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Distribution, Morphometric and Meristic Study of The Agamid Lizard *Laudakia tuberculata* Gray, 1827 in The North-Western Himalaya

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Abstract: The Agamidae family, which includes 52 genera and over 350 species, is a monophyletic group of acrodont lizards that evolved in eastern Asia during the late Cretaceous period. These are essential components of the arid terrestrial vertebrate fauna found at low to high altitudes. Among the four species of the prominent genus Laudakia, species Laudakia tuberculata (Gray, 1827) dominates the Garhwal region of the Indian Himalayas. The current study documents the distribution, morphometric and meristic study of Laudakia tuberculata in the Garhwal region, ranging from 350 to 2200 m asl altitude. The species prefers mountainous habitats, such as holes, cliffs, and rocky structures with deep crevices near streams and rivers, old houses, stony walls, and highways. The male individuals are bigger in size and show magnificent blue shades during the breeding season, an abdominal and pre-anal callous patch of scale, indicating noticeable sexual dimorphism. The morphometric analysis revealed substantial ($p<0.05$) variations in body weight (Wt), snout-vent length (SVL), head length (HL), head width (HW), forelimb length (FLL), hindlimb length (HLL), and tail width (TW) except tail length (TL) and total body length (TBDL) between both sexes at different elevations. The subtropical population have significantly ($p<0.05$) larger TL and TBDL compared to temperate populations indicating altitude governing the morphology of Laudakia tuberculata.

Keywords: Distribution • Morphometric • Meristic • Habitats • Sexual dimorphism

Introduction

Genus *Laudakia* (Gray, 1845) belongs to the family Agamidae of the order Squamata. Agamids are a monophyletic (Joger, 1991); (Honda *et al*., 2000) group of acrodont lizards. Family Agamidae (Gray, 1827) comprises more than 350 species (Baig *et al*., 2012) with a taxonomic history of 264 years back in 1758 when Linnaeus classified *Lacerta stellio* as the group's initial member (Baig *et al*., 2012). Taxonomy of central Asian Agamids has been reported with a high level of ecological and morphological diversity (Ananjeva & Tuniyev, 1992); (Arnold, 1999); (Clemann *et al*., 2008). *Laudakia* serves as an excellent model organism for deciphering information on speciation and evolution of lizards in the Himalayas. The genus *Laudakia* is widely distributed in Iran, Afghanistan, Pakistan, India, China, and Nepal in Asia. The species inhabits rocky mountainous habitats of the north-western Himalayan belt and also low elevation regions like the foothills. Updated taxonomy of the genus *Laudakia*, dividing it into three genera: *Laudakia* (Gray, 1845), *Paralaudakia*, and *Stellagama* (Baig *et al*., 2012). *Laudakia* comprises four species in the North-Western Himalayan region: *L. himalayana* Steindachner, 1867 (Himalayan Agama), *L. tuberculata* Gray, 1827 (Kashmir rock Agama), *L. agrorensis* Stoliczka, 1872 (Agror Agama), and *L. dayana* Stoliczka, 1871 (Hardwar Agama). None of them have been thoroughly investigated in terms of ecology, habitat preference, and behaviour.

The most frequent reptile in the North-Western Himalayan region is *Laudakia tuberculata*, also known as Kashmir rock agama, which is found between 310 and 3650 meters above sea level (Saikia *et al*., 2007). The species exhibits sexual dimorphism where larger individuals are generally males. They tend to develop brilliant shades of blue color at the commencement of the breeding season (Fig. 4). This agamid lizard can only be found in rocky outcrops, and crevices near streams and rivers. They are the most characteristic and active occupants of the old world's terrestrial mountainous habitat (Engelmann *et al*., 1986). The genus *Laudakia*is generally overlooked and a long-term systematic scientific database is lacking. Localized seasonal information on the species morphology and distribution has been reported from different regions of Uttar Pradesh (Waltner, 1991) and Garhwal (Bahuguna, 2008). It is believed that a thorough understanding of lizard's morphology and habitat ecology needs to be studied.

L. himalayana* (Himalayan Agama)/ *Paralaudakia himalayana

Himalayan agama is widely distributed in Himalayan and Trans-Himalayan Mountain ranges, Karakorum and Southern Pamir ranges, Tibet, Turkistan, Western Tajikistan, and Western Kyrgyzstan. The genus has also been named as *Paraludakia* (Baig *et al*., 2012). Three subspecies of the genus are *P*. (*himalayana*) *badakshana*, *P*. (*himalayana*) *bochoriensis*, and *P*. (*himalayana*) *himalayana*. All the three subspecies were found to be distributed between 1000-3500 m asl (Baig *et al*., 2012).*Paralaudakia* (*himalayana*) *himalayana* occurs above 2000 m. *P. himalayana* was recorded between 2300-3430 m altitudes (Ficetola *et al*., 2010) confirming a wider range. The same species was reported from 3000-3200 m in Gilgit and Chitral regions (Khan, 2006). This species was also reported from the Duda regions of Doda district in Jammu & Kashmir at an elevation of 1151 m asl (Manhas *et al*., 2018b). *P. himalayana* was found in a high elevation region of Jammu & Kashmir, including Dras, Kargil, and Leh (Sahi, 1979).

