

A new Subspecies of the Booted Eagle from Southern Africa, inferred from biometrics and mitochondrial DNA

Reuven Yosef, Gerhard Verdoorn, Andreas Helbig and Ingrid Seibold

ABSTRACT

The population of Booted Eagles *Hieraaetus pennatus* breeding in Southern Africa is proposed to comprise a new subspecies, *H. p. minisculus*, based on its small size and three differences in the DNA sequence of 1041 base pairs of its mitochondrial *cytochrome b* gene. It is suggested that its common name be the Southern Booted Eagle.

ACCOUNT

Only two subspecies of the Booted Eagle *Hieraaetus pennatus* are recognized at present, *H. p. pennatus* (Gmelin), 1788 and *H. p. harterti* Stegmann, 1935 (Brown & Amadon 1968). The breeding range of the nominate subspecies is described as south Europe to North Africa and the Caucasus, and of *H. p. harterti* as in southwest and central Asia. Cramp and Simmons (1980) state that there is a cline of increasing size from west to east, but that birds in central Asia do not warrant recognition as a third subspecies, *H. p. milvoides* Jerdon 1839. For further discussion of the sub-specific taxonomy and nomenclature of this species refer to Porter (1970) and Brooke (1974).

It appears that early researchers were unaware of the breeding population of Booted Eagles in southern Africa (e.g. Brown & Amadon 1968). Upon discovery, it was assumed that these birds were of the nominate subspecies that had recently initiated breeding in the region (Tarboton 1994). Furthermore, Tarboton mentioned that a nest found in 1917 in the southern Cape region was incorrectly ascribed to a different species, and so was paid no further attention. In 1972, a pair of Booted Eagles was discovered nesting in the western Karoo, and since then many other breeding pairs have been discovered in the southern Cape.

Tarboton (1994) contends that "despite other uncertainties, it is clear that the Booted Eagle has established itself as a breeding species in southern Africa in comparatively recent times." Steyn (1996) reports that an estimated 400 pairs breed in the Western and Eastern Provinces of South Africa, and that the previously unrecorded Booted Eagle may actually be the most common breeding eagle in the region. Brown *et al.* (1982) contend that the European and North African breeding populations are not racially distinct from the Southern African population, but Steyn (1996) thought that the situation required "further elucidation", with which we concur.

On a visit to South Africa in February 1997, RY and GV observed that a Booted Eagle *Hieraaetus pennatus* at the RESCUE (Raptor Education and Special Care Unit) rehabilitation centre was smaller than those on migration at Eilat and those that breed in Europe and Asia. Blood samples were taken from this individual and from three others held at the World of Birds aviaries, Cape Town, and sent to AH and IS for DNA-sequencing. In addition, biometrics were taken from specimens of skins in the Transvaal Museum at Pretoria, South Africa, and in the Natural History Museum at Tring, United Kingdom.

Table 1. Data on specimens of *Hieraaetus pennatus* examined at the Transvaal Museum (TM), Pretoria, the Natural History Museum (NHM), Tring, at the United States National Museum of Natural History (USNMNH), Washington, D.C., and at the Museum of Comparative Zoology (MCZ), Harvard University.

