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## A FURTHER TAXONOMIC REASSESSMENT OF *Cyrtodactylus madarensis* SHARMA, 1980 (SQUAMATA: GEKKONIDAE) NOW IN THE GENUS *Eublepharis* Gray, 1827 (SQUAMATA: EUBLEPHARIAE)

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### Abstract

A recent phylogenetic study identified the population of *Eublepharis* Gray, 1827, from Rajasthan (India) as a distinct taxon from *E. macularius* (Blyth, 1854). A taxonomic reassessment of the population based on literature, existing museum material, and molecular data allowed me to assign the name *E. madarensis* (Sharma, 1980) to this population. A redescription and rediagnosis of the species are presented based on museum material and images of uncollected individuals. A discussion on the assignment of the nomen ‘*madarensis*’ is presented. The species appears to be distributed along the Aravalli hills, and most records of the species lie outside of protected areas.

**Keywords:** Eublepharidae, India, Sauria, synonymy, taxonomy

### Introduction

The eublepharid lizard genus *Eublepharis* Gray, 1827 contains seven species (Mirza & Gnanaswar 2022), and a recent molecular phylogeny hints at the presence of additional species (Agarwal *et al.* 2022). Of the seven species, five are recorded from India, *E. fuscus* Börner, 1974, *E. hardwickii* Gray, 1827, *E. macularius* (Blyth, 1854), *E. pictus* Mirza & Gnanaswar, 2022 and *E. satpuraensis* Mirza, Sanap, Raju, Gawai & Ghadekar, 2014 (Mirza *et al.* 2014, Mirza & Gnanaswar 2022, Uetz & Hošek 2023). In addition, Agarwal *et al.* (2022) presented sequences of two unnamed lineages from India, one from the Himalayas and the other

from Rajasthan. A scrutiny of the literature on eublepharid lizards (Börner 1974, 1976, 1981; Sharma 1980; Grismer 1988, 2008; Tikader & Sharma 1992) suggests that two names are available to the population from Rajasthan, namely, *E. madarensis* (Sharma, 1980) and *E. macularius smithi* Börner 1981.

*Cyrtodactylus madarensis* was described by Sharma (1980) based on a single specimen from Madar near Ajmer, Rajasthan. Subsequently, Das (1992) discussed the taxonomic status of the species and transferred the species to the genus *Eublepharis* based on scrutiny of the images of the holotype of *Cyrtodactylus madarensis*. The holotype (Zoological Survey of India Jodhpur

V/1215) is an immature male bearing a movable eyelid and a banded pattern, as seen in juveniles of the genus *Eublepharis* (Smith 1935, Grismer 1988, Das 1992, Daniel 2002, Mirza & Upadhye 2010, Mirza *et al.* 2014, Mirza & Gnanaswar 2022). Furthermore, the original description lacks a detailed diagnosis and description of the species to distinguish it from related species from the region. Based on the lack of diagnostic characters and distribution close to the only other species of the genus *Eublepharis*, Das (1992) proposed to regard *Cyrtodactylus madarensis* as a junior synonym of *E. macularius* (Blyth 1854).

A year after Sharma (1980) described *Cyrtodactylus madarensis*, Börner (1981) described a new subspecies, *E. macularius smithi* from Delhi based on two adult female specimens. The two localities, Madar and Delhi are roughly 330 km apart and lie in the Aravali hill range. Molecular data for samples from near the Aravali hills suggests that the species is distinct from *E. macularius* and other congeners (Agarwal *et al.* 2022). Morphological data for *E. macularius smithi* types match those from the Aravalli hills and are here regarded as a single species. The description of *Cyrtodactylus madarensis* was published in 1980, and hence based on provisions ‘Principle of Priority’ in Article 23 of the International Code for Zoological Nomenclature (International Commission on Zoological Nomenclature 1999), ‘*madarensis*’ has priority over ‘*smithi*’.

In the present communication, I redescribe the species and revalidate it based on revised diagnostic characters based on the types, the molecular analysis of Agarwal *et al.* (2022), and additional uncollected material from the region.