***L. tuberculata* (Kashmir rock Agama)**

The first time the species was recorded from Bengal in India and was designated as the type locality (Smith, 1935). *L. tuberculata* is common in North-Western Himalayan regions and is widely distributed across Eastern Afghanistan, China, Kashmir, Northern Pakistan, the Tibetan plateau, India, and Nepal. In India species have been reported within an elevation of 310 m to 3650 m (Saikia *et al*., 2007). The species is a common and abundant reptile in Jammu and Kashmir (Koul and Duda, 1977); Himachal Pradesh (Saikia *et al*., 2007); (Singh and Banyal, 2013), Uttarakhand (Bahuguna, 2008); (Mehra *et al*., 2021),Uttar Pradesh (Waltner, 1991); Punjab, Haryana from Kalesar Wildlife Sanctuary (Vishwakarma *et al*., 2019), as well as Sikkim.In Himachal Pradesh, it has been recorded from the Trans-Himalayan district of Chamba (Singh and Banyal, 2013), Lahaul, Spiti and, Kinnaur at elevations of up to 3650 m (Saikia *et al*., 2007). In Uttarakhand, *L. tuberculata has* been reported from the western section of Terai Arc Landscape **(**TAL) in Ramnagar Forest Division (RFD) (Mehra *et al*., 2021). It also has been reported from the Binog wildlife Sanctuary (Mussoorie), Harshil valley in Uttarkashi, Rajaji National Park, and Nainital, Uttarakhand (Fig. 2).

***L. dayana* (Hardwar Agama)**

L. dayana was found at higher elevations, 3000 m asl, near the Sutlej River's bank (Baig *et al*., 2012). They occur at various elevations, but their sympatric relationships are unknown. Information is lacking about the vertical distribution patterns of *L. dayana* and *L. tuberculata* from Kashmir. Due to their allopatric distributions, further studies may establish that both species are two separate

populations of the same species, but due to morphological differences, both can be recognized as complete species.

***L. agrorensis* (Agror Agama)**

Agror Agama or *L. agrorensis* (Stoliczka, 1872) is distributed across the low elevations of 700-1300 m asl regions of Pakistan and Kashmir (Smith, 1935); (Baig *et al*., 2012); (Uetz *et al*., 2018), whereas *L. tuberculata* is found predominantly in higher elevation (1200-2200 m) mountain ranges, indicating species parallel distribution. Although their upper and lower altitudinal ranges differ, they may share distribution zones where both species are sympatric. The species has been documented in the Doda district of Jammu and Kashmir within an elevation of 1216-2198 m asl(Manhas *et al*., 2018a) and relatively higher than the previously recorded elevational range of approximately 700-1,300 m asl in Pakistan and Kashmir (Baig *et al*.,2012). The species occurrence in the Arandu (Chitral, Pakistan) mountain ranges which also extends into Afghanistan, suggests that it may be found in the country's eastern regions. *L. agrorensis*, has been reported at a low elevation of 1300 m asl in Shimla, while *L. dayana* has been found at a high elevation of 3000 m asl if the allopatric distribution is followed (Baig *et al*.,2012).

Materials and Methods

Study area

Uttarakhand is located between 28º 44' and 31º 28' N latitude and 77º 35' to 81º 01' E longitude in the North-Western Himalayan region. Uttarakhand is divided into 13 districts and is surrounded on the North by Tibet (China), on the South by Uttar Pradesh, Nepal in the East, bordered on the Northwest by Himachal Pradesh, and on the West by the Indian state of Haryana. The state covers around 53,484 square kilometers with 93% of it being mountainous. Kumaon and Garhwal are the two divisions of Uttarakhand. Garhwal division was selected to conduct extensive studies on *Laudakia*. Garhwal Himalaya (latitude 29º 26' to 31º5'N and longitude 78º to 88º E) covers a total area of 30,090 square kilometers (Wadia, 1968). Altitudinally three broad habitats can be identified, viz. subtropical (400-1200 m), temperate (1200-3000 m), and alpine (above 3,500 m). Garhwal Himalaya supports a vast range of habitat types and a complex faunal pattern with its varied topography and climatic conditions.

