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Correspondence

Dice Snakes in the western Himalayas: discussion of potential expansion routes of *Natrix tessellata* after its rediscovery in Pakistan

Konrad Mebert [1] & Rafaqat Masroor [2]

[1)] Section of Conservation Biology, Department of Environmental Sciences, University of Basel, St. Johanns-Vorstadt 10, CH-4056 Basel, Switzerland

[2)] Pakistan Museum of Natural History, Garden Avenue, Shakarparian, 44000-Islamabad, Pakistan

Corresponding author: Konrad Mebert, e-mail: konradmebert@yahoo.de

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The dice snake (*Natrix tessellata*) has a large distribution range, extending from central (Germany) and southern Europe (Italy, Balkans) in the west, south to Egypt, and east as far as northwestern China and Afghanistan (Mebert 2011a and refs. therein). From Pakistan, *N. tessellata* has been documented only once (Wall 1911) with three specimens from an altitude of ca. 6,000 feet a.s.l. (~ 1,830 m) near Mastuj, Tehsil of District Chitral, Khyber Pakhtunkhwa Province. The only female, collected between 14 and 22 July 1910, laid two eggs and subsequently died. However, a recent reappraisal of the locality has shown that Mastuj actually lies at 7,450 ft a.s.l. (~ 2,270 m, see Mebert et al. 2013). Furthermore, Wall (1911) described the species as being common "in a piece of ground adjoining a stream", we presume that he in fact referred to a tributary to the Mastuj (= Kunar) River, as it appears unlikely that he would call the relatively wide (40–140 m), variably meandering Mastuj River merely a "stream". It is precisely at the village of Mastuj, where the Yarkhoon River and Mastuj River join and form a large alluvial plain with numerous smaller ponds and streams. Wall (1911) also mentioned that locals reported of snakes frequenting hot springs in the area, which he was unsuccessful to obtain, though.

Although Wall (1923) later listed only one specimen of *N. tessellata* from the Chitral Valley, we assign his previous account more credibility, since the capture of three specimens was explicitly mentioned only a year after his visit to Chitral. Unfortunately, Wall (1911, 1923) failed to indicate where those specimens were stored, leaving us unable to re-examine his *N. tessellata* from Chitral. To our knowledge, no additional dice snakes were subsequently added to any scientific collection, nor was there any particular search for them in Pakistan. Extensive surveys by the Pakistan Museum of Natural History and other experts in different parts of northern Pakistan failed to find this species (e.g., Baig 2001, Khan 2002, Masroor 2012).

During recent herpetological surveys of wetlands conducted in the framework of the Pakistan Wetlands Programme (PWP) by WWF-Pakistan, a single female of *N. tessellata* was collected at 1,845 m a.s.l. from the Gahkuch Wetlands of Ghizer District, Gilgit-Baltistan, Pakistan, on 20 August 2011. The dice snake was preserved as PMNH (Pakistan Museum of Natural History) No. 2478. A few corner data of this rediscovery were published in Masroor & Mebert (2012), whereas habitat details, pictures, and aspects dealing with its apparent limited range in a wider Central Asian context were detailed by Mebert et al. (2013). Herein we analyse and illustrate potential migration routes between the two sites in Pakistan.

We used Google Earth (version 6.1, 2011) to draw migration routes linking old and new records in northern Pakistan, incorporating information on riverine habitats and the altitudinal limits of *N. tessellata* from Central Asia and elsewhere. In a comparable case, the use of rivers for long-distance migration has been suggested for another high-altitude semi-aquatic colubrid, the hot spring snake *Thermophis baileyi* from valleys on the Tibetan Plateau (Hofmann et al. 2012). The resolution of most satellite images on GE are sufficient to identify open, rocky river banks with a southerly exposition, which are key features of the preferred habitat of dice snakes as compiled in Mebert (2011a).

