

## Contribution to the knowledge of the genus *Lytorhynchus* Peters, 1863 (Reptilia: Squamata: Colubridae) with special reference to the Iranian taxa

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### Abstract

The genus *Lytorhynchus*, spanning from the Sahara's western fringes to the Middle East, eastern Pakistan, and northwestern India, has seen numerous species and subspecies classifications over the years. Many of these have been deemed synonymous due to overlapping morphological traits, a problem compounded by the absence of a comprehensive phylogenetic study. The taxa residing in Iran exhibit morphological variations attributable to their broad distribution and disjunct populations. Of the seven recognized species, three have been confirmed in Iran, although some populations display pholidosis distinct from initial descriptions. Species identification has also been fraught with ambiguities. This study aims to elucidate the diagnostic characteristics of taxa and furnish an updated identification key by revisiting past studies and examining new voucher specimens. The biogeography of Iranian taxa is also explored.

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### Introduction

The name *Lytorhynchus* Peters, 1863 comprises two root words, “lytós = loosened and rhyngchos = snout” (Schleich et al. 1996). All the members of this genus are characterized by their flattened snout and a large rostral scale. The genus contains seven accepted species inhabiting the “Deserts and xeric shrublands” biome north of the Tropic of Cancer, from the Atlantic coast of Africa to north-west India, including the Sahara Desert, the whole Arabian Peninsula, the Iranian Plateau and the southern Turanian plain (Turkmenistan) (Sindaco et al., 2013). *Lytorhynchus diadema* (Duméril, Bibron, and Duméril, 1854) is widespread from the Sahel to Saudi Arabia; *L. gasperetti* Leviton, 1977 is endemic to the southwest of Saudi Arabia; *L. kennedyi* Schmidt, 1939 is reported

from Jordan, Iraq, Syria, and Saudi Arabia; *L. maynardi* Alcock and Finn, 1897 from Afghanistan, Iran and Pakistan; *L. paradoxus* (Günther, 1875) from Pakistan and India; *L. ridgewayi* Boulenger, 1887 from Afghanistan, Iran, Pakistan, Turkmenistan and Uzbekistan (Uetz et al., 2023); and *L. gaddi* Nikolsky, 1907 from Saudi Arabia, Iraq and the southwest of Iran (Leviton et al., 1992).

Based on the snout and rostral scale morphology, Leviton and Anderson (1970) divided the members of this genus into two groups: the western “*diadema* group” including, *L. diadema*, *L. kennedyi*, and *L. gaddi* and the eastern “*ridgewayi* group” including, *L. ridgewayi*, *L. paradoxus*, and *L. maynardi*. Seven years later, Leviton (1977) described, *L. gasperetti* and placed it in the western “*diadema* group”.

Given the extensive distributional range of the genus *Lytorhynchus*, many subspecies and various morphs have been described (*L. diadema arabicus* Haas, 1952 and *L. d. mesopotamicus* Haas, 1952, both from Iraq, *L. d. hirouxii* Doumergue, 1901, from Algeria and Tunisia, and *L. d. hoggarensis* Angel, 1944 from the Hoggar mountains in the south of Algeria), all of them currently considered as synonyms of *L. diadema* (Arnold, 1980; Gasperetti, 1988; Sindaco et al., 2013). The taxonomic status of *L. kennedyi* is unsettled since Gasperetti (1988), Martens (1993) and Sindaco et al. (2006) considered it at the specific level, whereas Moravec (1995), Disi et al. (2001) and Amr and Disi (2011) considered it as a pattern morph of *L. diadema*. Nevertheless, this taxon is here considered as a full species. *Lytorhynchus menticornis* Werner, 1927 from Pakistani Sindh has been considered to be a synonym of *L. paradoxus* (Leviton and Anderson, 1970; Sindaco et al., 2013; Wallach et al., 2014). Further, *L. ridgewayi* var. *roseni* Elpatjewsky and Sabanejew (1906), collected from Konarak City, Sistan and Baluchistan Province, Iran is not recognized as a valid taxon but rather as a synonym of *L. ridgewayi*, as is *L. gabrielis* Werner, 1938 from Ziarat near Quetta, West Pakistan (Smith, 1943; Leviton and Anderson, 1970; Sindaco et al., 2013; Wallach et al., 2014).

Phylogenetic relationships among the taxa of *Lytorhynchus* are still incompletely known, since Tamar et al. (2016) analyzed just three taxa (*L. maynardi*, *L. diadema* and *L. gaddi*) and found a deep divergence between *L. maynardi* and the *L. diadema* complex; in addition, the phylogenetic tree shows a deep divergence between *L. diadema* and *L. gaddi* Nikolsky.

Numerous species and subspecies have been recognized in the genus *Lytorhynchus* over the years. Many of these have been considered synonymous due to the overlap of morphological traits, a complication that is further exacerbated by the lack of a comprehensive phylogenetic study. The taxa found in Iran display morphological variation, which can be attributed to their extensive distribution and disjunct populations. This study endeavors to clarify the diagnostic characteristics of taxa, with a particular focus on resolving ambiguities in the enumeration of certain characteristics. By revisiting previous studies and examining new voucher specimens, particularly those pertaining to Iranian taxa, an updated identification key is provided (Appendix 1). Additionally, this study explores the biogeography of Iranian taxa.

## Material and Methods

Specimen comparison was based on morphological data provided by previous authors (Boulenger, 1887, 1896; Schmidt, 1939; Leviton and Anderson,

1970; Leviton, 1977; Leviton et al., 1992; Martens, 1993; Latifi, 2000; Sindaco et al., 2006; Agarwal and Srikanthan, 2013), and on other *Lytorhynchus* specimens housed in the ZMSBUK and SUHC collections (see Appendix 2). The following institutional acronyms are used in this publication: BMNH (new name NHMUK), The Natural History Museum [formerly British Museum of Natural History], London, England; CAS, California Academy of Sciences, San Francisco, USA; DOE, Museum of the Department of Environment of Kerman Province, Kerman, Iran; FMNH, Field Museum of Natural History, Chicago, USA; MNHN, Muséum National d'Histoire Naturelle, Paris, France; SUHC, Sabzevar University Herpetological Collection, Sabzevar, Khorasan Razavi Province, Iran; ZMSBUK, Zoological Museum of Shahid Bahonar University of Kerman, Iran; ZSI, (new name ASK) Zoological Survey of India, Kolkata [Calcutta], India.

The following characters were used for the morphological comparison and also in the mentioned references: snout and rostral shape, body and tail scales; number of prefrontal, preocular, postocular, subocular, loreal, temporal, supralabial, infralabial, ventral and subcaudal scales; number of scale rows at forepart of body (one head length posterior to the head), at midbody (midpoint of SVL) and at the posterior part of body (one head length anterior to the vent); and pattern including number of dorsal body blotches on trunk and on tail separately.

## Results

The morphological diagnoses of all recognized species have been meticulously reviewed, drawing upon a wealth of previous descriptions spanning over a century of research. This comprehensive review includes seminal works by Anderson (1898), Werner (1927, 1931, 1938), Schmidt (1939), Boulenger (1887, 1896), Hass (1952, 1957), Kalaf (1960), Kramer and Schnurrenberger (1963), Leviton and Anderson (1970), Leviton (1977), Leviton et al. (1992), Martens (1993), Schleich et al. (1996), Khan (2002), Sindaco et al. (2006), Agarwal and Srikanthan (2013), Shafiei et al. (2015), Toriki (2017), Salemi et al. (2018), and Alshammari (2021).

In addition to these literary sources, our analysis also incorporated the examination of preserved specimens, the details of which can be found in the Appendix 2. A comprehensive summary of the characteristics scrutinized in both the previous studies and our current investigation is presented in Table 1.