Methodology

The questionnaire was prepared, and local people were interviewed to collect information on the occurrence of agamids in different habitat types. The GPS location, coordinates, and altitude were recorded, where lizards were found. Indirect shreds of evidence such as fecal pellets and road kills were also used to estimate the presence of agamids. Based on preliminary information on the species, an extensive field site was selected within an altitudinal gradient of 350 m to 2200 m covering different habitat types. Three extensive study sites within the distribution range were selected (Fig. 1). One of the extensive study sites was at the Himalayan foothills within an altitude of 350-600 m asl, lat, 30° 07' 32.37" and long,78° 18' 50.93" dominated by Sal (*Shorea robusta*) deciduous forest (moist), North Indian Rosewood (*Dalbergia sissoo*), Teak (*Tectona grandis*), broadleaf mixed forests along with scrubs located at the bank of river Ganga. At mid subtropical regions around 1000-1200 m altitude, the second extensive study site known as the Nagani valley lat, 30° 19' 15.71" and long, 78° 21' 0.57" was at the bank of the Henwal River, which is a spring-fed tributary of River Ganga dominated by subtropical mixed deciduous, subtropical pine (*Pinus roxburghii*) forests along with farmlands and grasslands.

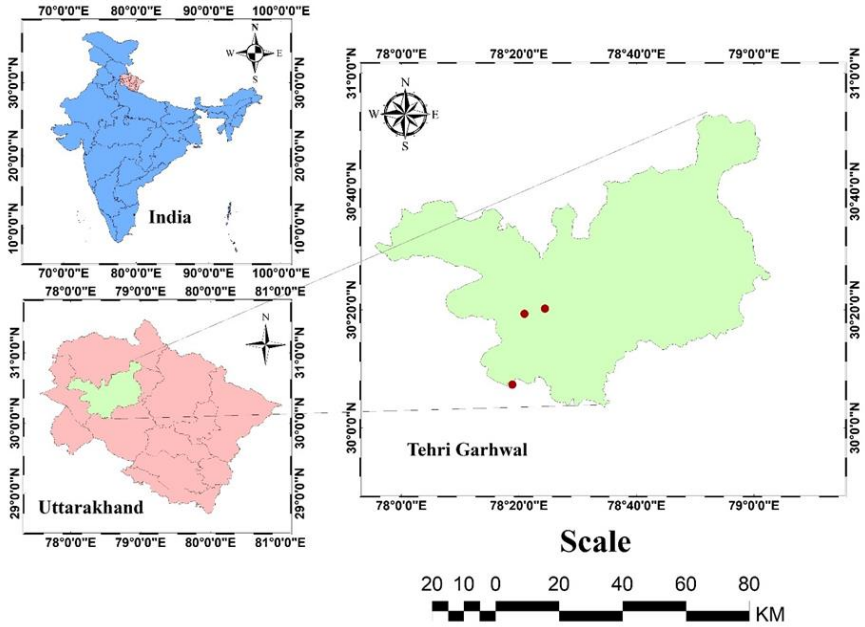

Fig. 1. ***Map of the study area***

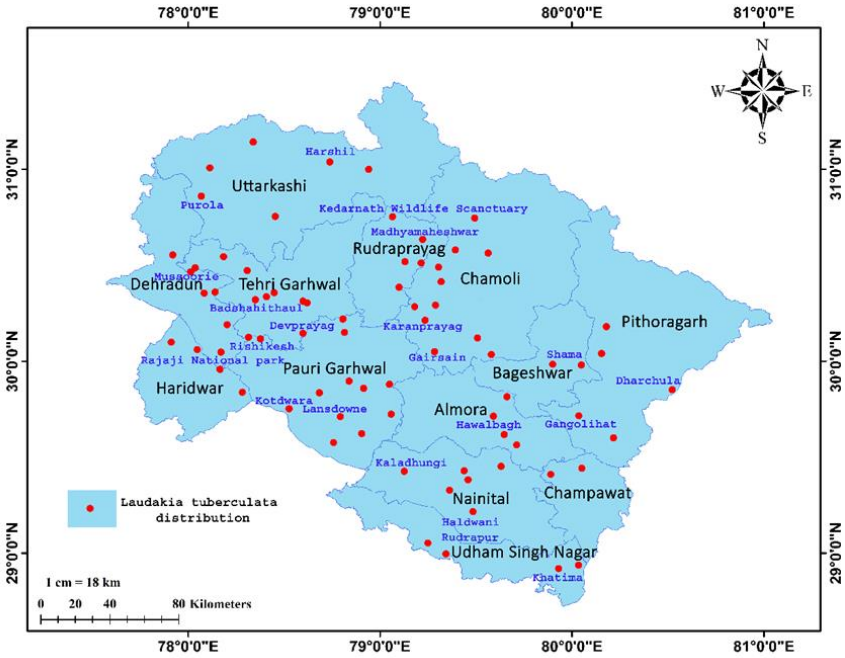

Fig. 2. ***Distribution map of genus Laudakia tuberculata in Uttarakhand***

The third extensive study site at 1700-1800 m asl lat, 30° 20' 10.58" and long 78° 24' 26.55" at the lower temperate habitat area is dominated by Chir pine (*Pinus roxburghii*), Himalayan blue pine (*Pinus wallichiana*) and mixed oak (*Quercus leucotricophora*) forests.