The new find, a large female (SVL = 870 mm, ventral scales = 176), represents only the second known locality for *Natrix tessellata* in Pakistan after those specimens reported 100 years earlier from Mastuj, Chitral Valley, by Wall

(1911). Due to the significant sexual dimorphism in many body characteristics (Mebert 2011b), only gender-specific comparisons are reasonable only in a regional context. Wall (1911) reported ventral and subcaudal counts for the two Mastuj-males, as 182 + 66 and 180 + 67, respectively. These values probably correspond to a count of 178-180 ventral scales after subtracting the 1–2 preventral scales (Mebert 2011c) according to the modern counting method introduced by Dowling (1951). These counts agree with those of other male dice snakes from regions of Central Asia (Mebert 2011c), and are summarized here for both sexes (sample size in parenthesis) Turkmenistan-Iran border: f. 173.7 (4) and m. 175.5 (4); western Turkmenistan-Uzbekistan: f. 173.1 (9) and m. 175.7 (4); Afghanistan-Tajikistan: f. 174.7 (3) and m. 178.5 (4); Kyrgysztan: f. 174.7 (8) and m. 178.0 (6); and Kizil, Aksu Region, and NW China: f. 175.1 (14) and m. 179.3 (3). The other morphological characteristics of the Gahkuch dice snake are within the normal range of character expression in females of this species (e.g., Mebert 2011c, Rajabizadeh et al. 2011).

The fact that it took more than 100 years for a generally prolific and widespread snake species to be rediscovered (refs. in Mebert 2011a) is certainly surprising. How is the dice snake from Mastuj, Chitral Valley, linked to Gahkuch in the Ghizer River Valley? The straight-line distance between these two sites is only 115 km, but these two sites are isolated from each other by high mountain ranges (Hindu Kush and Karakoram Range of the western Himalayas) with mostly unsuitable habitats for dice snakes at higher elevation. Hence, there is currently no corridor for dice snakes to migrate between these two sites. Below, we discuss several potential routes for the colonization of the upper Ghizer River by dice snakes based on topography, climate, palaeohistory, and biological information on *N. tessellata*.

Route 1 via Shandur Pass: This route from Mastuj to Gahkuch extends over a distance of ca. 170 km through river valleys (Fig. 1). From Mastuj (Chitral Valley), it follows the Mastuj-Laspur River upstream, crosses the Shandur Pass as the highest point at 3,700 m a.s.l., from where dice snakes could continue into the Ghizer River Valley, colonize and pass the Lakes Phander (2,910 m a.s.l.) and Khalti (2,220 m a.s.l.) to reach as far as Gahkuch. The Shandur Pass constitutes the only pass below 4,000 m a.s.l. for dice snakes to migrate between the Chitral District and the Karakoram Mountains of Gilgit-Baltistan other than alternative routes that include the lowlands of Pakistan and are longer by a factor of 10 (see Routes 2 and 3 below). Although this pass is currently exposed to a climate that is too cold for dice snakes to survive, this species may have colonized it during the warmer Atlantic period or HCO (= Holocene Climatic Optimum) from ~ 8 ka to 5 ka BP to overcome altitudes higher than the currently known upper limit for *N. tessellata* at 2,800 m a.s.l. (Bannikov et al. 1971, Rajabizadeh et al. 2011). Schlütz & Zech (2004) corroborate the existence of a HCO for the Himalayan region, as Lake Rukche (3,500 m a.s.l.), Gorkha Himal, Central Nepal, were evidently once dominated by vegetation elements (*Ilex*, *Coriaria*, *Myrsine* and *Engelhardia*) that indicate a warmer and more humid climate at that elevation during the mid-Holocene (7.8 to 2.75 ka BP) than today, paralleling a warmer period during the Holocene revealed farther west in the Karakoram Mountain Range and on the Tibetan Plateau (Miehe 1996, Tianchi 1988). Given that the temperature change, as a function of altitude (lapse rate), is about 0.5–1.0 °C (avg. 0.6 °C) per 100 m in altitude (Glickman 2000), it would have provided dice snakes with suitable temperatures at levels up to 800 m higher during the HCO than their upper elevation reached today. Even though minor glacial advances and retreats in the Tibetan and Himalayan regions throughout the mid-Holocene period reflect a more complex climatic pattern between 8.3 and 5.4–5.1 ka (e.g., Owen 2009), there was still a period of 3,000 years during which the climate was warmer than today.