In the subsequent sections, we delve into the diagnostic features of the taxa, with each taxon's unique features and relevant literature citations discussed separately for clarity and ease of reference.

**Table 1:** Comparative morphological characters in the genus *Lytorhynchus* based literatures, voucher specimens of ZMSBUK, SUHC and our observations R: rostral scale (NTA: narrowly truncated anteriorly; BT: broadly truncated; NP: narrow and pointed); IS: ratio of internasal suture to prefrontal suture length; P: prefrontal plate(s); SO: ratio of supraocular plate width to frontal width; PrO: preocular scales; PoO: postocular scales; SuO: subocular scale(s); Lo: loreal (Tri: triangular; Sq: squarish; Tra: trapezoidal; Pe: Pentagonal); T: temporal scales (first row + second row); SL: supralabial scales (in contact with the eye); IL: infralabial scales (in contact with anterior chin shields); CS: ratio of anterior chin shields to posterior pair length (L: anterior pair longer; E: equal or little shorter; S: anterior pair shorter); DRS: dorsal scales (one head length posterior to the head—midbody—one head length anterior to the vent); V: ventral scales; CP: cloacal plate (D: divided; E: entire); SuC: subcaudal scales; BB: body blotches (on trunk + on tail).

Characters	<i>L. diadema</i>	<i>L. gaddi</i>	<i>L. kennedyi</i>	<i>L. gasperetti</i>	<i>L. maynardi</i>	<i>L. paradoxus</i>	<i>L. ridgewayi</i>
R	BT	BT	BT	BT	NP	NP	NTA
IS	<1/3	<1/3	~ 1/3	~ 1/3	~ 1/2	> 1/2	~ 1/3 (if P divided)
P	2	2	2	2	2	2	1 or 2
SO	< 1/2	< 1/2	~ 1/2	~ 1/3	< 1/2	< 1/2	~ 1/2
PrO	2 or 3	2 or 3	2 or 3	3 or 4	2 (rarely 1)	3	1–3
PoO	2 or 3	2 or 3	2 or 3	2	2 (rarely 3)	2 or 3	2 or 3
SuO	0	0	0	0	2 or 3	0	1 or 2
Lo	1 (Sq)	1 (Sq)	1 (Sq)	1 (Tra or Sq)	1 (Pe)	1 (Pe)	1 (Sq or Pe)
T	1+2 or 2+2 or 2+3	2+2 or 2+3 or 2+4	1+2 or 2+2	2+2	2+2 or 2+3	2+2 or 2+3 or 2+4	2+3 or 1+3
SL	7–8 (4 <sup>th</sup> , 5 <sup>th</sup> or 4 <sup>th</sup> and 5 <sup>th</sup> )	8 (4 <sup>th</sup> , 5 <sup>th</sup> or 4 <sup>th</sup> and 5 <sup>th</sup> )	8–9 (5 <sup>th</sup> )	8–9 (4 <sup>th</sup> , 5 <sup>th</sup> )	7	8 (5 <sup>th</sup> )	7–8
IL	? (3)	9–11 (3)	10 (?)	10 (3)	11 (4)	10–11 (4–5)	10 (4)
CS	E	E	?	E	E	S	L
DRS	?:19:?	21:19:15	21:19:13	?:19:15	19–21:19:15–17	21:19:15	19–21:19:17
V	152–178	173–195	153–183	157–165	184–208	168–188	160–190
CP	D	D	D	D	D	D	E or D
SuC	33–49	33–55	35–44	40–44	52–65	40–53	40–55
BB	30–52 +9–13	31–55 +9–16	22–29 +6–8	33+?	35–55 +12–15	40–52 +?	36–49 +10–13

### Species accounts

#### *Lytorhynchus diadema* (Duméril, Bibron, and Duméril, 1854) (Figs. 1, 8A, B)

*Heterodon diadema* Duméril, Bibron and Duméril, 1854: 779–780.

**Holotype:** MNHN 7560, an adult (total length = 380 mm) female# from Algeria and desert of western North Africa.

**Diagnosis:** Rostral broadly truncated and angularly bent; internasal suture much shorter than prefrontal suture; two prefrontals; two or three preoculars; two or three postoculars; subocular absent; one squarish loreal scale; temporals 1+2 or 2+2 or 2+3; 7–8 supralabials, 4<sup>th</sup> or 5<sup>th</sup> (or both) in contact with eye; unknown infralabials, three in contact with anterior chin shields; posterior chin shields as long as (or a little longer than the) anterior chin shields; dorsal scales smooth, in ?:19:? rows; ventrals 152–178; ventrals + subcaudals 197–215; cloacal plate divided; 33–49 subcaudal scales arranged in two rows. Body pale yellow, brown, reddish brown or red with 30–52 brown to black ovoid blotches or crossbars usually distinct but never intense black on trunk and 9–13 on tail.

**References:** Anderson (1898); Boulenger (1896); Werner (1931); Kramer and Schnurrenberger (1963); Leviton and Anderson (1970); Leviton et al. (1992); Schleich et al. (1996).

#### *Lytorhynchus gaddi* Nikolsky, 1907 (Figs. 2, 8D)

*Lytorhynchus gaddi* Nikolsky (“1905” 1907: 294)

**Syntypes:** ZISP 10288.1-2, 2 specimens, “Dizful in Arabistano” [Dezful, Khuzestan Province, Iran, 32.36 N 48.41 E]. Leg. N. A. Zarudny, 14-16.III.1904.

**Diagnosis:** Rostral broadly truncated and angularly bent; internasal suture much shorter than prefrontal suture; two prefrontals; two or three preoculars; two or three postoculars; subocular absent; one squarish loreal scale; temporals 2+2 or 2+3 or 2+4; 8 supralabials, 4<sup>th</sup> or 5<sup>th</sup> (or both) in contact with eye; 9–11 infralabials, three in contact with anterior chin shields; posterior chin shields as long as (or a little longer than the) anterior chin shields; dorsal scales smooth, in 21:19:15 rows; ventrals 173–195; ventrals + subcaudals 197–215; cloacal plate divided; 33–47 subcaudal scales arranged in two rows. Body pale yellow with 31–55 brown ovoid blotches on trunk and 9–16 on tail.