At the extensive study sites, Line Transects (Burnham *et al*., 1980) of 1 kilometer was walked and in each transect quadrats of 1M×1M were laid after an interval of every 200 meters. In these quadrats, the herb (Bonham, 1989), fern, shrub, and grass cover

(Alaback, 1982) were measured. Plant cover is assessed by subdividing the $1m^2$ quadrat into 16 smaller units. The length of the plant is measured from ground level up to the top of the fully extended leaf using a measuring tape and their numbers were counted, in the case of grasses, the number of clumps were counted. Plant species were identified (Naithani, 1984-1985: Gaur, 1999).

Animals were captured by noose method (Bloomberg and Shine, 1996) and, hand with gloves. A noose is formed by using a hollow plastic pipe of 1-1.5 m in length with a noose tied at one end. Fisher line thread is used for making a noose. Mosquito netting is also used for capturing lizards. Weight was measured using an electronic Kitchen digital weighing scale to the nearest 1 gm. The morphometric measurements were made using a digital calliper (0.1mm scale) and meristic characters were recorded using a hand lens. The specimens were marked using enamel paint (Bloomberg and Shine, 1996), images were taken with Canon EOS 1500 D DSLR camera and then animals are released back to their natural habitat. Terminology for the morphological description was followed (Ananjeva *et al*., 2011) and (Baig *et al*.,2012).

Morphometric and meristic (pholidosis) characters and their abbreviations were as follows: Weight (Wt), Snout-vent Length (SVL), Head Length (HL), Head Width (HW), Forelimb Length (FLL), Hindlimb Length (HLL), Tail Length (TL), Tail Width (TW), Total Body Length (TBDL), Supralabials (SL), Infralabials (IL), Scales b/w Nostrils (SBN), Scales b/w Nostril and Tympanum, Subdigital lamellae on 4th finger (SDLF 4thF), Subdigital lamellae on 4th toe (SDLF 4thT), number of scales in a single row between posterior edges of eyes (SACH), number of scales between nostril opening and the posterior edges of the eye (SBNE), number of longitudinal rows of enlarged scales on the vertebral region (LVS).

Data analysis

Data analyses were carried out using Statistical Package for the Social Sciences (SPSS) software version 23.0. The significance level for all the statistical tests was set at p =0.05 at 95% confidence interval. We used an independent sample t-test to detect differences between all males and females at three different study sites. One-way analysis of variance (ANOVA) was used to compare males at three different study sites. Females of three study sites were also compared using One-way ANOVA. Post hoc test (Tukey test) was used for multiple comparisons of males and multiple comparisons of females' morphometric characters.

Results And Discussion

Direct and indirect evidence revealed that *Laudakia tuberculata* is present throughout the North-Western Himalayas within an altitude of 350 m asl to 2200 asl.

Male

The dorsal side of head is pale brown or grey and comparatively more uniform. The ventral side of head is pale greyish. Dark black markings are present in the centre of head and they are diffused, light orange wash is visible on the posterior side of head. Reticulated patterns of grey, yellow, and light brownish-black color can be seen on anterior and posterior sides of head. Black and dark bluish edgings are present around the eyes and lips. The throat pattern is distinct for each individual, having a network of dark black blotches and diffused dark black markings in the centre part, and sides are covered with specks of cream color (Photo plate 1). Ventral body colouring is bluish or greenish-grey, or olive-brown with black and yellow patches of various sizes, or dark-brown without any pattern. Anterior area of chest has light or dark orange mixed with blue wash on a dark grey background and sometimes only grey and light black blotches on a creamish background. The posterior side is creamish colored with grey marks. Sometimes bluish specks are scattered

all over the body but are more prominent in anterior half and towards the margins. The ventral surface of limbs is blue. Bluish coloration is more intense on the dorsal side of both forelimbs and hindlimbs (Photo plate 2). The basal half of tail is bluish and greyish but the distal half is dark black. Tail autotomy is followed by tail regeneration. Therefore, new tail is raised from the fracture plane, and have dark coloration.

Female

Adult females have an olive-brown or dark-greyish dorsal coloration with cream-colored marks scattered uniformly. Their heads are usually not as blue as males, and the gular area is not as prominently marked with black-colored blotches on a creamish-yellow background, while the chest and belly have fewer and smaller black blotches. The gular region has uniformly arranged black blotches and sometimes they are also centrally more pronounced as in males. During the breeding season, the cream-colored chest may have a little orange to dark-orange wash. Females do not have abdominal or pre-anal callosities. Limbs are cream-colored with grey or black blotches. In many individuals' limbs coloration is same in both sexes. The proximal half of tail is brown or light grey and cream-colored but the distal half is dark brown or black colored.

