of juvenile plumage of *Spizaetus floris* and *S. cirrhatus limnaeetus*.

Characters	<i>Spizaetus floris</i>	<i>S. cirrhatus limnaeetus</i>
Morphs	Light	Light, dark and intermediate
Mantle and back	Blackish-brown	Brown with a saddle-like band formed by lighter-coloured upperwing-coverts
Primaries	Distinctive white patch on the upperside of the primaries	No such patch
Tail	Terminal bar broader than the other bars	Terminal bar of the same width as the other bars

Table 4. Measurements of mean wing length in mm (range in parentheses) of *Spizaetus floris* and Javan specimens of *S. cirrhatus limnaeetus*.

<i>Spizaetus floris</i>			<i>S. cirrhatus limnaeetus</i>	
Male	Female	Unknown	Male	Female
(n=3)	(n=1)	(n=3)	(n=4)	(n=4)
439	456	451	378	412
(430–450)		(441–462)	(365–387)	(407–426)

white bars. The primaries have more distinct dark bars than found in *floris* (Plate 2e,d).

In juvenile *floris*, the terminal dark bar of the tail is more diffuse compared with adult birds. This is most easily seen on the ventral side of the tail (Plate 1e,f). The juvenile plumage of *floris* is similar to that of juvenile *limnaeetus*, which also has a pure white head with small dark spots and a white underside. However, the colour of the mantle and back is darker in *floris*, lacking the light saddle-like band on the upperwing-coverts of *limnaeetus*. It also has distinctive white patches on the upperside of the primaries, not found in *limnaeetus*, and the dark terminal tail-bar of *floris* is broader than the other six bars (c.32 mm versus 15 mm), whereas in *limnaeetus* it is of the same width as the other bars (Plates 1d, 2b). The plumage differences between *floris* and *limnaeetus* are summarised in Tables 2–3.

Measurements indicate that *floris* has considerably longer wings than *limnaeetus* from Java (Table 4). However, the number of specimens is small and certainly does not represent the range of variation within each of the two taxa. Brown and Amadon (1968) reported wing lengths of 380–430 mm for male *limnaeetus* and 405–462 mm for females, probably based on measurements of Himalayan specimens. They recorded wing lengths of *floris* to be 485 mm for males and 495 mm for females, but we do not know which birds they measured, as these measurements are larger than on any museum specimens known to us.

Distribution

We found that *floris* was distributed in all parts of the islands of Lombok, Sumbawa and Flores, as well as on two satellite islands, Satonda near Sumbawa and Rinca

near Komodo. Six of the seven known specimens of *floris* are from Flores (Table 1). On this island, the species was previously known from about ten sites and it has been assumed to be uncommon (C. Trainor *in litt.* 2000). A specimen at Bogor museum was collected by Rensch (1931) on Sumbawa, and Butchart *et al.* (1996) recorded an individual on Sumbawa in 1993. Verheijen (1961) listed the bird for Paloe, a small island 16 km off the north coast of Flores. Coates and Bishop (1997) also mentioned Komodo in the range for this species, but did not refer to any particular observation. These records do not contain further details that allow verification.

On Lombok, we observed *floris* in Sesaot at the border of Rinjani National Park on 18 September 2002. This is the first record from Lombok. The bird was identified by its white head and underside together with its diagnostic white patch on the upperside of the outer primaries, which distinguish it from immature *limnaeetus*. Later we observed the species at three other locations on the border of Rinjani National Park (Senaru, Pidana and Pusuk: Prawiradilaga *et al.* *in prep.*). These observations are of particular importance since Lombok is just east of Bali, the easternmost extent of the distribution of *limnaeetus*.

Ecology

Verhoeve and Holmes (1998) described the habitat of this species as cultivated hills and woodland from sea level to 1,000 m. We observed it in lowland and submontane forest up to 1,600 m, but the majority of individuals were in lowland rainforest. Occasionally individuals were seen over cultivated areas, but always close to intact or semi-intact forest.

In all villages we visited we found that local people were familiar with an eagle with a white head that reportedly hunted chickens and small pigs around villages. However, the possibility of confusion with other raptors cannot be excluded. On one occasion we witnessed a Flores Hawk Eagle hunting in the middle of a village in the early morning, and on several occasions we observed individuals hunting over cultivated landscapes near forest.