However, numerous studies from the Western Himalayas and therefore closer to the Gahkuch site, the Pamir Mountains and Central Asia, indicate that drier conditions persisted during the HCO (e.g., Lioubimtseva & Cole 2006, Beer et al. 2008, Demskea et al. 2009), in contrast to the monsoon-influenced, more humid sites in the central and eastern Himalayas (Schlütz & Zech 2004). Aridification in the Karakoram Mountain Range would decrease the extent of "shading" forest growth and promote open alpine meadows and steppe vegetation instead. A more open landscape allows an increased amount of solar radiation to reach the surface, warming soil and rocks, and thus providing a suitable thermal microhabitat for *N. tessellata*. Such an environmental situation is commonly found in dice snake habitats in Central Asia today (e.g., Rajabizadeh et al. 2011, Tuniyev et al. 2011).

Seasonal migration is yet another possibility by which the dice snake may overcome altitudes above the vertical range used during their period of activity. Numerous reports indicate that dice snakes living in deep river valleys move higher up on slopes to possibly evade potentially fatal flooding, but also for hibernation, ecdysis, embryogenesis and oviposition. These sites lie on thermally beneficial, rocky slopes up to hundreds of metres above their aquatic foraging habitats (e.g., Mebert 2011a, Tuniyev et al. 2011). In this context, dice snakes from the Shandur Pass, a plateau of 6 km in length with various lakes and streams, may temporarily occupy the sunny slopes just above the pass, and later in the year descend on either side of the pass to reach their activity habitats, and so could also disperse farther downstream along the Ghizer River.

Route 2 via Lowari Pass: A second, longer migration route between the Gahkuch site and Mastuj runs downstream along the Mastuj-Chitral-Kunar-River system (all one river) to Mirkhani, from there upstream along Ashret River to the Lowari Pass (3,136 m a.s.l., see Fig. 1). Unlike the Shandur Pass of Route 1, the Lowari Pass has no plateau, but consists of a sharp ridge with no wetlands. However, there are accessible mountain brooks within 1 km on both

sides below the pass. As in Route 1, dice snakes may have traversed the Lowari Pass during the HCO and expanded downstream along the Dir-Panjkora-Kabul Rivers to where this system joins the Indus River near Attock, approximately 60 km east of Peshawar, and from there dice snakes continued their expansion upstream to the Gahkuch site. This entire route stretches over 900 km through river valleys, circumventing most of the high Karakoram Mountain Range of northern Kashmir as described in Mebert et al. (2013).

Route 3 via Jalalabad, Afghanistan: This route would lead through the Chitral Valley downstream along the Chitral-Kunar River system into Afghanistan as far as Jalalabad, where it joins the Kabul River. This large river system is inhabited by dice snakes today (outside of Fig. 1 with vouchers: CAS 115972, FMNH 161179 and 161180, ZFMK 14542–44, ZMUC R60100; see Appendix:). Continued expansion downstream and east into Pakistan would connect it with Route 2 near Peshawar. Route 3 stretches over at least 1060 km of riverine habitat.

Route 4 via Khost, Afghanistan: A fourth potential route from Afghanistan into Pakistan along the Kurram River system is based on a *Natrix tessellata* voucher from Khost, Paktia Province, Afghanistan, in the Zoological Museum Kabul (= ZMK, erroneously cited as ZFMK in Gruschwitz et al. 1999). This specimen probably was destroyed in Kabul in the 1990s (W. Böhme, pers. comm.) and cannot be verified anymore. Both, the Kurram River, and the