Picture 1. Male Throat Display

Picture 2. Male During Breeding season

Picture 3. Male abdominal callous patch

Picture 4. Juvenile

Morphometric and meristic characters of *Laudakia tuberculata*

Observations revealed that Kashmir rock agamas have dorsoventrally flattened bodies, with distinct, large, and superficial tympanum, a triangular head, mid-dorsal region of body has large and heterogenous scale rows (Table 1 and 2). The gular pouch is absent. Throat or gular region is plicate. Scales of upper head are smooth, unequal, and heterogenous, sometimes keeled. Scales on sides of head, neck, and around tympanum are low spinose

scales. Ventral band scales are keeled and larger than dorsals. The sides of body being covered by scattered enlarged mucronate scales. Ventral scales are smooth but smaller than the enlarged vertebral and enlarged than smaller dorsals and gular scales. The body's lateral side skin is loose and forms a dorsoventral fold. Limbs are Strong and covered with mucronate scales, fingers and toes are compressed, and toes are longer having Subdigital lamellae with strong claws. The fourth toe is among the longest toe than others. The tail is flattened and oval at the base having caudal whorls. Caudal whorls are arranged in the form of distinct rings or annuli. There are four whorls of enlarged mucronate scales dorsally but it gets reduced to three ventrally in each tail segment. The tail is substantially longer than the body and the head combined. Dorsal scales are keeled and larger than the ventral (Table 1 and 2).

Table 1. Meristic characters of *L. tuberculata* (male) at different study sites

Sex: Male		**Site 1: Lower sub-tropical (N=20)**	**Site 2: Middle sub-tropical (N=20)**	**Site 3: Lower temperate (N=45)**
Meristic Characters		**Mean ± SE**	**Mean ± SE**	**Mean ± SE**
Supralabials	SL	11.1±0.20	10.15±0.33	9.91±0.12
Infralabials	IL	10.1±0.19	10.1±0.20	10.13±0.13
Scales b/w nostrils	SBN	5.6±0.17	5.3±0.13	5.04±0.11
Scales b/w nostril and tympanum		24.95±0.28	23.45±0.37	22.84±0.31
Scales b/w nostril and eye	SBNE	15±0.28	13.55±0.25	13.84±0.21
Scales b/w post edges of eyes	SACH	14.35±0.23	14.55±0.26	14.82±0.28
Subdigital lamellae on 4th finger	SDLF4thF	26.8±0.37	27.75±0.29	23.2±0.4
Subdigital lamellae on 4th toe	SDLF4thT	31.3±0.38	30.9±0.33	27.44±0.47
Long rows of scales on vertebral region	LVS	14.85±0.2	14±0.23	13.75±0.18

Table 2. Meristic characters of *L. tuberculata* (female) at different study sites

Sex: Female		**Site 1: Lower Sub-tropical (N=10)**	**Site 2: Middle sub-tropical (N=12)**	**Site 3: Lower temperate (N=34)**
Meristic Characters		**Mean ± SE**	**Mean ± SE**	**Mean± SE**
Supralabials	SL	10.7±0.3	10.17±0.21	10.1±0.13
Infralabials	IL	9.9±0.23	9.83±0.3	9.87±0.21
Scales b/w nostrils	SBN	5±0.26	4.92±0.23	5.06±0.12
Scales b/w nostril and tympanum		23.4±0.45	24.5±0.38	23.23±0.27
Scales b/w nostril and eye	SBNE	14.3±0.37	14.25±0.35	12.9±0.19
Scales b/w post edges of eyes	SACH	14.6±0.37	14.17±0.41	14.39±0.19
Subdigital lamellae on 4th finger	SDLF4thF	25.7±0.42	26.75±0.35	24.48±0.41
Subdigital lamellae on 4th toe	SDLF4thT	29.3±0.56	29.08±0.29	28.52±0.3
Long rows of scales on vertebral region	LVS	14.6±0.31	15.17±0.37	14.03±0.23

At Site 1 and 2, Wt, SVL, HL, HW, FLL, and TW of males was found not significant (p = n.s.) but HLL, TL, and TBDL of Site 1 and 2 were significantly different ($p<0.05$). Individuals from S3 were significantly different from both S1 and S2 males in Wt,

SVL, HL, HW, FLL, HLL, and TW ($p<0.05$). At S3 TL and TBDL were significantly different from S1 ($p<0.05$), but TL and TBDL of S3 and S2 were not significantly different (Table 3). In females, Wt, SVL, HL, HW, FLL, TL, and TW of S1 and S2 were not significantly different (p=n.s.) but HLL, TBDL of S1 & S2 were significantly different ($p<0.05$). At S3 Wt, SVL, HL, HW, FLL, HLL, TL, TW, and TBDL is significantly different from both Site 1 and 2 ($p<0.05$) (Table 4).

Variations in altitudes, growth rate is also varied in several species (Stearns, 1992) and (Sears and Angilletta, 2004). The possible reasons for the significant differences between the lower and higher elevation populations could be the variations in temperature, and the food resources. Ectotherms living at high elevation sites grow slower than low altitudes ectotherms. The limited thermal opportunities for their activity (Grant and Dunham, 1990); (Sorci *et al*., 1996), or the limitations of food resources (Chown and Klok, 2003); (Hodkinson, 2005) could be another reason for the difference in total body length (TBDL) and weight (Wt) between individuals of lower and higher elevation.