## Material and Methods

**Morphology and morphometry.** All measurements were taken following Mirza & Sanap (2014) with Mitutoyo™ digital calipers (Mitutoyo Corporation, Kawasaki, Japan) (to the nearest 0.1 mm): snout-vent length (SVL, from tip of snout to vent), trunk length (TRL, distance from axilla to groin measured from posterior edge of forelimb insertion to anterior edge of hind limb insertion), body width (BW, maximum width of body), crus length (CL, from base of heel to knee), tail length (TL, from vent to tip of tail), tail width (TW, measured at widest point of tail), head length (HL, distance between retroarticular process of jaw and snout tip), head width (HW, maximum width of head), head height (HH, maximum height of head, from

occiput to underside of jaws), forearm length (FL, from base of palm to elbow), ear length (EL, longest dimension of ear), orbital diameter (OD, greatest diameter of orbit), nares to eye distance (NE, distance between anteriormost point of eye and nostril), snout to eye distance (SE, distance between anteriormost point of eye and tip of snout), eye to ear distance (EE, distance from anterior edge of ear opening to posterior margin of eye), internarial distance (IN, distance between nares), interorbital distance (IO, shortest distance between left and right supraciliary scale rows).

Dorsal longitudinal tubercle rows (DTR) were counted from across the dorsum of the trunk, ventral scales across the belly (VS), post cloacal spurs (PCS). Meristic counts and external observations of morphology were made using a Leica™ S8APO (Leica Camera, Wetzlar, Germany) dissecting microscope. Images of the specimens were taken with a Canon™ 70D mounted with a Canon™ 100 mm macro illuminated with two external Canon™ 430EX-II flashes (Canon Inc., Tokyo, Japan). Institutional abbreviations: Bombay Natural History Society, India (BNHS), Senckenberg Naturmuseum Frankfurt, Germany (SMF), Zoological Survey of India (ZSI).

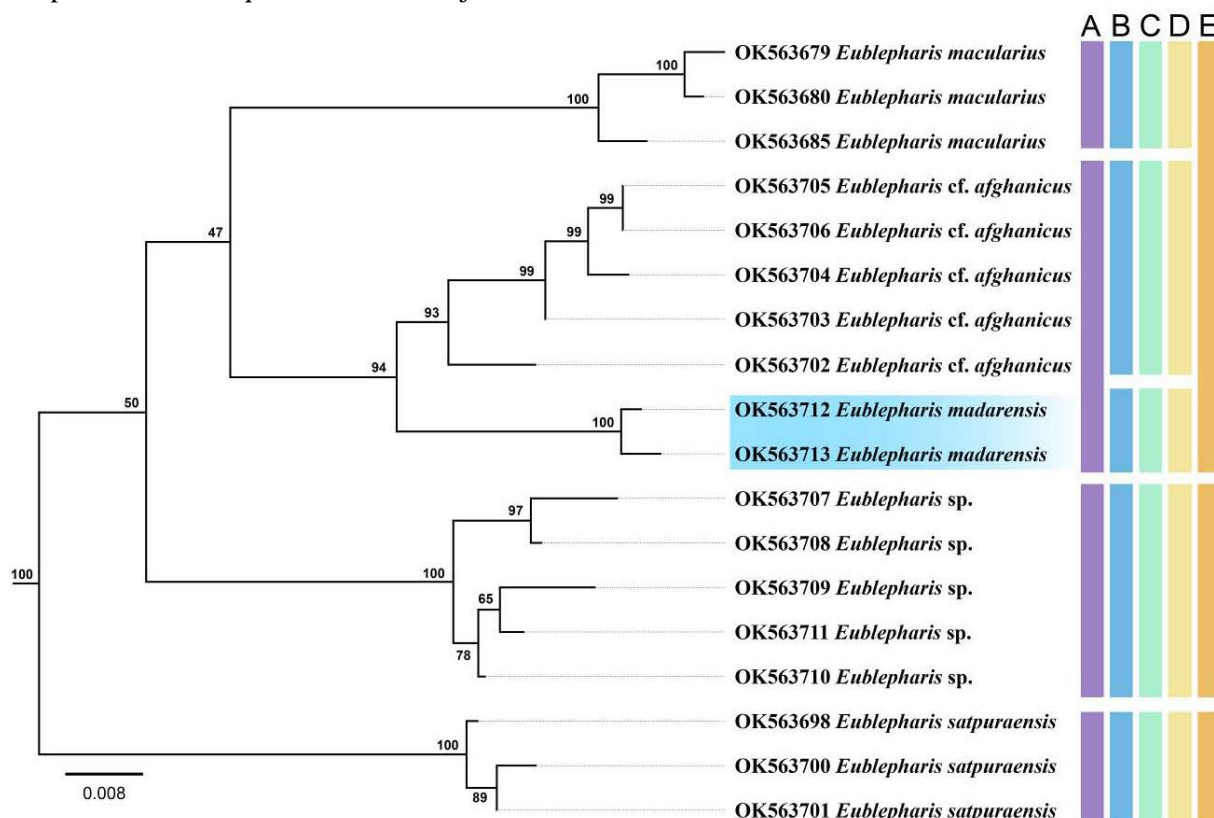
**Molecular analysis.** Sequence data for NADH dehydrogenase subunit 2 (ND2) was acquired from Agarwal *et al.* (2022), listed in Table S1. The sequences were aligned with CLUSTALW (Thompson *et al.* 1994) with default parameters in MegaX (Kumar *et al.* 2018). The aligned dataset was subjected to Maximum Likelihood phylogeny on the IQ-TREE online portal (Minh *et al.* 2020). The data was partitioned based on codon positions, and model selection was chosen on an auto parameter (Kalyaanamoorthy *et al.* 2017). The analysis was executed with HKY+F+I (first codon position), HKY+F+G4 (second codon position) & TN+F+G4 (third codon position) model for sequence substitution with an ultra-fast search method with 1000 iterations. Genetic sequence divergence (*p*-distance) was calculated in MegaX with partial deletion of missing data.