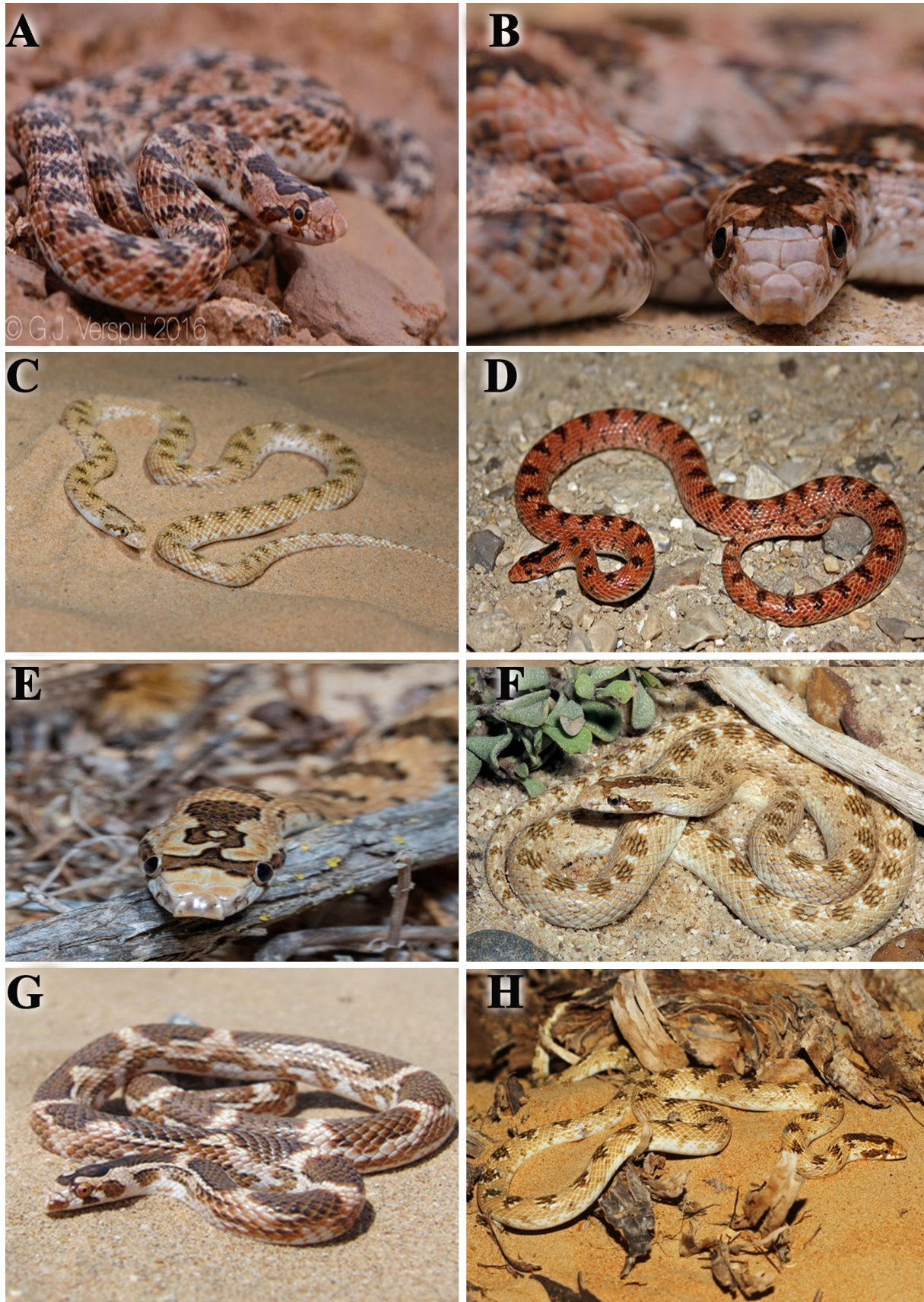
**References:** Anderson (1898); Schmidt (1939); Hass (1952, 1957); Kalaf (1960); Leviton and Anderson (1970); Leviton et al. (1992).

#### *Lytorhynchus gasperetti* Leviton, 1977 (Fig. 3)

*Lytorhynchus gasperetti* Leviton, 1977: 17–19, Fig. 1.

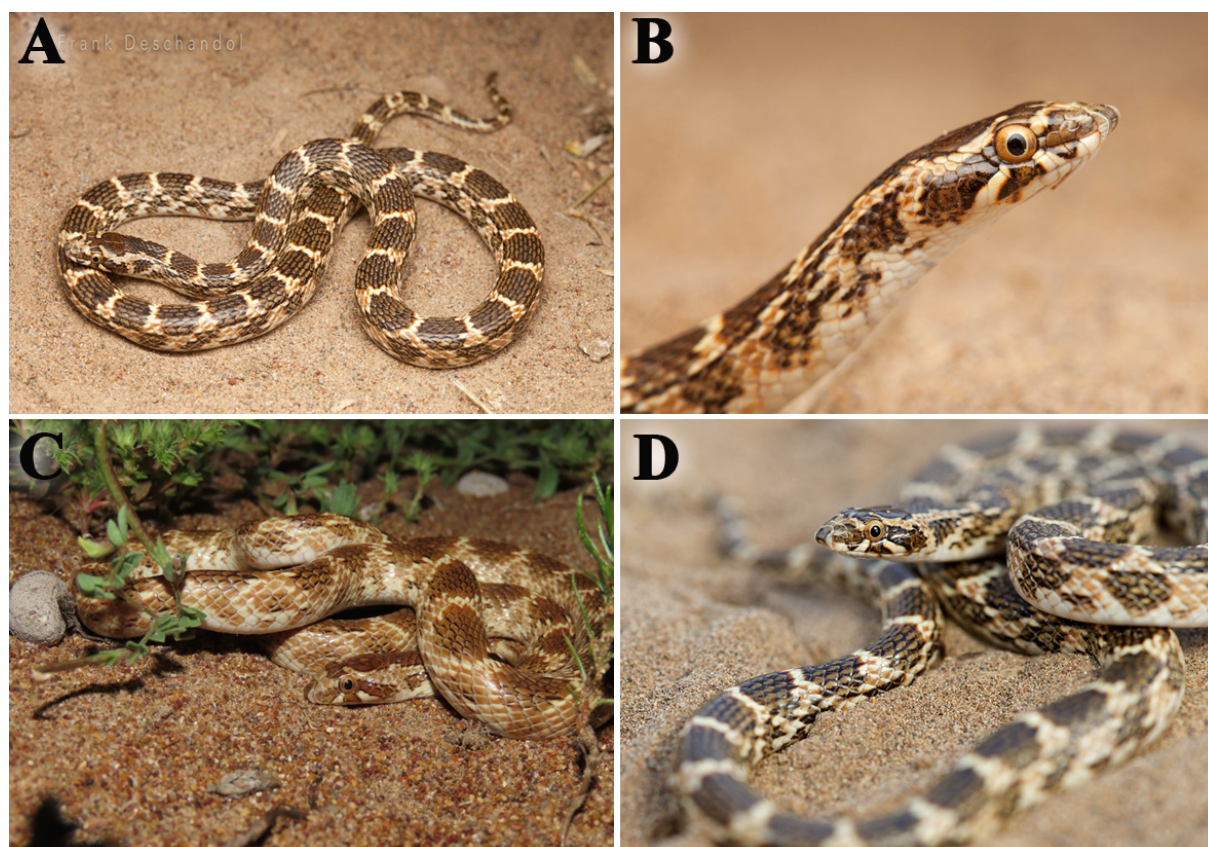
**Holotype:** CAS 134150, an adult (total length = 380 mm) female# from Khasawiyah (16°56'N, 42°37'E), Saudi Arabia.





**Figure 1:** Some ecomorphs of *Lytorhynchus diadema* from Morocco (A, B, G) and the Middle East (C-F, H) (Uetz et al., 2023).





**Figure 2:** *Lytorhynchus gaddi* from Khuzestan Province, SW Iran, (A, B) photos by Frank Deschandel, (C) photo by Alvand Mohammadalizadegan, (D) photo by Matthieu Berroneau.



**Figure 3:** *Lytorhynchus gasperetti* from the Asir Mountains, Saudi Arabia; photo by Tony Phelps.

**Diagnosis:** Rostral broadly truncated and angularly bent; internasal suture much shorter than prefrontal suture; two prefrontals; 3 or 4 preoculars, uppermost largest; preoculars two and three slightly smaller, the third resting upon 4<sup>th</sup> and 5<sup>th</sup> supralabials; two postoculars; one small trapezoidal or squarish loreal,

narrower anteriorly than posteriorly; temporals 2+2+3; 8–9 supralabials; ten infralabials, three in contact with anterior chin shields, posterior chin shields as long as the anterior pair; dorsal scales moderately keeled and in 19 rows decreasing to 15 one head length before the vent; outer three rows of

scales on each side smooth; ventrals 157–165; cloacal plate divided; and 40–44 subcaudal scales count arranged in two rows. Dorsum with a vertebral row of 33 longitudinally white rectangular bars, each narrowly edged by black and connected to one another by a mid-dorsal series of lighter brownish blotches (the most prominent on the anterior half of the body), lateral sides of the body with a row of brownish blotches, and a ventrolateral series of smaller dark blotches on the outer two scale rows that alternate in position with the lateral markings.