Sexual dimorphism was observed among the individuals in the wild. At all the three study sites males are larger than females in all the characters. Independent sample t-test shows that Wt, SVL, HL, HW, FLL, HLL, and TW of males and females are significantly different ($p<0.05$) but TL and TBDL are not significantly different (p=n.s.). Sexual differences in head and body size are caused by sexual selection. But some researchers have shown that sexual size dimorphism (SSD) can also result from natural selection (Anderson and Vitt, 1990); (Ruby and Baird, 1993) or also from a wide range of local environmental processes (Shine, 1990). Male biased sexual size dimorphism (SSD) has advantages, large males with large head size has an advantage in male-male combat and aggressive Fights. Females may prefer large males in mate choice. Therefore, males are always larger in head and snout-vent length than that of females.

Callose gland

In the integument of Rock Agamas, callose scales are present which are holocrine epidermal glands with hyperdeveloped keratin layers. Callous scales are a large patch of thickened ventral scales, present only in males at abdominal and precloacal positions. During the breeding season, callous scale's glandular secretions are linked to territoriality, social behaviour, and chemical communication (Dujsebayeva et al., 2007). Pheromones are secreted from callous glands that spread across the substrates and aid in the marking of individuals' territory (Waltner, 1991). During breeding season from April to September male individuals undergo territorial and head-bobbing behaviour along with the bluish head, limbs, distal half of tail, and flanks. The aggression and Fights among the male individuals with other subordinate males reflect territorial behaviour. Females lack these glands and hence they are not territorial. Males have a larger body and a large voluminous head than females. Females have light coloration on different body parts, but not as intense as males. The gular region and throat coloration are more organized in males having fused markings of blue and black color. Throat display is also common during breeding season performed by males from the highest perch positions displaying their dominance (Photo plate 3).

Table 3. Morphometric characters of *L. tuberculata* (male) at different study sites

Sex: Male		Site 1: Lower sub-tropical (N=20)	Site 2: Middle sub-tropical (N=20)	Site 3: Lower temperate (N=45)	F value	P value	P value (Tukey test)		
Morphometric Characters		**Mean ± SE**	**Mean ± SE**	**Mean ± SE**			**S1& S2**	**S1& S3**	**S2& S3**
Weight	Wt (gm)	67.65±3.85	64.9±2.88	44.78±2.4	20.036	0.000	.845	.000	.000
Snout vent Length	SVL (mm)	124.54±2.68	119.9±2.19	107.21±2.05	15.862	0.000	.482	.000	.001
Head Length	HL (mm)	37.82±0.93	35.44±0.67	30.67±0.64	25.361	0.000	.149	.000	.000
Head width	HW (mm)	28.97±0.75	27.11±0.61	23.31±0.57	20.607	0.000	.221	.000	.000
Forelimb Length	FLL (mm)	59.58±1.14	56.67±0.7	48.78±0.8	40.509	0.000	.150	.000	.000
Hindlimb Length	HLL (mm)	92.56±1.53	85.65±1.22	75.55±1.07	48.231	0.000	.005	.000	.000
Tail Length	TL (mm)	203.66±6.41	177.32±8.34	176.34±3.54	6.853	0.002	.013	.002	.991
Tail Width	TW (mm)	17.76±0.48	17.24±0.29	15.36±0.3	13.397	0.000	.668	.000	.001
Total Body Length	TBDL (mm)	328.21±5.9	297.3±10.31	283.55±4.73	11.562	0.000	.016	.000	.307

Table 4. Morphometric characters of *L. tuberculata* (female) at different study sites

Sex: Female		Site 1: Lower sub-tropical (N=10)	Site 2: Middle sub-tropical (N=12)	Site 3: Lower temperate (N=34)	F value	P value	P value (Tukey test)		
Morphometric Characters		**Mean ± SE**	**Mean ± SE**	**Mean ± SE**			**S1 & S2**	**S1 & S3**	**S2 & S3**
Weight	Wt (gm)	60±2.05	61.17±3.18	39.87±1.92	28.648	0.000	.962	.000	.000
Snout vent Length	SVL (mm)	121.68±2.22	123.44±1.43	100.61±1.7	42.786	0.000	.922	.000	.000
Head Length	HL (mm)	34.75±0.59	35.36±0.87	28.59±0.35	56.021	0.000	.799	.000	.000
Head width	HW (mm)	23.86±0.25	24.32±0.4	20.88±0.32	25.924	0.000	.786	.000	.000
Forelimb Length	FLL (mm)	54.42±0.51	52.69±0.43	47.06±0.5	44.200	0.000	.251	.000	.000
Hindlimb Length	HLL (mm)	84.94±0.4	77.26±0.42	71.47±0.97	36.153	0.000	.001	.000	.001
Tail Length	TL (mm)	207.45±3.9	185.42±3.21	163.89±5.56	11.306	0.000	.038	.000	.050
Tail Width	TW (mm)	16.32±0.33	16.3±0.27	14.12±0.23	20.940	0.000	.999	.000	.000
Total Body Length	TBDL (mm)	329.12±5.9	312.89±5.67	264.89±5.84	26.582	0.000	.200	.000	.000