## Results

**Molecular results.** ML phylogeny inferred from 1041bp of mitochondrial ND2 gene (Fig. 1). The analysis recovered comparable results to Agarwal *et al.* (2022) and with slight discrepancies from Mirza & Gnanaswar (2022). According to results in the present work and

Agarwal *et al.* (2022), *E. angramainyu* is sister to all other *Eublepharis*, and the *E. hardwickii* group is sister to the *E. macularius* clade (containing *E. macularius*, *E. fuscus*, *E. satpuraensis*, *E. sp.* Himalayas, *E. sp.* Rajasthan, *E. sp.* Pakistan). The relationships within the *E. macularius* clade have poor to moderate support. Representative sequences from Rajasthan are

sister to *E. cf. afghanicus* from the Himalayas (India & Pakistan). The two species are 4–5% divergent for ND2 gene (Table S1) and based on species delimitation analysis results presented by Agarwal *et al.* (2022), the Rajasthan population of *Eublepharis* is distinct in three (PTP, bPTP and 5% *p*-distance) of the five criteria.



**Figure 1.** ML phylogeny inferred from mitochondrial ND2 gene for members of the genus *Eublepharis* spp. Species delimitation criteria after Agarwal *et al.* (2022) (A) mPTP, (B) PTP, (C) bPTP, (D) 5% ND2 divergence, (E) lowest ND2 divergence (7%). See Figure S1 for the complete tree.

## Systematics

*Eublepharis madarensis* (Sharma, 1980)  
(Figs. 2, 5; Table 1)

*Cyrtodactylus madarensis* Sharma, 1980: 111  
*Eublepharis macularius smithi* Börner 1981: 6  
*Eublepharis macularius*—Das, 1992: 55  
*Eublepharis* sp. Rajasthan—Agarwal *et al.* 2022: 2, 8  
*Eublepharis* cf. *smithii*—Mirza & Gnaneshwar 2022:  
78–79

**Holotype.** Immature male, Jodhpur V/1215, collected from Madar near Ajmer, Rajasthan.

**Other material examined.** Female holotype (SMF 60980) and female paratype (SMF 60979) of *E. macularius smithi* Börner 1981, collected from Delhi by leg. ded. G. A. Philipp on 30 July 1965.

**Diagnosis.** A medium-sized *Eublepharis* reaching SVL of 140 mm, with 18 rows of tubercle-like feebly keeled scales across the dorsum intermixed with much smaller scales, five pale bands including the nuchal loop and caudal constriction on the body; moderately tuberculate subdigital lamellae, 18–19 on digit IV of pes; 13 precloacal pores in an angulate series lacking a diastema.