In one village in Mbeliling, Flores we were informed about a large tree that was cut down in late August containing a nest with a large nestling hawk eagle. The bird was taken and sold to a bird market. This suggests breeding during the dry season. Verheijen (1964) listed one nest in March, two in April and one in August. However, there is a possibility of misidentification since other sympatric eagles are not mentioned in the paper. Display flight and copulation have also been observed on Flores in June–July 2003 (J.-M. Thiollay *in litt.* 2003).

DISCUSSION

Systematics

The longest distance of open sea between the islands in the Lombok strait between Bali (where *limnaeetus* occurs) and Lombok (where *floris* occurs) is 24 km (via Nusa Penida). This distance is of the same magnitude as the distances between other islands within the range

of *floris*. During the Pleistocene glacial sea-level depressions this distance was even shorter, perhaps not more than 1 km (Van Oosterzee 1997). A similar situation is found among other *Spizaetus* species within the islands of South-East Asia. For example, Javan Hawk Eagle *S. bartelsi* is separated by the narrow Sunda strait from the closely related Blyth's Hawk Eagle *S. alboniger* and Wallace's Hawk Eagle *S. nanus* on Sumatra.

It is possible that *limnaeetus* and *floris* might have come into secondary contact, after eastward expansion of *limnaeetus*. However, they may not yet have evolved sufficient ecological differences to avoid competition and/or hybridisation. If hybridisation between *floris* and *limnaeetus* commonly occurs, it would be expected that dark morphs (which are common in *limnaeetus* on Java) would have been recorded in the range of *floris*, particularly on Lombok. However, since only four individuals have been identified on Lombok so far, the possibility of a hybrid zone there cannot be rejected. On the other hand, it seems unlikely given the lack of dark morphs (or even dark-headed birds) recorded in a total of 42 field observations and seven specimens of *floris* from Flores and Sumbawa. Thus it is reasonable to conclude that hybridisation is not occurring, at least not frequently.

The distributions of *floris* and *limnaeetus* are commonly regarded as allopatric, being separated only by a narrow strait between Bali and Lombok. However, Changeable Hawk Eagle has a considerable ability to colonise distant islands. For example, Thiollay (1996) found a dark morph *limnaeetus* on Nias 125 km west of Sumatra in 1992 (there had been no previous records), and we observed a light morph *limnaeetus* on Krakatau, 12 km from the Javan mainland, in 1997. The distributional boundary between Bali and Lombok could therefore arguably be considered parapatric.

The argument that parapatric and ecologically incompatible taxa are best treated as subspecies because they are necessarily very closely related (Bock 1986, Amadon and Short 1992) is certainly not universally valid (Garcia-Moreno and Fjelds  1999). Helbig *et al.* (2002) recommended that diagnosable taxa that are strictly parapatric and do not hybridise should be ranked as separate species, because it appears unlikely that such a situation can be maintained without intrinsic reproductive isolation. Natural selection would favour interbreeding between two populations that are in contact at an ecotone or trivial ecological barrier if hybrids have no fitness disadvantage. If such interbreeding does not occur despite the lack of an effective extrinsic barrier, mixing may be being prevented by intrinsic isolating mechanisms.

No mixing of *floris* (n=5) and *limnaeetus* (n=5) mtDNA haplotypes was observed among birds sampled from Indonesia, suggesting reproductive isolation, albeit based on small sample sizes (Gamauf *et al.* in prep.). The genetic distance between these two taxa was found to be only 1% (Gamauf *et al.* in prep.), indicating that they were separated during the Pleistocene. During that period there were several cool and dry periods (e.g. 80,000 and 190,000 years ago) and biogeographic evidence indicates that Asian rainforests were fragmented (Brandon-Jones 1996). The Flores Hawk Eagle probably evolved in a refuge somewhere in the Lesser Sundas. Theoretical models

suggest that the evolution of reproductive isolation can be fast (Lande 1981, Barton and Charlesworth 1984), and that morphological character states can evolve within well under one million years (Nilsson and Pelger 1994), especially if there is strong selection combined with bottleneck effects and coalescence. This view is supported by empirical data on birds. For instance, mtDNA cyt b sequences differ between Sanford's Sea Eagle *Haliaeetus sanfordi* and White-bellied Sea Eagle *H. leucogaster* by only 0.3% (Wink *et al.* 1996), but they are regarded as separate species. Recent studies indicate that avian speciation can involve little genetic change and occur rapidly in small populations (e.g. Grant *et al.* 2000).