**Remark:** The coloration and body pattern like *L. diadema*. The count of dorsal blotches just mentioned for trunk and tail pattern is unknown.

**Reference:** Leviton (1977).

***Lytorhynchus kennedyi* Schmidt, 1939 (Figs. 4, 8C)**

*Lytorhynchus kennedyi* Schmidt, 1939: 75.

**Holotype:** FMNH 19586, an adult male# (total length = 380 mm) between Homs (34°44' N, 36°43' E) and Palmyra (34°33' N, 38°17' E), Syria.

**Diagnosis:** Rostral broadly truncated and angularly bent; internasal suture very short; two prefrontals; two or three preoculars; two or three postoculars; subocular absent and eye in contact with 5<sup>th</sup> supralabial; one squarish loreal; temporals 1+2 or 2+2; 8–9 supralabials; 10 infralabials; unknown ratio between the length of posterior chin shields and anterior pair; dorsal scales smooth, in 21:19:13 rows; ventrals 153–183; cloacal plate divided; and 35–44 subcaudal scales arranged in two rows. Body reddish brown with 22–29 widely spaced black dorsal crossbars on trunk and 6–8 on tail.

**Remark:** One specimen from Wadi al Mera, Saudi Arabia, was reported to have eight infralabial scales (Alshammari, 2021).

**References:** Schmidt (1939); Leviton and Anderson (1970); Leviton et al. (1992); Martens (1993); Moravec (1995); Sindaco et al. (2006); Torki (2017); Alshammari (2021).

***Lytorhynchus maynardi* Alcock and Finn, 1897 (Figs. 5, 8F)**

*Lytorhynchus maynardi* Alcock and Finn, 1897: 562–563.

**Syntypes:** BMNH 1946.1.14.79, a male#, and ZSI 14223–25 (total length = 381–400 mm) from Near Robat, south of the Koh e Malik do kand, Afghan–Baluch Boundary.

**Diagnosis:** Snout cuneiform and projected; elongated large rostral, four-sided, concave inferiorly; internasal suture shorter than prefrontal suture; two prefrontals; two preoculars (rarely one); two postoculars (rarely three); two or three suboculars; one pentagonal loreal; temporals 2+2 or 2+3; 7 supralabials (rarely 6 or 8 in one side); 9–13 infralabials, 3–5 in contact with anterior chin shield;

posterior chin shields as long as than anterior pair; dorsal scales smooth, in 19–21:19:15–17 rows; ventrals 184–208; cloacal plate divided; and 52–65 subcaudal scales arranged in two rows. Dorsum yellowish with a distinct, well-defined series of 35–55 black blotches on trunk and 12–15 on tail.

**Remark:** Salemi et al. (2018) reported that three specimens from a remote region of the species range have 21 dorsal rows at midbody. Unfortunately, these specimens are not accessible, and the authors have not responded. However, the photo of one specimen used in their paper resembles *L. maynardi*. If their counting is accurate, it is possible that a cryptic species or subspecies diverged from the main range in a different ecoregion in southeastern Iran. In contrast, except for the three specimens, it appears that maybe Iranian specimens have more infralabial scales than those from Pakistan. Sheikh et al. (2019) examined 8 specimens near Zabol and determined that Iranian specimens have 10–13 infralabials, with one specimen recorded from this area in 2015 having 11–12 infralabials (left/right) (Shafiei et al., 2015). On the other hand, Khan (2002) considered 9–11 infralabials for Pakistani specimens in his book.

**References:** Mertens (1969); Leviton and Anderson (1970); Khan (2002); Shafiei et al. (2015); Torki (2017); Salemi et al. (2018); Sheikh et al. (2019).

***Lytorhynchus paradoxus* (Günther, 1875) (Figs. 6, 8E)**

*Acontiophis paradoxa* Günther, 1875: 232–233, fig. 5.

**Holotype:** BMNH 1946.1.14.75, an adult (total length = 305 mm) male# from Khassia, Bulandshahar District, Uttar Pradesh, North India.

**Diagnosis:** Snout cuneiform and projected; rostral large, strongly projecting and angularly bent; internasal suture shorter than suture between prefrontals; two prefrontals; three preoculars; two or three postoculars; subocular absent and eye in contact with 5<sup>th</sup> supralabial; one small pentagonal loreal; temporals 2+2 or 2+3 or 2+4; 8 supralabials; 10 or 11 infralabials, four or five in contact with anterior chin shield; anterior chin shields shorter than posterior pair; dorsal scales smooth, in 21:19:15 rows; ventrals 168–188; cloacal plate divided; and 40–53 subcaudal scales arranged in two rows. Dorsum creamy with 40–52 series of transverse brown spots and less distinctive lateral series of smaller spots on each side.

**Remark:** Anderson and Leviton (1970) and Khan (2002) just mentioned the count of body blotches on trunk and pattern of tail is unknown.

**Reference:** Boulenger (1896); Werner (1927); Mertens (1969); Leviton and Anderson (1970); Khan (2002); Agarwal and Srikanthan (2013); Torki (2017)

***Lytorhynchus ridgewayi* Boulenger, 1887 (Fig. 7A-C)**

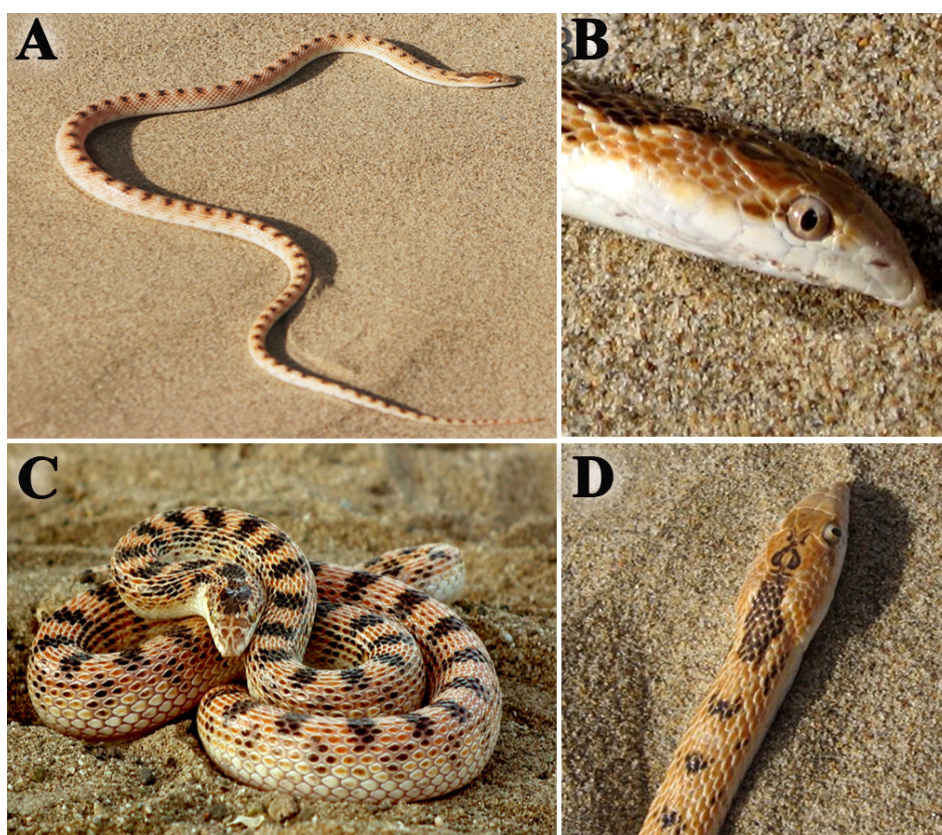
*Lytorhynchus ridgewayi* Boulenger, 1887: 413–414.