**Comparison.** *Eublepharis madarensis* differs from other members of the genus based on differing or non-overlapping characters as follows: three pale bands between the nuchal loop and the caudal constriction (vs. two in *E. fuscus*, *E. hardwickii*, and *E. pictus*); five pale bands including the nuchal loop to the caudal constriction (vs. four in *E. satpuraensis*); scales on the dorsum heterogeneous consisting of small

flat, rounded or sub-hexagonal scales intermixed with large unkeeled tubercles in 18 longitudinal rows (23–26 rows of large flat, moderately keeled scales intermixed with smaller scales in *E. hardwickii* and *E. pictus*, 20 rows of tubercle rows in *E. satpuraensis*). *Eublepharis madarensis* is most similar to *E. macularius* and a putative synonym *E. macularius afghanicus* Börner, 1976 of *E. macularius* in bearing tuberculate lamellae and the number of pale bands on the dorsum of the body. *Eublepharis madarensis* differs from *E. macularius afghanicus* and *E. macularius* in having a reticulate pattern, at the nape and then forming stripes on alternating pale and dark bands (vs. a more spotted pattern throughout the animal on alternating pale and dark bands in *E. macularius* and *E. m. afghanicus*); vertebral stripe present on anterior part of trunk (absent in *E. macularius*); feebly tuberculate lamellae (strongly tuberculate in *E. macularius afghanicus* and *E. macularius*).

**Description.** Based on the female holotype (SMF 60980) of *E. macularius smithi*, the type is well preserved; it is laid out linearly with a curved tail. The specimen appears emaciated in comparison with the paratype.

A large-sized gecko (SVL 85 mm) with a fairly large head (HL/SVL ratio 0.19), head as long as wide (HW/HL ratio 0.91), head depressed (HH/HL ratio 0.51), distinct from neck; canthus rostralis inflated; snout short (SE/HW ratio 0.55), obtusely pointed from dorsal view and acutely in lateral view, longer than eye diameter (OD/SE ratio 0.65); scales on the snout heterogeneous in shape and size, smaller ones with rounded edges and larger ones sub-hexagonal, convex. The scales in the interocular and temporal region intermixed with large tubercles, that are 3–4 times larger than the adjacent scales and are rounded, and feebly keeled. These tubercles are nearly equidistant from each other and cover the dorsum of the animal, including the lateral aspect of the head near the angle of the jaw, and the hind limbs up to the caudal constriction; eyes large (OD/HL ratio 0.32), pupil vertical with crenulated edges; supraciliaries 20, anterior ones smaller, these gradually increase in size; ear opening large, sub-oval, obliquely oriented, smaller than orbital diameter (EL/OD ratio 0.43), three large conical tubercles present on the anterior wall of the ear opening; eye to ear distance much greater than diameter of eye (EE/OD ratio 1.43); rostral quadrangle much wider than deep, divided by a median suture for its entire length; rostral in

contact with nasal, first supralabial and internasals; two large and two slightly smaller internasals between nasals, nostrils large situated medially in the nasal scale; mental sub-quadrangular, wider than long; scales bordering the mental and infralabials large, gradually these reduce in size on throat up to the upper thoracic region. Overall, these scales are circular, convex, smaller than the ones on ventral aspect of trunk; supralabials ten on left and eleven on right side; supralabials (to angle of jaw) ten on either side; infralabials (to angle of jaw) ten on either side.

Body elongate (TRL/SVL ratio 0.44) and dorsoventrally flattened; lacking distinct ventrolateral furrow; dorsal scalation on trunk comprises heterogeneous scales consisting of smaller flat round-edged or sub-hexagonal scales intermixed with large rounded tubercle scales, the large scales are arranged in 18 longitudinal rows at midbody; tubercles 4–5 times longer than adjacent scales and 2–3 times wide; ventral scales on trunk smooth, flat, smaller than dorsal scales; midbody scales across belly 26.

Limbs short, stout; digits bearing horizontally oriented smooth, un-notched lamellae on ventral surface; clawed, claw slightly smaller than the length of the lamellar region; forelimbs short (FL/SVL ratio 0.14), equal in length with the hind limbs (CL/SVL ratio 0.17). The terminal phalanx of all digits curved, arising angularly from the distal portion of the expanded lamellar pad, free portion of the phalanx of all digits half to more than half as long as the dilated portion. Lamellae beneath the digits tuberculate, except for the 2-3 terminal ones; lamellae number on right manus 8-12-13-14-12; right pes 8-13-15-17-16. Relative lengths of digits: III>V>IV>II>I (left manus), V>II>IV>III>I (left pes).