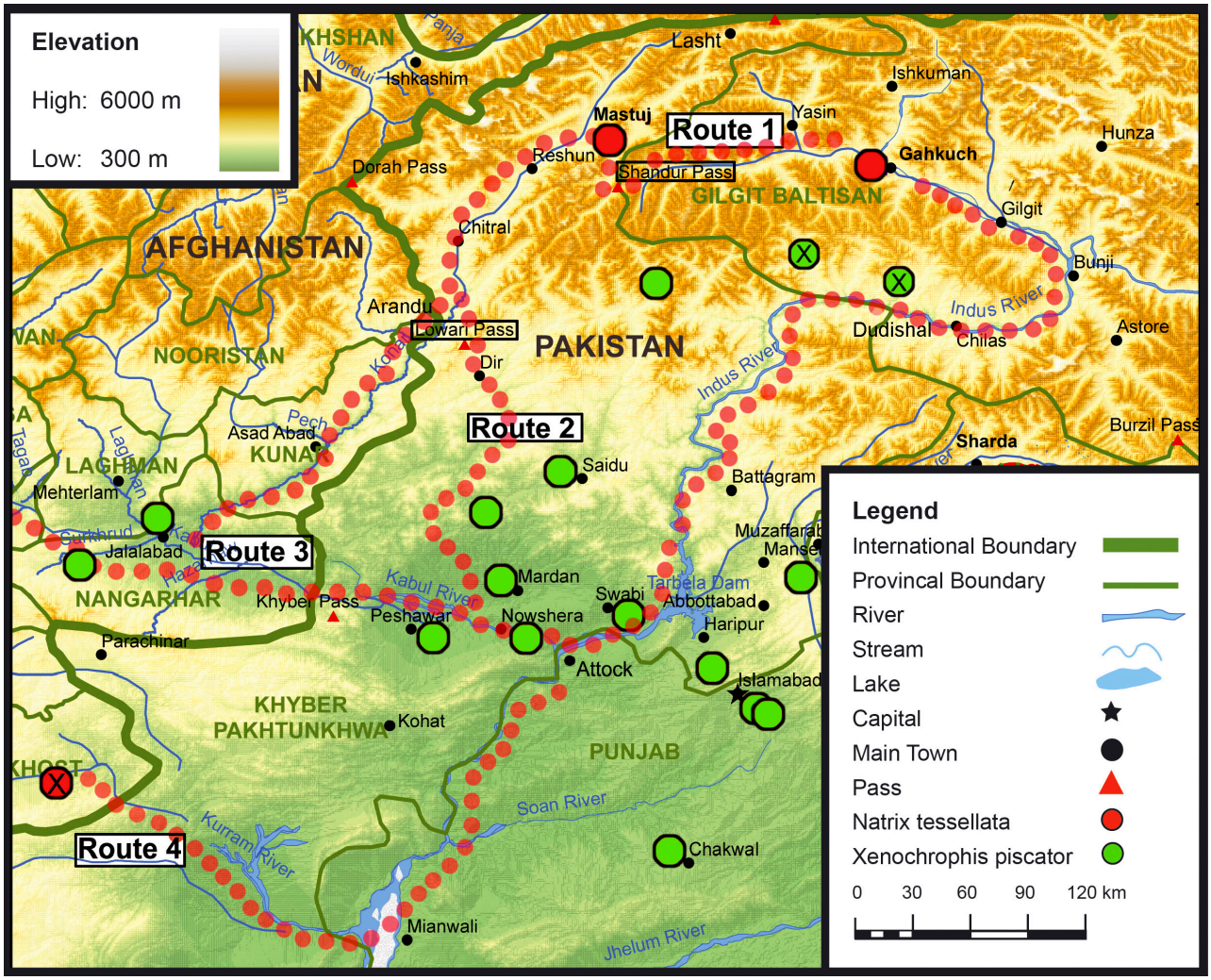

Figure 1. Northern Pakistan with the two localities (large red dots) from which *Natrix tessellata* was recorded: Mastuj (Wall 1911) and Gahkuch (Masroor & Mebert 2012). The lines of small red dots show proposed expansion routes for dice snakes from Mastuj to Gahkuch via the Shandur Pass (Route 1) or via the Lowari Pass (Route 2), and potential routes through Afghanistan via Jalalabad and Kabul (Route 3) or Khost (Route 4). Green dots represent records of a putative competitive snake, *X. piscator*. Dots with X-marks denote unvouchered or non-expert records for these species.