<i>Date</i> <i>(Specimen Number)</i>	<i>Location</i>	<i>Sex/ Age</i>	<i>Wing length</i>	<i>Tail length</i>	<i>Body length</i>	<i>Culmen</i>	<i>Hind claw</i>
Holotype	RESCUE, South Africa	U	330	175	430	23.0	23.5
10.05.1935 (21178; TM)	Assab, Namibia	M Ad	343	186	461	19.5	24.0
19.08.1937 (21179; TM)	Klipfontein	M Ad	343	181	446	20.5	24.5
24.02.1909 (5491, TM)	Transkei	F Ad	364	187	485	22.0	25.0
POSSIBLE <i>H. p. minisculus</i> SKINS:							
??-??-1864 (342, NHM)	Chibisa, Zambesi	U	345	188		23.7	23.9
97-??-???? (43.2.28.62, NHM)	South Africa	U	355	191		21.1	23.1
20.02.1923 (404158, USNMNH)	Malawi	M	346				
29.12.1914	Kugersdorp	F	407	204	542	25.0	30.0
24.12.1891 (18001, TM)	Vryburg, Kalahari	F Ad	399	206	522	25.0	29.0
28.11.1915 (13331, TM)	Pretoria	F Ad	399	226	546	25.0	29.0
17.11.1912 (4830, TM)	Matatiele, NE Cape	F Juv	384	184	526	26.0	30.0
14.02.1912 (9284, TM)	Pretoria	F Ad	388	205	555	24.5	28.0
29.12. 1914 (14574, TM)	Krugersdorp	F Ad	407	204	542	25.0	30.0
??-09-1903 (1484, TM)	Rhodesia	? ?	374	188	478	23.5	28.0
12.02.1884 (343, NHM)	Rustenberg Transvaal	F Ad	385	200		24.3	28.7
??-??-1877 (56031, USNMNH)	Greece	M	362				

<i>Date</i> (<i>Specimen</i> <i>Number</i>)	<i>Location</i>	<i>Sex/ Age</i>	<i>Wing length</i>	<i>Tail length</i>	<i>Body length</i>	<i>Culmen</i>	<i>Hind claw</i>
22.03.1877 (56032, USNMNH)	Hungary	F	342				
29.03.1894 (152787, USNMNH)	Egypt	F	391				
30.12.1945 (399824, USNMNH)	India	F	408				
30.12.1945 (399825, USNMNH)	India	F	365				
12.12.1948 (408023, USNMNH)	Nepal	F	394				
28.12.1912 (433525, USNMNH)	South Africa	?	360				
10.04.1910 (152792, MCZ)	Caucasus	M	368				
29.07.1917 (152793, MCZ)	Turkestan	F	399			24.0	25.0
??.05.1886 (71035, MCZ)	Palestine	?	386			26.0	27.0
??.??.???? (71036, MCZ)	Palestine	?	423			broken	30.0
??.??.???? (71037, MCZ)	Palestine	?	383			25.0	27.0
??.??.1879 (33601, MCZ)	India	?	364			23.0	24.0
??.??.???? (92686, MCZ)	India	?	427			24.0	31.0

We compared our data with the biometrics of Eurasian birds and with skins in museums. Because Palearctic birds mingle with the local breeding population during the austral summer, we follow Brooke (1974) in separating the data for museum specimens collected during the austral summer from those collected during the breeding season in southern Africa (Tables 1 & 2). Our conclusion from the morphometric data is substantiated by the DNA-sequencing done later.

Nucleotide sequences of the mitochondrial *cytochrome b* gene (1041 base pairs) were compared between three Booted Eagles of the Palearctic breeding population (one from Germany; two migrants caught in Eilat, Israel) and two individuals of the South African breeding population (holotype plus one captive bird from the World of Birds, Hout Bay near Cape Town). Total cellular DNA of each individual was isolated from blood samples. The *cytochrome b* gene was amplified via polymerase chain reaction and sequenced directly as described in Seibold and Helbig (1995). Both South African birds differed from the Palearctic ones at three out of 1041 (0.29%) nucleotide positions (Table 3). The sequences are deposited at the EMBL databank under accession numbers Y15760 (*H. p. pennatus*) and Y15761 (*H. p. minisculus* (ssp. nov.)).

The sequence divergence of 0.29% between the Palearctic and the South African populations indicates that some genetic differentiation has taken place since both last shared a common ancestor. It is not important how large the percentage difference is, but whether the differences are consistent, and so the differences should be confirmed by sequencing samples from more specimens for both areas. All three substitutions are synonymous third codon position transitions, i.e. they do not affect the amino acid sequence of the gene product. The sequences presented correspond to positions 14995 through 16023 of the *Gallus gallus* mitochondrial genome (Desjardins & Morais 1990).

The result is consistent with a recent colonization of southern Africa by Booted Eagles from the Palearctic, probably within the Holocene. Therefore morphological differences seen today between the subspecies must have evolved rapidly, probably due to strong selection pressures in the newly colonized, southern African environment.