Tail stout, subtly flat on its ventral aspect, round in cross section, longer than snout-vent length (TL/SVL ratio 0.68). Caudal segments distinct on the original tail; pholidosis of original tail dorsum with small, juxtaposed scales intermixed with large sub-conical tubercles in a whorl or 9-10 rows on the first segment, thereafter reduces in number on subsequent segments. Ventral aspect with large, broad scales, median row of scales not enlarged. Two sub-conical post cloacal spurs, anterior one larger than the posterior spur.

**Colouration.** In preservative, the background colouration is off-white with a yellowish tinge. The head bears a 3–7 scale wide dark brown reticulate pattern extending to the lateral aspect of the head. The labial scales lack a reticulate

pattern, but there are a few dark brown to grey blotches on a few of the labial scales. There is a crescent-shaped collar on the neck which bears a darker edge. The area between the neck and forelimbs bears four broad brown longitudinal stripes running from the neck to the insertion of the anterior limbs, interrupted by a broad pale band bearing two brown blotches on the right half of the animal. The trunk bears three (two on the trunk and one on the flank) brown bands with a few diffused patches. These three broad bands are interrupted by pale bands with brown blotches. The tubercles in the broad brown bands are dark brown in colour whereas those in the pale bands are in a shade of off-white to pale. The number of pale bands between the nape and caudal constriction is three. The horizontal bands are interrupted medially by a pale longitudinal vertebral stripe from the nape to the caudal constriction. This alternating dark and light banding pattern is also observed on the tail. Ventrally, the animal lacks any pattern or pigmentation except for the tail, which bears brown caudal segment edges.

In life (based on uncollected material, Figs. 3A-B), the background colouration on the head is yellowish-grey, and that on the trunk and lighter part of the tail is in a shade of brilliant yellow. The head bears dark brown to black broad reticulate markings on the dorsum. The lateral aspect of the head, on each side, bears a lateral stripe that runs from the nasals to the postocular region along the supratympanic region and meets at the nape, forming a broad black crescent collar. The dark collar is bordered by a yellow band that runs from the angle of the jaw on each side of the head, merging at the nape. The light band bears two black blotches on either side of the midline of the vertebral column. The first dark band consists of a yellowish-brown background with four broad longitudinal stripes formed from the merging of spots/blotches. The pattern of alternate light and dark bands continues along the trunk to the original segments of the tail. The darker bands gradually turn darker, lacking yellow colouration. The legs are yellow with dark brown spots. The digits lack any pattern and are in a shade of grey.

**Remarks.** Based on uncollected material, the male specimen observed at Kumbhalgarh had 13 preloacal pores lacking diastema (Fig. 3D). Supraciliaries 20. The animal had 2 and 3 postloacal spurs (L/R). The lamellae on the right pes were 9-12-15-18-15 (Fig. 3E).