Chamkani River 50 km farther north in Paktia Province, appear to contain suitable riparian habitats for dice snakes. Both rivers flow east into Pakistan, merge near Bannu, where the riparian habitat of the Kurram River becomes increasingly lentic (slow moving, flat areas). The river continues east and joins the Indus River from where a subsequent upstream expansion of dice snakes would connect it with routes 2 and 3.

Large alluvial landscape and lentic river systems, as encountered along various routes (e.g., lower Kabul, Kurram, Dir and Indus Rivers), should not pose a barrier for the adaptable semi-aquatic dice snake, which also inhabits heavily irrigated areas bordering lowland rivers elsewhere, such as on the Euphrates in Iraq or the Nile River and Suez Canal in Egypt (refs. in Mebert 2011a, Ibrahim 2012). This raises the question why *N. tessellata* has apparently not expanded farther south along the Indus River and its tributaries into central and southern Pakistan, and why it has apparently not taken the long routes to reach the Gahkuch site that were even available during cooler periods in the Holocene. Are there other than structural factors, for example biotic ones, which create a barrier for the expansion of *N. tessellata*?

One such biotic element potentially functioning as a barrier for a further southward expansion of *N. tessellata* constitutes another water snake species from Pakistan, the superficially similar chequered keelback, *Xenochrophis piscator*. Both species occupy a wide variety of water systems and feed on equivalent semi-aquatic prey (e.g., Khan 2002, Mebert 2011a, Vogel & David 2012). They have an approximate parapatric distribution, as both currently known sites of *N. tessellata* in Pakistan are from the bottoms of valleys in the northern Hindu Kush-Karakoram Mountains, whereas *X. piscator* inhabits the southern versant of the western Himalayas and the adjacent parts of central and southern Pakistan. At a first glance, this situation is similar to the mostly parapatric distributions of the North American water snakes *Nerodia sipedon* and *Nerodia fasciata*. The former species dominates in the region containing systems that are often lotic (animated water bodies) in the hilly and mountainous inland terrain, whereas *Nerodia fasciata* inhabits the lentic systems (slow-moving or stagnant water bodies) of the lower flatlands. In transitional areas between hilly and flatland habitats, these two water snakes encounter one another in contact zones where hybridisation is common (Mebert 2008, 2010). In Pakistan, the known sites for *N. tessellata* are clearly associated with large lotic systems (the Ghizer and Mastuj Rivers) that are adjoined by smaller lentic systems, whereas *X. piscator* is linked to lentic habitats of the lowlands (Khan 2002, Masroor 2012). However, there are a few preserved specimens and a couple of unvouchered accounts of *X. piscator* from hilly terrain and mountain valleys in northern Pakistan and adjacent Afghanistan, from altitudes as high as 2,000 m a.s.l. (Masroor 2012, Mebert et al. 2013), which would require a more fine-tuned evaluation of interspecific habitat differences. Preliminary analyses indicate that *X. piscator* is the superior water snake species in the hot lowlands and warm mountain valleys of the Western Himalayas, possibly outcompeting *N. tessellata,* which in turn occupies (or is better adapted to) the drier and cooler mountain valleys farther north that are ecologically less accessible to *X. piscator* (Mebert et al. 2013).