Table 2. Comparison of biometrics of specimens of *Hieraaetus pennatus* examined at the Transvaal Museum (Table 1) with data from literature and field studies. Data presented: mean ($\pm$ SD) and range. Blank columns indicate lack of data.

Sex	N	Wing Chord (mm)	Tail length (mm)	Body Mass (g)	Culmen (mm)	Hind Claw (mm)
<i>H. p. minisculus</i> ?						
Male	2	343.0 (0)	184 (3.5)	540 (holotype)	20.0 (0.5)	24.3 (0.4)
Female	1	364	187	22.0	25.0	
Eilat, Israel (migratory birds)						
Male	8	357.1 (4.1) (352-362)	193.6 (8.4) (185-213)	590 (523-659)	22.4 (1.3) (21.1-25.4)	26.1 (1.3) (23.9-28.5)
Female	28	385.7 (9.1) (370-413)	204.8 (6.2) (194-220)	774 (642-1025)	25.0 (2.4) (22.4-36.4)	29.0 (0.9) (28.0-31.9)
Brown & Amadon (1968)						
Male		361 (352-378)	(188-192)			
Female		391 (375-403)	(205-211)			
Brown <i>et al.</i> (1982)						
Male	9	369 (353-390)	195 (187-202)	709 (510-770)		
Female	10	409 (380-428)	211 (196-218)	975 (840-1250)		
Weick (1980)						
Male		347-412	187-202	595-770	21.0-24.0	
Female		355-435	196-230	840-1145	24.0-26.0	
Cramp & Simmons (1980)						
Male	14	358 (10.7) (342-378)	195 (5.7) (186-204)	709 (n = 9) (510-770)	21.9 (1.0) (20.0-23.5)	24.4 (0.9) (22.9-25.4)
Female	24	393 (12.6) (374-425)	205 (4.2) (198-215)	975 (n = 10) (840-1250)	24.6 (1.2) (22.0-26.2)	29.1 (1.8) (25.0-31.0)

We appreciate that the taxonomy of the *Hieraaetus* eagles is still full of uncertainties, but this distinctive form cannot, on present evidence, be assigned to or treated as either of the two known subspecies of the Booted Eagle. We therefore consider that it should be treated as a new sub-species, and because it is the smallest of the three subspecies, we propose the name:

Hieraaetus pennatus minisculus subsp. nov.

English name

We suggest Southern Booted Eagle, after the region in which this sub-species is known to breed.

Holotype

Adult, unsexed, alive at the RESCUE rehabilitation centre, South Africa; private collection of GV. Found injured (fractured wing) by Jacques Fuller and Johan Esterhuizen in the Free State Province of South Africa in October 1995. Measurements were taken on 9 February 1997.

Table 3. Nucleotide sequences of the mitochondrial cytochrome b gene of three Booted Eagles of the Palearctic breeding population and two individuals of the South African breeding population. Both South African birds differ at three out of 1041 nucleotide positions (0.29%) from the Palearctic ones.