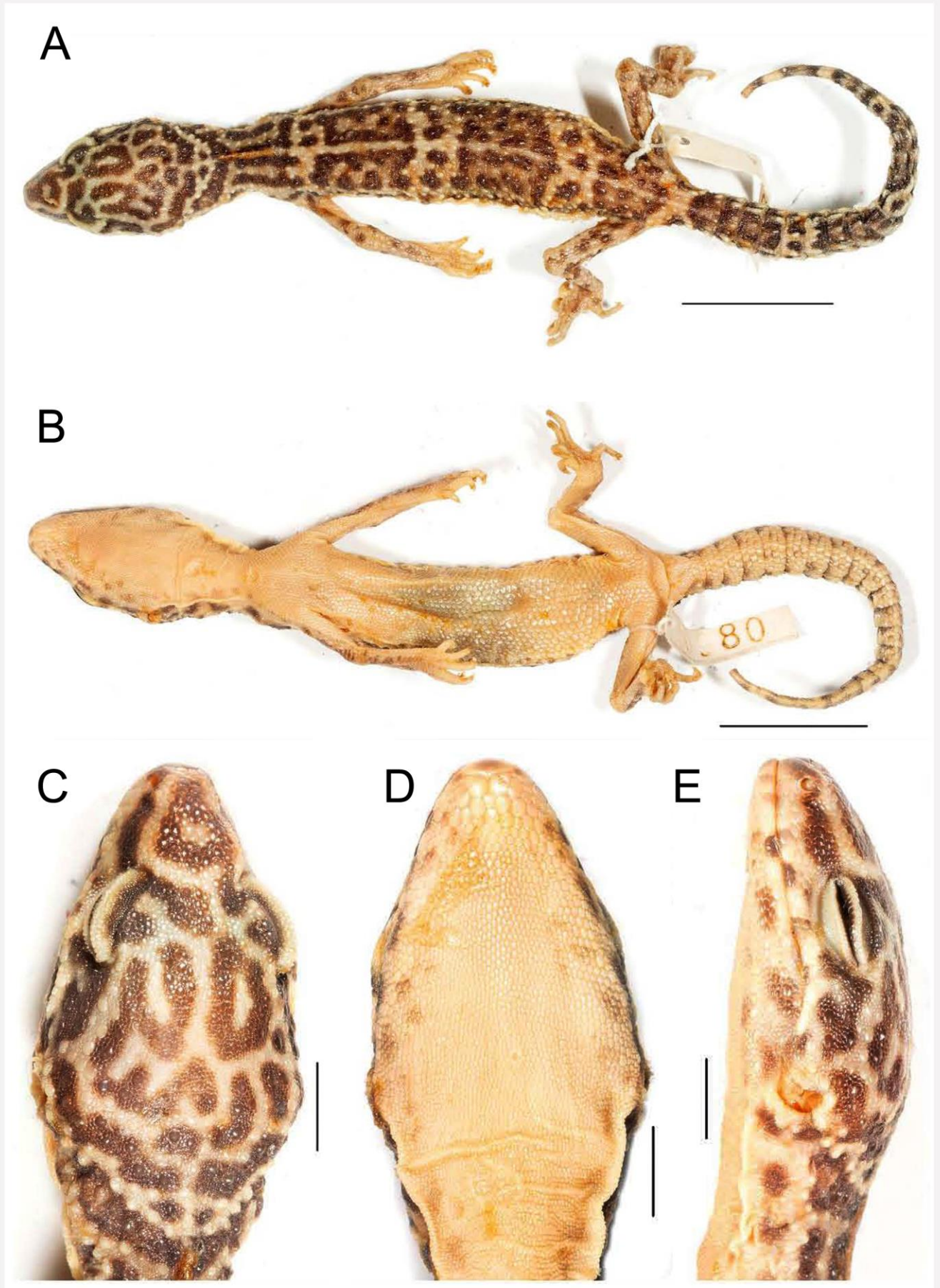
**Etymology.** The specific epithet refers to the locality, Madar, in the Indian state of Rajasthan, where the type of the species was collected. Suggested common name “Aravalli leopard gecko”.

**Table 1.** Morphological and meristic data for *E. madarensis*. All measurements in mm.

	Holotype of <i>E. macularius smithi</i> (SMF 60980)	Paratype of <i>E. macularius smithi</i> (SMF 60979)
Sex	female	female
SVL	85	95
TRL	37.8	42.3
CL	14.3	20.9
TL	68.1	50
TW	5.5	7.8
HL	16.2	15.4
HW	14.7	18.3
HH	8.3	8.6
FL	12.1	20.5
EL	2.3	8.5
OD	5.3	10.3
NE	6.3	11.23
SE	8.1	14.7
EE	7.6	14.8
IN	3.1	8.5
IO	6.7	12
Pores	-	-
Sup	9 & 10	10 & 10
Inf	11 & 10	9 & 9
DTR	18	18
VS	28	26
PCS	2	2
Lamellae manus (L)	8-13-15-15-10	8-11-12-13-10
Lamellae manus (R)	8-11-14-18-10	8-12-12-13-10
Lamellae pes (L)	8-13-15-19-14	8-12-15-18-12
Lamellae pes (R)	8-12-14-18-13	9-13-15-18-13