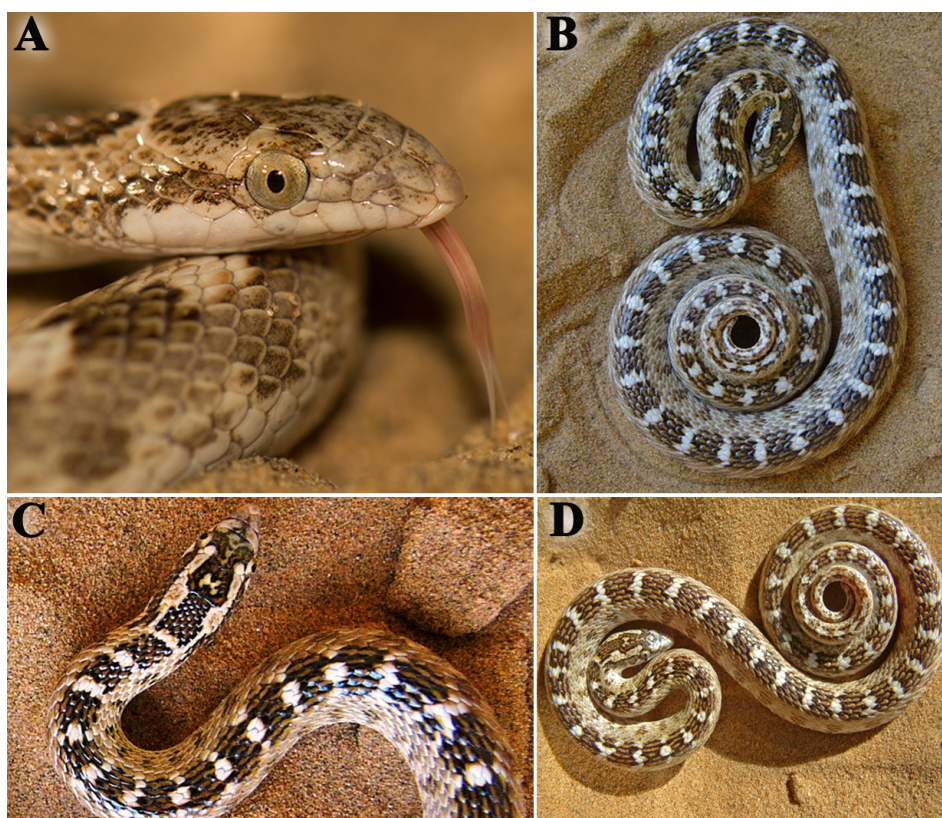


**Figure 4:** Holotype of *Lytorhynchus kennedyi*.





**Figure 5:** *Lytorhynchus maynardi* complex from Sistan and Baluchestan Province: (A, B) and (D) *L. maynardi* from Niatak district, photos by Hadi Fahimi (voucher number = DOE 20); (C) *L. maynardi* ssp. from 6 Km east Nikshahr, photo by Ali Salemi.



**Figure 6:** *Lytorhynchus paradoxus*, (A) from Thar Desert, Rajasthan; photo by Vipul Ramanuj, (B-D) from India, photos by Dharmendra Khandal.





**Figure 7:** *Lytorhynchus ridgewayi* complex: (A-C) *L. ridgewayi* from Khabr National Park, Kerman Province, SE Iran (voucher number A and C = ZMSBUK A26, B = ZMSBUK A10); (D) *L. ridgewayi* ssp. 1 from Karaj, N Iran, photo by Soheyl Sami; (E) and (F) *L. ridgewayi* ssp. 2 from Sang-e-Mes protected area, Bam City, Kerman Province (voucher number = ZMSBUK SWE-SMO3).

**Syntypes:** BMNH 1946.1.14.77–78, two male# [total length = 425 mm (longest syntype)] from Chinkalok (34°32'N, 61°53'E), Herat Province, Afghanistan.

**Diagnosis:** Snout moderately long and pointed; rostral narrowly truncated anteriorly with a trace of a short lateral cleft; internasal suture short; prefrontal single or divided; 1–3 preoculars; two or three postoculars; one or two suboculars; one small loreal; temporals 1+3 or 2+3; 7 or 8 supralabials; 10 infralabials, four in contact with anterior chin shield; posterior chin shields shorter than

anterior pair; dorsal scales smooth, in 19–21:19:17 rows; ventrals 160–190; cloacal plate entire or divided; and 40–55 subcaudal scales arranged in two rows. Dorsum light buff or greyish with series of 36–49 brown, black-edged squarish or transverse spots on trunk and 10–13 on tail.

**References:** Boulenger (1887, 1896); Elpatjewsky and Sabanejew (1906); Werner (1938); Leviton and Anderson (1970); Leviton et al. (1992); Mertens (1969); Khan (2002).



## Discussion

The genus *Lytorhynchus* in Iran is currently represented by three reported species (Shafiei et al., 2015). However, the potential for additional species or subspecies exists. Boulenger's (1887) description of *L. ridgewayi*, which was later confirmed by a larger study (Boulenger 1893), mentions a single prefrontal scale (Fig. 7B). Subsequent studies have noted variations, such as *L. ridgewayi* having 19 mid-dorsal and one or two prefrontal scales (Fig. 7A), leading to *L. gabrielis* F. Werner 1938 being considered synonymous with *L. ridgewayi* (Leviton and Anderson, 1970; Leviton et al., 1992). The complexity of Iranian *L. ridgewayi* specimens is intriguing, with morphological changes likely due to geographic separation resulting from the Central Plateau's gradual desiccation over millions of years (Aghanabati, 2004). Latifi's (2000) book "Snakes of Iran" describes *L. ridgewayi* as having 21 mid-dorsal rows and one prefrontal scale, and *L. diadema gaddi* as having 19 mid-dorsal and two prefrontal scales. However, subsequent researchers have made errors based on these descriptions. For instance, N. Moradi misidentified two specimens from Khabr National Park, leading to incorrect distribution maps for *L. diadema gaddi* (Moradi et al., 2013; Shafiei et al., 2015; Rajabizadeh 2018). Anderson and Leviton (1970) posited that *L. diadema gaddi* did not extend beyond Bushehr and Fars in southwestern Iran.

This study's findings suggest that Iranian *L. ridgewayi* with 21 mid-dorsal rows may constitute a separate species or subspecies, as first described by Latifi (2000). Additionally, a specimen from south of the Lut Desert, despite having 19 mid-dorsal rows, exhibits unique characteristics, including three prefrontal scales (Figs. 7F, 8J). This study categorizes specimens with 21 dorsal rows and one or two prefrontal scales as subspecies 1 (ssp. 1) (Fig. 7D), and the single specimen with three prefrontal scales as subspecies 2 (ssp. 2) (Figs. 7E, F, 8I, J).