Table 5. Habitat associations of *L. tuberculata* at different study sites

	Site 1: Lower sub-tropical	Site 2: Middle sub-tropical	Site 3: Lower temperate
Plants	**Common name (Botanical name)**	**Common name (Botanical name)**	**Common name (Botanical name)**
Herbs	Wall Lindenbergia (*Lindenbergia muraria*), Wavyleaf Mullein (*Verbascum sinuatum*), Moth Mullein (*Verbascum blattaria*), Diamond Flower (*Oldenlandia corymbosa*), Thornapple (*Datura metel*), Coat Buttons (*Tridax procumbens*), Mexican Tea (*Dysphania ambrosioides*), Wild Teasel (*Dipsacus fullonum*), Switch Sorrel (*Dodonaea viscosa*), Lanceleaf forget-me-not (*Cynoglossum lanceolatum*)	Black-Jack (*Bidens pilosa*), Bengal dayflower (*Commelina benghalensis*), Billygoat Weed (*Ageratum conyzoides*), Creeping Woodsorrel (*Oxalis corniculata*), Asthma Plant (*Euphorbia hirta*), Mexican Fireplant (*Euphorbia heterophylla*)	Black-Jack (*Bidens pilosa*), Mexican Devil (*Eupatorium adenophorum*), Spiny Sowthistle (*Sonchus asper*), Common Dandelion (*Taraxacum officinale*), Bugle (*Ajuga bracteosa*), Horseweed (*Conyza canadensis*), False Mint (*Dicliptera brachiata*), Billygoat Weed (*Ageratum conyzoides*), Annual Fleabane (*Erigeron annuus*), Great Mullein (*Verbascum thapsus*), Creeping Woodsorrel (*Oxalis corniculata*), Asthma Weed (*Conyza bonariensis*), Wall Lindenbergia (*Lindenbergia muraria*), Woolly Leucas (Leucas lanata), Rose Evening Primrose (*Oenothera rosea*), Chaff Flower (*Achyranthes aspera*), Common self-heal (*Prunella vulgaris*), Sowthistles (*Sonchus brachyotus*), Leaf Meadow-Rue (*Thalictrum foliolosum*), Pearly Everlasting (*Anaphalis busua*)
Shrubs	Fire- Flame (*Woodfordia fruticosa*), Giant Milkweed (*Calotropis procera*), Malabar Nut (*Adhatoda vasica*), Indian Squirrel (*Colebrookea oppositifolia*), Tail Yellow (*Cascabela thevetia*), Oleander Clove Basil (*Ocimum gratissimum*)	West Indian Lantana (*Lantana camara*), Fire Flame Bush (*Woodfordia fruticosa*), Small Flowered Poison Sumac *(Searsia parviflora)*	West Indian Lantana *(Lantana camara*), Arrowleaf Dock *(Rumex hastatus*), Sleepy Morning (*Waltheria indica)*, Asian Barberry (*Berberis asiatica*), Fire Flame Bush (*Woodfordia fruticosa*), Himalayan Musk Rose (*Rosa brunonii*)
Grasses	Hairy Cotton grass (*Eriophorum comosum*), Small Carpet grass (*Arthraxon hispidus*), Scutch grass (*Cynodon dactylon*), Fountain grass (*Pennisetum setaceum*)	Small Carpetgrass (*Arthraxon hispidus*), Coco-Grass *(Cyperus rotundus)*, Mauritian Grass (*Apluda mutica*), Scutch grass (*Cynodon dactylon*)	Hairy Cotton grass (*Eriophorum comosum*), Mauritian Grass (*Apluda mutica*), Black Speargrass (*Heteropogon contortus)*, Crow foot grass *(Eleusine Indica)*, Fountain grass (*Pennisetum setaceum*), Small Carpetgrass (*Arthraxon hispidus*), Little Lovegrass *(Eragrotis minor)*, Yellow Foxtail *(Setaria pumila*), Lemon Grass (*Cymbopogon citratus)*
Ferns			Woof Ferns (*Dryopteris*), Maidenhair Fern (*Adiantum*), Longleaf brake *(Pteris longifolia)*
Trees	Sacred Fig. Tree (*Ficus religiosa*), Indian Cedar (*Toona ciliata*), Sal (*Shorea robusta*), Shisham (*Dalbergia sissoo*), Teak (*Tectona grandis*)	Chir pine (*Pinus roxburghii*), Indian Cedar (*Toona ciliata*)	Chir pine (*Pinus roxburghii*), Banjh Oak (*Quercus leucotrichophora)*, Tree Rhododendron (*Rhododendron arboreum*), Bayberry (*Myrica esculenta*), Himalayan Cedar (*Cedrus deodara)*
Habitat Characteristics			Vegetation at 300 - 450 m altitudes around the bank of River Ganga was composed of herbs