In summary, the two shortest migration routes (1 and 2) between the confirmed localities of *N. tessellata* in northern Pakistan required the species to expand beyond high-altitude passes, which due to the harsh climate may only have been possible during warmer periods in the Holocene (i.e., HCO ~ 8 to 5 ka BP). The presence of extensive aquatic habitats on the plateau-like Shandur Pass affords Route 1 more plausibility as the principal migration route to colonize the Ghizer River, and thus reach the newly discovered site at Gahkuch. Satellite and Panoramio images on GE provide ample evidence that embankment habitats with complex rocky riparian microstructures and open (low vegetation) river banks, such as is typically occupied by *N. tessellata* all over its range today (refs. in Mebert 2011a), begin at Barsat (~ 3,300 m a.s.l.) near the confluence of Shandur and Ghizer Rivers and are abundant as far as Gahkuch, and beyond as well along many rivers and streams in the northern third of Pakistan. Widespread anthropogenic modifications serving to canalise, and thus control, rivers and gain agricultural land have likely accelerated the water current and thus diminished the access to the slow-current sections that are preferred as fishing grounds by dice snakes. However, larger alluvial plains with their multitude of small and slow-current tributaries were available during earlier periods (e.g., during the HCO) and likely provided better access to suitable habitats than is the case today and made a historic expansion to Gahkuch even more feasible. We consider routes 3 and 4, albeit containing putatively suitable habitat, as unlikely migration corridors for *N. tessellata* (Mebert et al. 2013) due to their extensive lengths, the lack of vouchers from Pakistan, and the presence of a potentially highly competitive and common semi-aquatic snake, *X. piscator*.

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References

Baig, K. J. (2001): Annotated checklist of amphibians and reptiles of the northern mountain region and Potwar Plateau of Pakistan. – Proc. Pakistan Academy of Sciences, **38**: 121–130.

Bannikov, A. G., I. S. Darevsky & A. K. Rustamov (1971): Zemnovodnye i presmy- kayushchiesya SSSR. [Amphibians and Reptiles SSSR]. – Publ. Mysl, Moscow, 303 pp.

Beer, R., F. Kaiser, K. Schmidt, B. Ammann, G. Carraro, E. Grisad & W. Tinner (2008): Vegetation history of the walnut forests in Kyrgyzstan (Central Asia): natural or anthropogenic origin? – Quaternary Science Reviews, **27**: 621–632.

Demskea, D., P. E. Tarasova, B. Wünnemann & F. Riedela (2009): Late glacial and Holocene vegetation, Indian monsoon and westerly circulation in the trans-Himalaya recorded in the lacustrine pollen sequence from Tso Kar, Ladakh, NW India. – Palaeogeography, Palaeoclimatology, Palaeoecology, **279**(3–4) 15: 172–185.

Dowling, H. G. (1951) A proposed standard system of counting ventrals in snakes. – British Journal of Herpetology 1: 97–99.

Glickman, T. S. (2000): Glossary of meteorology (2nd ed.). – American Meteorological Society, Boston, 855 pp.

Google Inc. (2011): Google Earth (Version 6.1.0.5001). – Available from <http://google-earth.soft32.com/old-version/392588/6.1.0.5001>

Gruschwitz, M., S. Lenz, K. Mebert & V. Laňka (1999). *Natrix tessellata* (Laurenti, 1768) – Würfelnatter. – pp. 581– 644 in: W. Boehme (Ed.): Handbuch der Reptilien und Amphibien Europas, Vol. 3/Schlangen II. – AULA-Verlag, Wiesbaden, Germany.

Hofmann, S., P. Fritzsche, T. Solhøy, T. Dorge, & G. Miehe (2012). Evidence of sex-biased dispersal in *Thermophis baileyi* inferred from microsatellite markers. Herpetologica, **68**(4): 514–522.

Ibrahim, A. A. (2012): New records of the Dice Watersnake, *Natrix tessellata*, in the Suez Canal zone and Sinai. – Amphibian and Reptile Conservation, **6**(2): 2–4.

Khan, M. S. (2002): A Guide to the Snakes of Pakistan – Ed. Chimaira, Frankfurt/Main.

Lioubimtseva, E. & R. Cole (2006): Uncertainties of climate change in arid environments of Central Asia. – Reviews in Fisheries Science, **14**: 29–49.

Masroor, R. (2012): A contribution to the herpetology of Northern Pakistan. The amphibians and reptiles of Margalla Hills National Park and surrounding regions. – SSAR, USA, and Chimaira Buchhandelsgesellschaft GmbH (Germany), 217 pp.

Masroor, R. & K. Mebert (2012): *Natrix tessellata* (Dice snake): Geographic distribution. – Herpetological Review, **43**(4): 621.