More extensive morphological studies as well as observations on breeding biology, behaviour and vocalisation may lead to the detection of further difference between *floris* and *limnaeetus*. However, using the biological species concept, there exists sufficient evidence to consider *floris* as a full species, principally because of: (1) apparent reproductive isolation based on lack of an effective distribution barrier and apparently no significant hybridisation between *limnaeetus* and *floris*; (2) distinct morphological differences; (3) distinct plumage differences; (4) significant, albeit small, genetic differences between *floris* and *limnaeetus*; and (5) apparently no mixing of mtDNA haplotypes between *floris* and *limnaeetus*.

Etymology

Hartert (1898) named the species after the island Flores where the holotype was collected. We propose the English name Flores Hawk Eagle and the scientific name *Spizaetus floris* to draw attention to the species's main distribution and restricted range. Sibley and Monroe (1990) used the name Sunda Hawk Eagle, which we find inappropriate, as it is unrecorded from the Greater Sunda islands.

Neoteny

Extensive field observations and examination of museum specimens confirmed that adult Flores Hawk Eagles have a number of traits (e.g. white head and underparts) that are typical of juveniles in other hawk eagle species e.g. Changeable, Sulawesi *S. lanceolatus*, and Philippine Hawk Eagles *S. philippensis* and the *stresemanni* race of Wallace's Hawk Eagle *S. nanus*. This could be considered a case of neoteny. A similar case is provided by Sanford's Sea Eagle, in which adults have a juvenile-like plumage that is very different from the adult plumage of the closely related White-bellied Sea Eagle (Wink *et al.* 1996).

Neoteny is often associated with increased body size (Gould 1977), and interestingly, Flores Hawk Eagle is much larger than Changeable Hawk Eagle. However, in all birds of prey the skeletal growth is completed before the final development of plumage in the late nestling stage. Thus, the development of the principal determinants of overall size are completed before plumage finishes developing. Neotenus morphology and behaviour is likely to reduce aggression from adults and facilitate sociality (Gould 1977, Lawton and Lawton 1986). This has been proposed as an explanation for neoteny in skuas *Catharacta* spp. (Andersson 1999), but it does not seem relevant to

Spizaetus eagles. We find no obvious explanation for why Changeable Hawk Eagle has evolved neoteny, but such a trait might perhaps arise by loss of genetic variation in small populations.

Conservation

On the basis of distances between three neighbouring territories, we estimate that the territory size for Flores Hawk Eagle is c.40 km². Given that it is primarily dependent on forest, this implies that the total population size for the species is probably less than 100 pairs (Prawiradilaga *et al.* in prep). The species qualifies at least as Endangered on the IUCN Red List under criterion C2a(i) (total population <2,500 individuals and all subpopulations <250 individuals), and it may even qualify as Critically Endangered under criterion C1 (population <250 individuals and continuing decline >10% per 10 years or three generations) given current rates of habitat destruction in the Lesser Sundas.

Habitat degradation and destruction are the most important threats to Flores Hawk Eagle. Although the species could probably survive in a partly cultivated landscape, protected areas in the species's range are presently too small for its long-term survival. Persecution because of its habit of stealing chickens, and capture for the cagebird trade pose additional threats. We found evidence of a recently robbed nest, and capture for the cagebird trade was also reported by Trainor and Lesmana (2000). We observed a juvenile Short-toed Snake Eagle and an adult White-bellied Sea Eagle that had been similarly captured on Flores.

Flores Hawk Eagle used to be regarded as a totem ('empo') among the Manggarai people in western Flores, who considered it to be an ancestor of humans, and therefore did not hunt it. However, these traditions have now broken down. Fortunately, some work is now underway to inform local people of the importance of this species (C. Trainor *in litt.* 2000).

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