such as Wavy Leaf Mullein (*Verbascum sinuatum*), Moth Mullein (*Verbascum blattaria*),Coat Buttons (*Tridax procumbens*), Shrub, Giant Calotrope(*Calotropis gigantea*), Thorn-Apple (*Datura metel*), Malabar nut (*Adhatoda vasica*), in association with grasses such as Hairy Cotton Grass(*Eriophorum comosum*) and Small Carpetgrass (*Arthraxon lanceolatum*). Vegetation at 1000-1200 m asl altitudes along the riverside in the Nagani valley is composed of herbs Mexican Fireplant (*Euphorbia heterophylla*), Black Jack (*Bidens pilosa*), Bengal Dayflower (*Commelina benghalensis*), Creeping Woodsorrel(*Oxalis corniculata*), Billygoat Weed (*Ageratum conyzoides*), Asthma Plant(*Euphorbia hirta*). Habitat type was composed of large rocks alongside the river, manmade walls, and steep rocky slopes along the roadside. Vegetation at 1700 m was composed of herbaceous vegetation such as Horseweed (*Conyza canadensis*), Sow Thistle (*Sonchus arvensis*),Common Dandelion (*Taraxacum officinale*), and Whitewort(*Leucas martinicensis*), shrubs such as West Indian Lantana (*Lantana camara*), Mexican devil (*Eupatorium* adenophorum), Arrowleaf Dock (*Rumex hastatus*), Billygoat Weed (*Ageratum conyzoides*) in association with grasses such as Mauritian Grass(*Apluda mutica*) andHairy Cotton Grass (*Eriophorum comosum*), and *Arthraxon* covering manmade walls and roofs of unoccupied old houses and roadsides rocky substratum. The presence of shrubs Arrowleaf Dock (*Rumex hastatus*), West Indian Lantana (*Lantana camara*), and grass clumps of Hairy Cotton Grass (*Eriophorum comosum*) protect them from predators and also serves as their feeding grounds. Rocks along the roadside were very large and due to vehicular traffic on roads, lizards mostly prefer to live on the highest substratum of rocks, where dominant males were seen to occupy the highest perch position showing their dominance. Sometimes when lizards are crossing roads, they became the victim of road accidents therefore they generally avoid the heavily disturbed area. They are not seen in areas where construction work is going on and they mostly occupy the least disturbed area around human habitations. Their breeding grounds were observed to be different from those of shelter and recorded to be the least disturbed.

Their shelters comprise rock crevices, cavities between larger stones, cliffs, unoccupied old houses, boulders along the roadside, square and round-shaped holes on manmade walls and pipe holes, and sometimes tree trunks also. The species prefers open areas of rocks having steep slopes and larger depressions, fissures on boulders suitable for their survival, and also protect them from predators. Therefore, vegetation covers are very essential for their survival. Lizards feed on insects present in different plant covers. The rocky substratum around the river bank containing rock crevices serves as a suitable microhabitat for agamids. Rock crevices serve as their roosting as well as egg-laying sites. Lizards were observed to feed on the benthic macroinvertebrate communities of the river. The rocky structure contains clumps of grasses Hairy Cotton Grass (*Eriophorum comosum),* Mauritian Grass(*Apluda mutica*), Small Carpetgrass (*Arthraxon lanceolatum*), and also herbaceous plants where different families of the insect live. During the monsoon season, insects increase in larger numbers, and lizards feed on them. The species has been documented preying on a diverse range of insects, indicating
that it plays an important part in prey-predator dynamics. To maintain a constant body temperature lizard, hibernate from mid-December to February end. During the monsoon season and rainy days, lizards retreat into their crevices and show the least activity. During summers when the temperature is very high, they move into shades or in crevices to balance their body temperature.

Conclusion

Laudakia tuberculata also known as Kashmir Rock agama is widely distributed (360-2250 m asl) agamid in Northwestern Himalayan region. The species exhibits sexual dimorphism, male seen as dark blue and female, light blue with brown or light grey. Foraging grounds were seen dominant with Grass clumps of Hairy Cotton Grass which protects them from predators. These agamids prefer rock crevices, cliffs and old abandoned concrete buildings. Morphometric characters i.e., Wt, SVL, HL, HW, FLL, HLL, and TW reveals that morphologically males and females are significantly different. Lizard populations of different altitudes when compared revealed that lizards at temperate region (higher altitude) differed significantly (smaller in size) from the sub-tropical (lower altitude) populations in several morphometric characters such as Wt, SVL, HL, HW, FLL, HLL and TW. Possibly effect of temperature and food resources could be the main reasons for their size differences.

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Conflict of interests

The authors declare that they have no conflict of interest.

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