<i>pennatus</i>	GGCTCCCTAC	TGGGAATCTG	CTACTAACA	CAAAATCTAA	CTGGCCTCCT	ACTAGCCATA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CACTACACCG	CAGACACAC	CCTAGCCTTC	TCGTCCGTIG	CCCACACATG	CCGAAACGTA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CAGTACGGCT	GACTAATCG	CAACCTACAT	GCCAATGGAG	CGTCCCTCTT	CTTCATCTGC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	ATCTACCTAC	ATATCGGCCG	AGGACTCTAC	TACGGCTCGT	A..	GGAAACCTGA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	AACACACGGA	TCATTCTCCT	ACTGAACCTT	ATAGCAACCG	CCTTCGTAGG	CTATGTCCCTC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CCATGAGGAC	AGATATCCTT	CTGAGGGGCC	ACAGTCATCA	CCAACCTATT	CTCAGCAATT
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CCGTACATTG	GACAAACCTT	CGTAGAGTGA	GCCTGAGGGG	GATTCTCCGT	AGATAACCCC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	ACCCCTACCC	GTTTCTTTGC	CCTACATTTC	TTACTCCCAT	TCCTTATCGC	AAGTCTTACC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CTAATCCAAC	TCACCTTCCT	GCACGAATCC	GGATCCAACA	ACCCTCTAGG	AATTATCTCA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	AACTGTGACA	AAATCCCAAT	CCACCCATAC	TTCTCCTTAA	AAGACATTCT	AGGATTCTTA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CTAATACTAC	TCCCACTAAC	AACCTAGGCC	CTATTCTCAC	CCAACCTATT	AGGTGACCCA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	GAAAACITCA	CCCCAGCAAA	CCCTCTAGTT	ACACCCCTTC	ACATCAAAAC	AGAATGATAC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	TTCCATTATG	CATATGCTAT	CCTAAGCTCA	ATCCCCAACA	AGCTGGGGGG	AGTACTAGCC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	CTAGCTGCCT	CAGTACTGAT	TCATTTCCTC	ATCCCCCTTC	TCCACAAATC	CAAAACAACGC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	ACAATAACCT	TTCCGAACCT	CTCCCAACTC	CTATTCTGAA	CCCTAATCGC	CAACCTCCTT
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	ATCCTCACAT	GAATCGCAG	CCAAACAGTA	GAACACCCAT	TTATCATCAT	TGGCCAACTC
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	GCCTCCCTCA	CCTACTTCTC	CACCCCTCTA	ATCTTCTTCC	CTTTAATTGG	AGCCCTCGAA
<i>minisculus</i>	..	..	..	..	..	..
<i>pennatus</i>	AATAAAATGC	..	..	..	..	..
<i>minisculus</i>	..	..	..	..	..	..

End (chicken position 16023)

Measurements of holotype

Wing chord 330 mm, tail length 75 mm, wing span 1050 mm, total body length 430 mm, tarsus 59 mm, culmen 23 mm, hallux 23.5 mm and body mass 540 g. The beak was bluish at the base and black at tip, the cere yellow, and the eye brown in colour.

We consider the holotype to be a poor indicator of the subspecies because it is an individual with a broken wing and living in captivity. As with most captive birds held in cages, we expect that the biometric measurements may not represent the wild population. In the holotype, we suspect that the measurements of the wing and the tail length (and hence the total body length) are influenced by exaggerated abrasion of the feathers. In contrast, the culmen has grown because of the lack of natural abrasion.

Measurements of other individuals.

Of the 10 skins in the Transvaal Museum (TM), one is from Roumania and seven were collected during the austral summer. The other three skins collected were distinctly small for a Booted Eagle (Fig. 1). Specimen #'s 21178 and 21179 are adult males and each had a wing chord of 343 mm, with tail length 186 mm and 181 mm, total body length 461 mm and 446 mm, culmen 19.5 mm and 20.5 mm, hind claw 24 mm and 24.5 mm respectively (Table 1). Specimen #5491 is an adult female with the wing chord 375 mm, tail length 187 mm, total body length 485 mm, culmen 22 mm, and hind claw 25 mm.

At the Natural History Museum at Tring, there are two specimens that were collected in southern Africa and one from Zambesi (Table 1). The biometrics of the two southern African birds are similar to those reported above. However, lack of collector's information (especially date) prevents us from adding them to the southern African list with certainty.

This uncertainty also holds for the individual collected in Malawi (specimen #404158) which is at the United States National Museum of Natural History, Washington, D.C. The date on which the bird was collected is within the period when Palaearctic wintering birds are still present. However, the wing chord is comparatively short in relation to the other skins (Table 1). Although total body length was also measured, the data are not included because differences in preparation style have influenced the measurement, and skins ranged from understuffed with very short necks to overstuffied and expanded skins (Christopher Milerisky, USNMNH).

None of the seven skins at the Museum of Comparative Zoology, Harvard University, are from southern Africa (Table 1). Four of the specimens were collected in the late 1800s, two in India and two in Palestine (present-day Israel). The other three were collected in the first two decades of the century, one in the Caucasus region, one at Karabura, Turkestan, and one in Palestine.