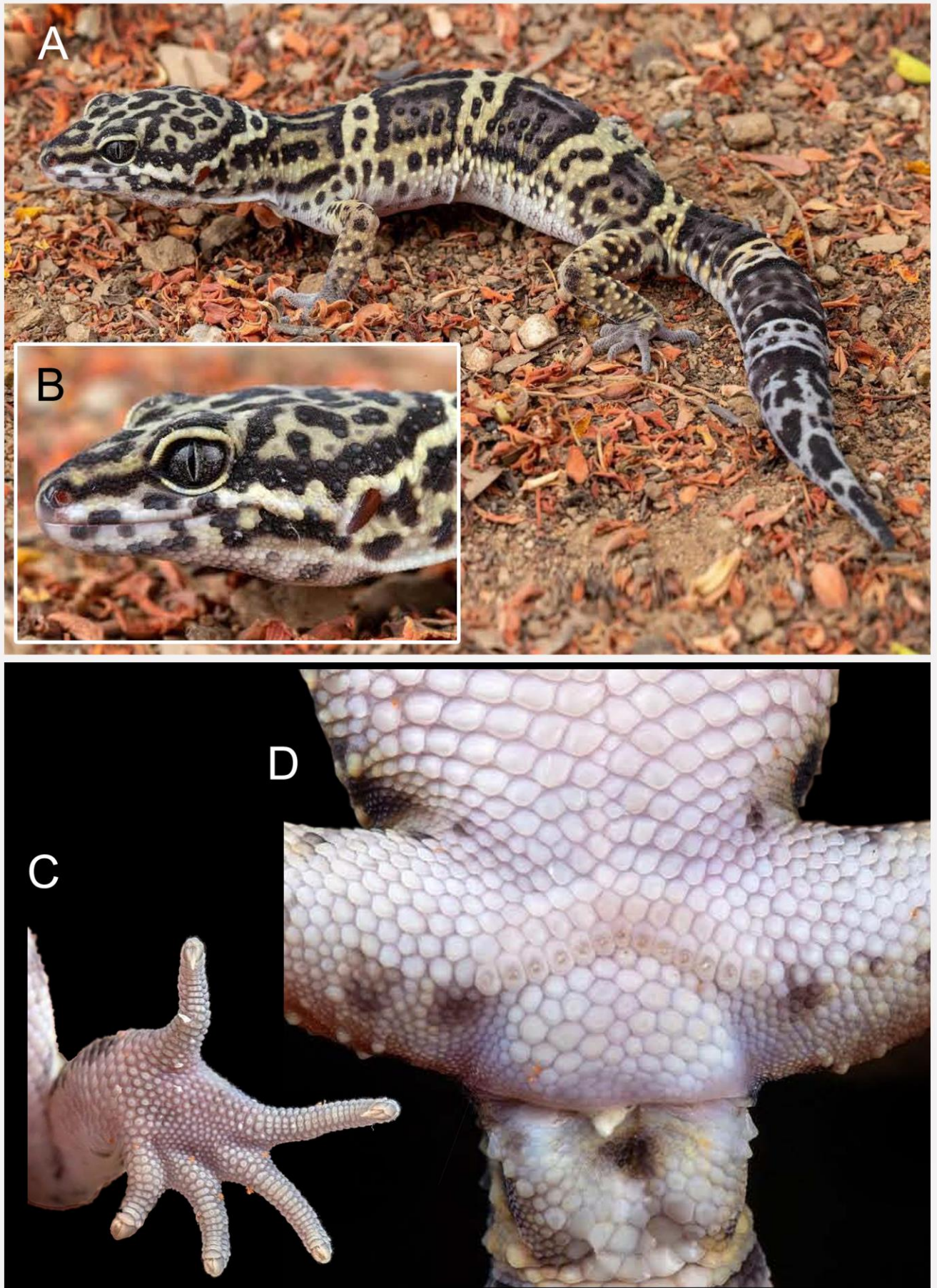
**Distribution and natural history.** The holotype of *E. madarensis* was collected from Madar near Ajmer in the west Indian state of Rajasthan (Fig. 4). The type specimens of *E. m. smithi* bear the locality ‘Delhi’. Other records of the species are from Pilani, Dholpur, Bundi, Kumbhalgarh, and Jawai, all from Rajasthan state. The distribution is largely centered along the Aravalli Hills and most localities lie outside protected areas.