Mebert, K. (2008): Good species despite massive hybridization: genetic research on the contact zone between the watersnakes *Nerodia sipedon* and *N. fasciata* in the Carolinas, USA. – Molecular Ecology, **17**: 1918–1929.

Mebert, K. (2010): Massive hybridization and species concepts: insights from watersnakes. – VDM Verlag, Saarbrücken, Germany, 187 pp.

Mebert, K. (Ed.) (2011a): The Dice Snake, *Natrix tessellata*: Biology, Distribution and Conservation of a Palaearctic Species. – Mertensiella, **18**, DGHT, Rheinbach, Germany.

Mebert, K. (2011b): Sexual dimorphism in the Dice snake (*Natrix tessellata*). – Mertensiella, **18**: 94–99.

Mebert, K. (2011c): Geographic variation of morphological characters in the Dice snake (*Natrix tessellata*). – Mertensiella, **18**: 11–19.

Mebert, K., R. Masroor & M. J. I. Chaudhry (2013): The Dice snake, *Natrix tessellata* (Serpentes: Colubridae) in Pakistan: analysis of its range limited to few valleys in the western Karakoram – Pakistan Journal of Zoology, **45**(2): 395–410.

Miehe, G. (1996): On the connexion of vegetation dynamics with climatic changes in High Asia. – Palaeogeography, Palaeoclimatology, Palaeoecology, **120**: 5–24.

Owen, L. A. (2009): Latest Pleistocene and Holocene glacier fluctuations in the Himalaya and Tibet. – Quaternary Science Reviews, **28**: 2150–2164.

Rajabizadeh, M., S. Javanmardi, N. Rastegar-Pouyani, R. Karamiani, M. Yusefi, H. Salehi, U. Joger, K. Mebert, H. Esmaeili, H. Parsa, H. Gholi Kami & E. Rastegar-Pouyani (2011): Geographic variation, distribution and habitat of *Natrix tessellata* in Iran. – Mertensiella, **18**: 414–429.

Schlütz, F. & W. Zech (2004): Palynological investigations on vegetation and climate change in the Late Quaternary of Lake Rukche area, Gorkha Himal, Central Nepal. – Vegetation History and Archaeobotany, **13**(2): 81–90.

Tianchi, Li (1988): A preliminary study on the climatic and environmental changes at the turn from Pleistocene to Holocene in East Asia. – GeoJournal, **17**: 649–657.

Tuniyev, B., S. Tuniyev, T. Kirschey & K. Mebert (2011): Notes on the Dice snake (*Natrix tessellata*) from the Caucasian isthmus. – Mertensiella, **18**: 343–357.

Vogel, G. & P. David (2012): A revision of the species group of *Xenochrophis piscator* (Schneider, 1799) (Squamata: Natricidae). – Zootaxa 3473: 1–60.

Wall, F. (1911): Reptiles collected in Chitral. – The Journal of the Bombay Natural History Society, part **21**(1): 132–145.

Wall, F. (1923): A hand-list of the snakes of the Indian Empire. – Journal of the Bombay Natural History Society, **29**(2): 598–632.

Appendix

Voucher specimens: CAS (California Academy of Sciences, USA) 115972: Paghman, Kabul Province, Afghanistan, ~ 2440 m, 11–12 July 1965, W. S. Street; FMNH (Field Museum of Natural History, USA) 161179 and –80: 2 specs., Paghman, Kabul Province, Afghanistan 11–12 July 1965, W. S. Street; ZFMK (Zoologisches Forschungsinstitut und Museum Alexander Koenig, Germany) 14542–44: 3 specs., Jalriz, Sanghlak (Maidan), Wardak Province, Afghanistan, 2400 m, 31 March 1974, H. Seufer; ZMUC (Zoological Museum of the University of Copenhagen, Denmark) R60100: Sar-i-Chiasma, Koh-i-Baba Mts., SW of Kabul, near Jalriz and Jalez, Wardak Province Afghanistan, 1948, N. Haarloev.