It has been shown that in Eurasia the Booted Eagle is clinally larger from west to east, i.e., birds from Spain and North Africa have the shortest wing, increasing to the largest in Turkestan and Siberia (Cramp & Simmons 1980). The birds that breed in southern Africa are smaller than both Eurasian subspecies. They are also local and either do not migrate at all or migrate shorter distances than those of the Palearctic populations. Hence, we would expect the wing to be shorter (Table 2) and more rounded, i.e., primary feathers less elongated (cf. Jenni & Winkler 1994). This is borne out by the fact that, for the migratory subspecies, the primary feather projection is usually P7 (or P6 because of abrasion) and the primary projection of the holotype is P5.

Based on the morphological, genetic, and geographical distribution findings mentioned above, we suggest that the Booted Eagle that breeds in southern Africa is a different, as yet undefined, subspecies.

ACKNOWLEDGMENTS

We thank Erez Yosef for his help and insight in the early stages of this discovery. Hadoram Shirihaï examined skins at the Natural History Museum, Tring, on behalf of RY. Christopher Milensky kindly identified and measured the skins at the United States National Museum of Natural History. Dr. R. Paynter, Jr., Museum of Comparative Zoology, Harvard University, allowed RY access to

skins. We thank J. Fuller, J. Esterhuizen and Neil Greenwood for the care and rehabilitation of the type specimen. Financial support was received from the Leslie Brown Award (Raptor Research Foundation). David Parkin and Peter Alden commented on an earlier draft of the manuscript.

REFERENCES

- BROOKE, R. K. 1974.** On the material evidence of *Hieraaetus pennatus* in southern Africa. *Bull. Brit. Orn. Club* 94: 154-158.
- BROWN, L. & D. AMADON 1968.** *Eagles, Hawks and Falcons of the world*. McGraw Hill Book Co., New York.
- BROWN, L. H., E. K. URBAN & K. NEWMAN 1982.** *The Birds of Africa*. Vol. 1. Academic Press, London.
- CRAMP, S. & K. E. L. SIMMONS (eds). 1980.** *The Birds of the Western Palearctic*. Vol. 2. Hawks to Bustards. Oxford University Press, Oxford.
- DEL, HOYO, J., A. ELLIOT & J. SARGATAL (eds). 1994.** *Handbook of the Birds of the world*. Vol. 2. New World Vultures to Guinea-fowl. Lynx Edicions, Barcelona.
- DESJARDINS, P. & R. MORAIS 1990.** Sequence and gene organization of the chicken mitochondrial genome. *J. Mol. Biol.* 212: 599-634.
- HOWARD, R. & A. MOORE 1984.** *A complete checklist of the birds of the world*. Oxford University Press, Oxford.
- JENNI, L. & R. WINKLER 1994.** *Moult and ageing of European Passerines*. Academic Press, London.
- PORTER, R. F. 1970.** Studies of less familiar birds - 161. Booted Eagle. *Br. Birds* 63: 333-337.
- SIEBOLD, S. & A.J. HELBIG 1995.** Evolutionary history of New and Old World vultures inferred from nucleotide sequences of the mitochondrial cytochrome *b* gene. *Phil. Trans. Royal Soc. London B* 350: 163-178.
- STEYN, P. 1996.** *Nesting birds - the breeding habits of Southern African birds*. Fernwood Press, Vlaeberg.
- TARBOTON, W. 1994.** *South African birds of prey*. Struik Publishers, Cape Town.
- WEICK, F. 1980.** *Birds of Prey of the world*. Collins, London.

Reuven Yosef
International Birding & Research Center in Eilat
P. O Box 774
Eilat 88000
Israel

Gerhard Verdoorn
Endangered Wildlife Trust
P.O. Box 72155
Parkview 2122
South Africa

Andreas Helbig and Ingrid Seibold
Vogelwarte Hiddensee
Univ. Greifswald
D-18565 Kloster
Germany