The position of preocular scales and subocular scales has led to errors in species descriptions over the decades. For example, Anderson (1898) considered one subocular and one or two preoculars for *L. diadema* and *L. diadema gaddi*, while the subocular scale described by him is never close to the center of the pupil and is actually the lowest preocular (Fig. 8A). Similarly, Hass (1952) has considered a subocular for *L. gaddi*. Schleich et al. (1996) mentioned that *L. diadema* occasionally has a subocular. Fig. 8B shows which scale position probably involved these authors. Leviton (1977) also mentioned the existence of this scale in the description of *L. gasperetti*, but he did not consider it as a subocular scale. The position of this scale shows that it is never close to the center of the pupil and is actually the lowest preocular (Leviton, 1977). In contrast, Böttger (1880) and Werner (1931) did not consider subocular scales for *L. diadem*. In fact, it

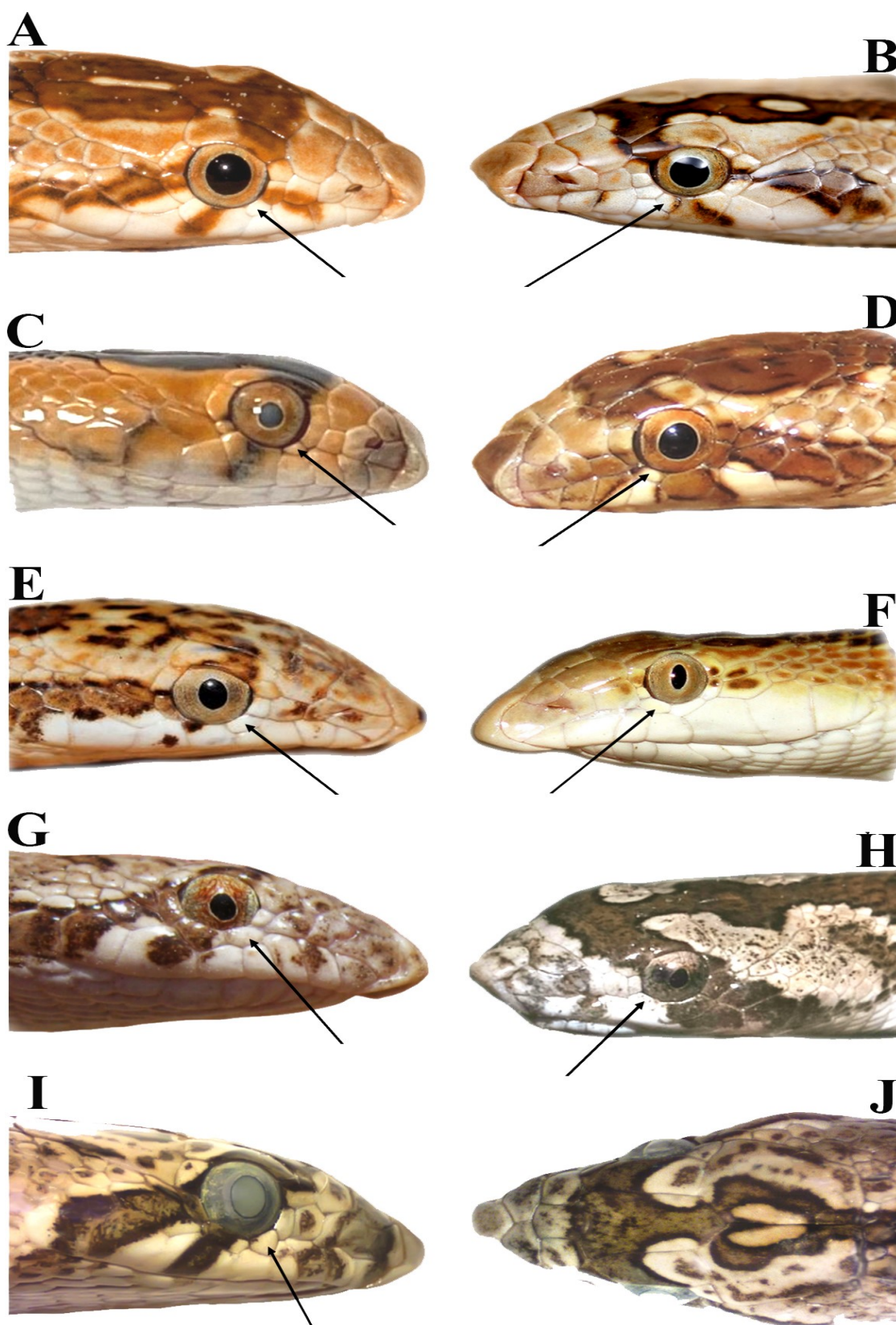
can be said that *L. diadema*, *L. gasperetti*, *L. kennedyi* (Fig. 8C) and *L. gaddi* (Fig. 8D) do not have a subocular, and the eye is in contact with one (or rarely two) supralabial. In the "ridgewayi" group, only in *L. paradoxus*, is the eye in contact with one (or rarely two) supralabial. In previous studies, a subocular was not considered present for this species (Boulenger, 1893; Bhide et al., 2004; Agarwal and Srikanthan, 2013). Furthermore, the lowest preocular has been called the "presubocular" (Agarwal and Srikanthan, 2013). The position of the scale depicted in Fig. 8E indicates that it never reaches the center of the pupil and is included among the preoculars. Among the Iranian *L. ridgewayi* ssp.1, there is typically only one subocular, and the lowest preocular never reaches the center of the pupil (Fig. 8H). Conversely, *L. ridgewayi* sens. strict. and ssp. 2 with 19 rows of mid-dorsal scales usually have two suboculars, with the anterior one reaching the center of the pupil (Fig. 8G, I). However, Boulenger's description of *L. ridgewayi* and subsequent study of additional specimens outside Iran considered only one subocular and 19 rows of mid-dorsal scales (Boulenger, 1887, 1893).

## Biogeography

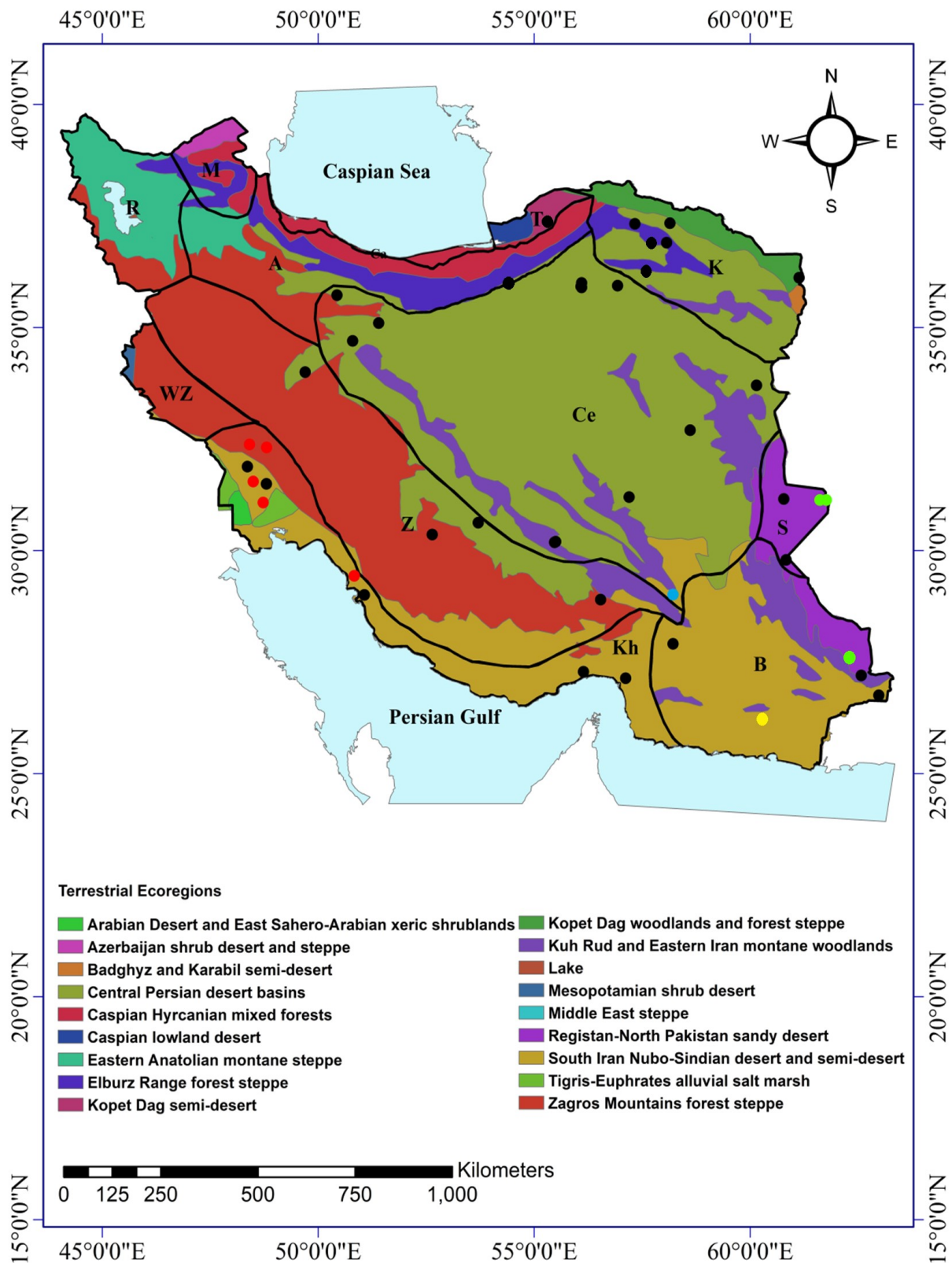
The *Lytorhynchus* taxa are distributed from the extreme Western Sahara and Atlantic coasts through North Africa, the Middle East to Western Asia. While *L. diadema* and *L. ridgewayi* have a wide distribution and various ecotypes, the remaining species are restricted to unique ecoregions (e.g., *L. maynardi*) or have only been observed in their type localities to date (e.g., *L. gasperetti*). From a biogeographical perspective, all of the species primarily exist in the southern regions of the Western Palearctic; however, *L. diadema* and *L. paradoxus* have penetrated the northern Afrotropical and northwestern Oriental realms, respectively (Sindaco et al., 2013).