## Plate 6

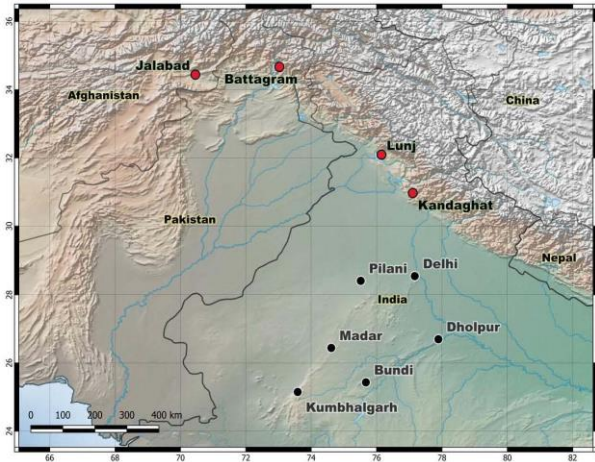


**Figure 2.** The female holotype (SMF 60980) of *Eublepharis macularius smithii* (now a junior synonym of *Eublepharis madarensis*): (A) dorsal and (B) ventral views of full body (scale: 20 mm), and (C) dorsal, (D) ventral, and (E) lateral views of the head (scale 5 mm)

## Plate 7



**Figure 3.** An adult male of *Eublepharis madarensis* (not collected) from Kumbhalgarh Wildlife Sanctuary: (A) dorso-lateral view of the full body, (B) lateral view of the head, (C) ventral view of the right pes (note moderately tuberculate lamellae), and (D) cloacal region with precloacal pores; © Photo: Rajesh Chaudhari.



**Figure 4.** Map of northwest India showing the distribution of *Eublepharis madarensis*. Note: type locality of *E. macularius smithi* ‘Delhi’ and *E. madarensis* ‘Madar’.

### Discussion

A phylogenetic study of the genus *Eublepharis* by Agarwal *et al.* (2022) largely resolved the taxonomy of the genus, especially regarding the confusion between the several synonyms and subspecies of *E. macularius*. The study further identified several genetically distinct lineages whose taxonomic status needed investigation. One such population of eublepharid lizard from Rajasthan was demonstrated to be distinct from *E. macularius*. The analysis for species delimitation further recovered the two representative sequences from Rajasthan as a distinct species through different criteria of species delimitation using molecular data, mPTP, PTP, bPTP and sequence divergence (Agarwal *et al.* 2022, Mirza & Gnaneswar 2022). *Eublepharis madarensis* shows an uncorrected pairwise sequence divergence of 4–5 % from *E. cf. afghanicus* and 6–25% from congeners (Supplementary Table 1). Intraspecific sequence divergence observed is 0–1% (n=2). *Eublepharis madarensis* and *E. cf. afghanicus* are shallowly divergent species occupying two distinct geographic realms. The former is distributed across the dry Aravalli Hills in Rajasthan (Fig. 4) whereas the latter is found in the Himalayas and the Hindu Kush mountains.

*Eublepharis macularius afghanicus* Börner, 1976 was described from Jalbad near Kadul, Afghanistan. Agarwal *et al.* (2022) generated sequences of a population from the Himalayas of India (Himachal Pradesh) and Pakistan (Khyber Pakhtunkhwa) as well as from some captive animals to which they attribute the name ‘*afghanicus*’, which in the current work is

referred to as *E. cf. afghanicus* (OK563702–OK563706). A second unidentified *Eublepharis* also occurs in Khyber Pakhtunkhwa (*Eublepharis* sp. Pakistan, OK563707–OK563711). Given that there are no sequences of *E. macularius afghanicus* from near the type locality, the identity of these two populations remains undetermined. Based on the original description of *E. m. afghanicus*, it appears to be similar to *E. madarensis*. However, procuring specimens and tissue samples from Afghanistan will be difficult.

*Eublepharis madarensis* appears to have a patchy distribution across forested and rocky Aravalli Hills and is not common wherever it occurs. Several records of the species are along the borders of the neighbouring states with which Rajasthan shares similar biotopes, and *E. madarensis* may likely be distributed in Madhya Pradesh and Gujarat too. Based on IUCN conservation prioritization criteria, we propose to list *E. madarensis* as Near Threatened (NT) pending further information on local population estimates. All known species of *Eublepharis* have been collected for the pet trade and may even be smuggled illegally. Its listing as Near Threatened may contribute to minimizing the illegal trade. The new amendment to the Wildlife Protection Act 1972 lists all members of the genus *Eublepharis* in Schedule I, providing the highest order of protection to these lizards. This protection will further help curb collection for trade within India. However, it also impacts further studies on these species as securing collection permits from the Forest Department and the ministry will be nearly impossible. The present work suffers from a lack of fresh material of *E. madarensis* as well as representatives of *E. cf. afghanicus* from the Himalayas due to this new amendment.

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