Sindaco et al. (2008) divided the Western Palearctic into seventeen subregions and transition zones based on lizard distribution. According to this division, Iran encompasses parts of four of these regions. Two of these regions, "Arabian" and "Turanian," extend to western and southwestern Iran and a small portion of northern Iran, respectively. However, Iranian species are predominantly widespread in the Central Plateau and on the inner slopes of the Zagros and Alborz Mountains, which are designated as "Iranian." The Zagros and Alborz Mountains belong to the "Western Asian Mountains Transition Zone," a broad and morphologically complex area of western Asia with a high rate of endemism, where species from different biogeographical areas coexist. Based on this subdivision, two taxa, *L. maynardi* and *L. gaddi*, are endemic to the "Iranian" and "Arabian" regions, respectively. However, due to the wide range of the *L. ridgewayi* complex, these taxa are found in three regions: "Turanian," "Iranian," and the easternmost borders of the "Western Asian Mountain transition zone."



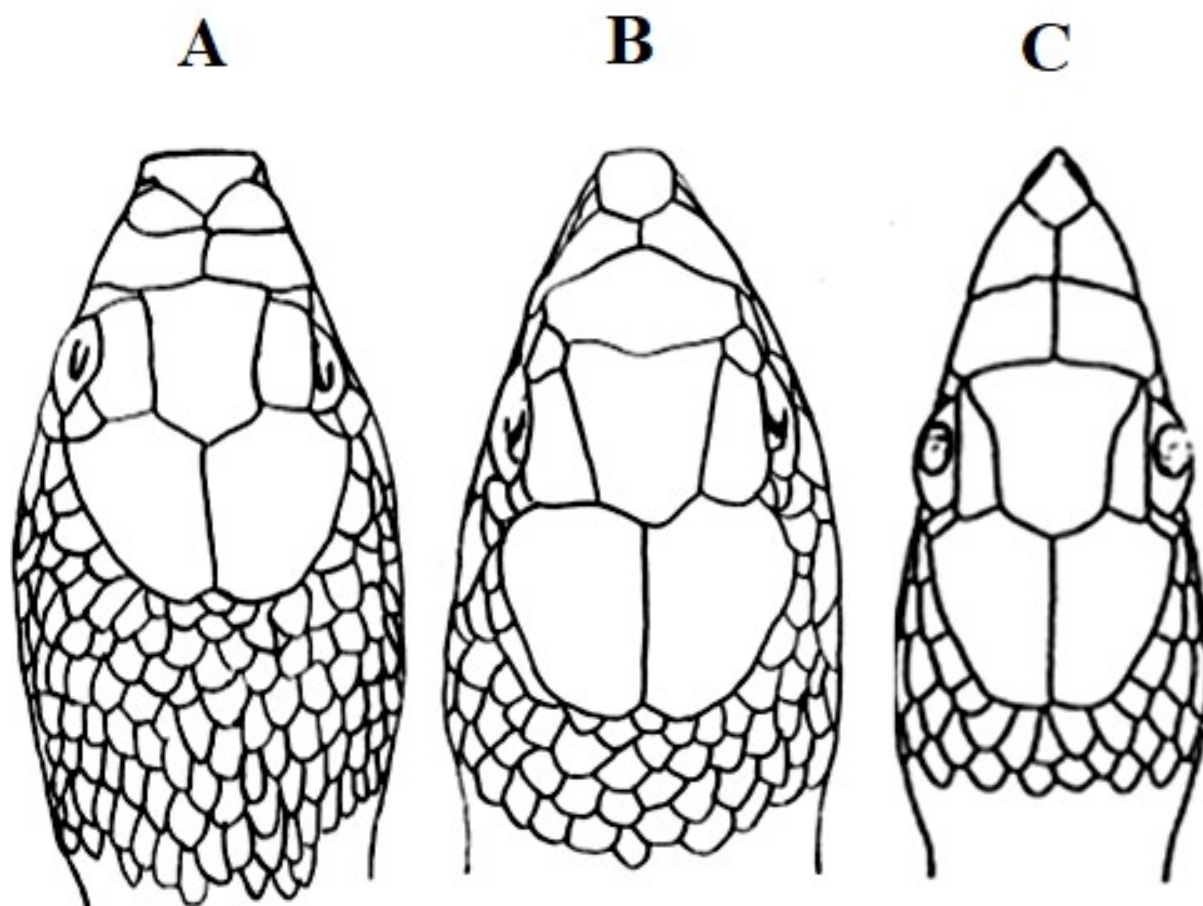


**Figure 8.** Comparison of pholidosis of the head in lateral view among the species: (A) *L. diadema*, photo by Luke Verburgt; (B) *L. diadema* photo by Matthieu Berroneau; (C) *L. kennedyi*, photo by Ahmed Mohajja Alshammari; (D) *L. gaddi* photo by Alvand Mohammadalizadegan; (E) *L. paradoxus* photo by Achyuthan Srikanthan; (F) *L. maynardi* photo by Hossein Nabizadeh; (G) *L. ridgewayi* (voucher number = ZMSBUK A26); (H) *L. ridgewayi* ssp. 1; (I) and (J) *L. ridgewayi* ssp. 2 (voucher number = ZMSBUK SWE-SMO3).



**Figure 9:** Distribution map of the genus *Lytorhynchus* in Iran with combinations of physiographic subdivision map Anderson (1999) (abbreviations of regions explained in the text) and ecoregions map Olsen et al. (2001); black dots. *L. ridgewayi* and *L. ridgewayi* ssp. 1; blue dot. *L. ridgewayi* ssp. 2; red dots. *L. gaddi*; green dots. *L. maynardi*; yellow dot. *L. maynardi* ssp.





**Figure 10:** Snout and rostral situation: (A) rostral broadly truncated (based on “diadema” group); (B) rostral narrowly truncated (based on *L. ridgewayi* complex); (C) rostral long and cuneiform (based on *L. maynardi* and *L. paradoxus*).

Iran is divided into thirteen distinct physiographic regions based on Anderson's classification system (Anderson, 1999). While Anderson did not provide precise geospatial coordinates delineating the boundaries of each region, we used geographic information system (GIS) software (ArcGIS 9.3, Esri) to generate proposed regional borders aligned with Anderson's textual descriptions. By matching Anderson's map with the ecoregions map prepared by Olson et al. (2001), the biogeography of the Iranian taxa can be better discussed (Fig. 9).

Except for *L. ridgewayi* ssp. 2, *L. ridgewayi* and *L. ridgewayi* ssp.1 do not have a recognizable distribution pattern and have been caught or observed in most areas near one another. For example, two specimens collected from the Khabr National Park coexist in the same habitat within about a 30 Km distance. Therefore, in the following, the *L. ridgewayi* complex has been considered for three *L. ridgewayi* and *L. ridgewayi* ssp. 1 and 2. Based on Anderson's physiographic subdivision, the *L. ridgewayi* complex, with the widest distribution, exists in several regions: “Turkmen Steppe” (T), “Kopet Dagh” (K), “Central Plateau” (Ce), “Sistan Basin” (S), “Iranian Baluchistan and Makran Coast” (B), “Khuzestan Plain and the Persian Gulf coast”

(Kh), and edges of the “Zagros Mountains” (Z). Considering the ecoregions map of Olson, it is clear that this species complex inhabits two of the widest ecoregions of Iran, including “Central Persian desert basins” (CPD) and “South Iran Nubo-sindian desert and semi-desert” (NBS). Although this species has been recorded in the vast ecoregion “Zagros Mountains forest steppe,” their specific localities are generally located in warm and low-altitude plains and close to ecoregion CPD. In northern Iran, the Drafshi snake is a rare species and observed just in the ecoregion ‘Kopet Dagh semi Desert’, in region T. In addition, this species has also been recorded in the ecoregion “Registan-North Pakistan sandy desert” (RNP). However, unlike *L. maynardi*, which inhabits sand dune deserts in S, this species does not inhabit the sand dunes of the ecoregion RNP and is not sympatric with *L. maynardi*.

*Lytorhynchus maynardi* is endemic to the deserts of southern Afghanistan, such as Dasht-e Margo and Registan Desert (Khan 2002; Sindaco et al. 2013). In southeastern Iran, this species is common in ecoregion RNP, particularly in regions S and B. The first record of *L. maynardi* from Iran was a single specimen collected by Balouch (1972) from Shahrokhabad, south of Shahdad City, Kerman

Province. This record was not confirmed by Latifi (2000), and Sindaco et al. (2013) recently referred to Shahrokhabad as a doubtful record. In November 2017, a second individual was photographed from the Lut block, but no specimen was collected, and we cannot confirm the location of the photo. Additionally, three specimens were documented 6 kilometers east of Nikshahr (Salemi et al., 2018), representing a remote area beyond previous records (Shafiei et al., 2015; Rajabizadeh, 2018; Sheikh et al., 2019). Notably, these specimens exhibit distinct morphological features, particularly in terms of mid-dorsal rows, when compared to other individuals of the same species. The Eastern Mountains, including the Taftan Volcanic complex, act as a natural barrier between this isolated population and the main populations. Furthermore, the presence of this distinct group within a different ecoregion (NBS of B) prompts us to consider the intriguing possibility that it represents a diverged subspecies of *L. maynardi* (Fig. 5C)

With the ambiguities in the identification of *L. gaddi* in Iran eliminated, this snake is found to be distributed only in southwestern hot sand dune deserts, inhabiting only the ecoregion NBS of Kh. The western range of this species extends to Saudi Arabia and Iraq (Leviton et al., 1992).

Except for regions T with four, and K and Ce, which have three climate types, regions S, B, and Kh have only the “Subtropical hot and arid” (SHA) climate type (Walter and Lieth, 1960–1967). According to the species distribution data, it has been determined that the *L. ridgewayi* complex has been recorded only in the areas of regions T, K and Ce, which have the climate type SHA (Taghdisi et al., 2012; Hosseinian Yousefkhani et al., 2014; Nasrabadi et al., 2016; Rajabizadeh 2018). On the other hand, by examining the main biomes of the regions (Olson et al., 2001), it is clear that *Lytorhynchus* taxa are generally seen in the biome “Desert and Xeric shrublands”, however, the *L. ridgewayi* complex also inhabits the biome “Montane grasslands and shrublands” of regions B, K, and Ce.

Considering the wide distribution of the genus and the existence of numerous ecomorphs and the overlap of characteristics, morphological studies alone cannot determine the taxonomic status of the species. However, in the Appendix 1, the up-to-date identification key for taxa is presented. It should be noted that a comprehensive phylogeographic study currently underway by the authors and colleagues will in the near future clarify the taxonomic relationships of the southwest Asian taxa and the precise biogeography of the genus *Lytorhynchus*.

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## Author contributions

All of the authors contributed to data collection, including voucher specimens and field sampling. Taxonomic identification of specimens was conducted by N.M. The manuscript was drafted by N.M. S.S. provided supervision throughout the study and writing process.

## Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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**Appendix 1: Species identification key of genus *Lytorhynchus***

1a. Snout truncated (Fig. 10A); rostral broadly truncated.....2  
 1b. Snout pointed (Fig. 10B, C); rostral not truncated or narrowly truncate anteriorly.....5  
 2a. Mid-dorsal scales keeled.....*L. gasperetti*  
 2b. dorsal scales smooth.....3  
 3a. Pattern of black crossbars very sharply defined, bars with intense black pigment, 22–29 blotches on body, 6–8 on tail.....*L. kennedyi*  
 3b. Pattern of dark brown to black ovoid bars distinct or not, but if distinct not intense black, each scale in dark bar usually with light center; 30–55 blotches on body, 9–16 on ail.....4  
 4a. Ventrals 152–178; total of ventrals and subcaudals 197–215.....*L. diadema*  
 4b. Ventrals 173–195; total of ventrals and subcaudals 212–240.....*L. gaddi*  
 5a. Rostral long and cuneiform (Fig. 10C).....6  
 5b. Rostral narrowly truncated (Fig. 10B)..... 8  
 6a. One or two supralabials (usually 5<sup>th</sup>) in contact with eye.....*L. paradoxus*  
 6b. Suboculars present and eye not in contact with eye.....7  
 7a. Mid-dorsal scales in 19 rows.....*L. maynardi*  
 7b. Mid-dorsal scales in 21 rows.....*L. maynardi* ssp.  
 8a. Mid-dorsal scales in 19 rows.....9  
 8b. Mid-dorsal scales in 21 rows, prefrontal 1 or 2, subocular usually 1.....*L. ridgewayi* ssp. 1  
 9a. Prefrontal 1 or 2, subocular usually more than 1, dorsal scales one head length anterior to the vent 17.....*L. ridgewayi*  
 9b. Prefrontal 3, dorsal scales one head length anterior to the vent 15.....*L. ridgewayi* ssp. 2

**Appendix 2: Material examined**

***Lytorhynchus ridgewayi*:** Iran. ZMSBUK: A10, A26: Khabr National Park, Kerman Province; L1: Sirjan, Kerman Province. SUHC: A1. Khorasan Province. A3. Khorasan Province. ERP 2065. Harat, Yazd Province. ERP 2106. Esfand-Abad, Fars Province.

***Lytorhynchus maynardi*:** Iran. DOE 20. Niatak, Sistan and Baluchistan Province. SUHC: A2. Nushki, Pakistan. A4. Nushki, Pakistan.