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HERPETOFAUNA ASSEMBLAGE IN TWO WATERSHED AREAS OF KUMOAN HIMALAYA, UTTARAKHAND, INDIA

Kaleem Ahmed & Jamal A. Khan

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Herpetofauna assemblage in two watershed areas of Kumoan Himalaya, Uttarakhand, India

Kaleem Ahmed¹ & Jamal A. Khan²

^{1,2}Conservation Ecology Research Group, Conservation Monitoring Centre, Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.

¹ kahmed2@myamu.ac.in (corresponding author), ² secretarywsi@gmail.com

Abstract: We surveyed herpetofauna along the poorly-explored region of two watersheds of Kumoan Himalaya, Dabka and Khulgarh. Adaptive cluster method was used to collect forest floor reptiles, and stream transect was used for stream reptiles and amphibians. In total, 18 species of reptiles were recorded in two watersheds, with 15 and nine species recorded in Dabka and Khulgarh, respectively. Forest floor density of reptiles was 87.5/ha in Dabka and 77.7/ha in Khulgarh. In terms of species, *Asymblepharus ladacensis* and *Lygosoma punctatus* density were highest in Dabka and Khulgarh, respectively. Eight species of amphibians were recorded in Dabka with a density of 9.4/ha and four species in Khulgarh with density of 5.2/ha. In both watersheds, density of *Euphlyctis cyanophlyctis* was highest. Reptilian and amphibian diversity of Dabka was 1.52 and 1.23, respectively, and in Khulgarh 0.43 and 0.23, respectively. In both watersheds reptile density, diversity and richness decreased with increasing elevation. Reptile density showed a weak correlation with microhabitat features such as litter cover, litter depth, and soil moisture in both watersheds. Amphibian density was positively correlated with soil moisture, litter cover, and litter depth. Comparison showed that Dabka is richer and more diverse than Khulgarh, presumably because of the undisturbed habitat, broad and slow stream, and deeper forest litter of the former.

Keywords: Amphibians, Dabka, Khulgarh, microhabitat, reptiles, watersheds, western Himalaya.

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Author details: DR. KALEEM AHMED is working as Assistant Professor in the Department of Wildlife Sciences, AMU, Aligarh and engaged in the field of wildlife research from last ten years. DR. JAMAL A. KHAN is a renowned Wildlife Scientist, Professor and Chairman of Department of Wildlife Sciences, AMU, Aligarh.

Author contribution: The data collection, analysis and writing was done by KA under the guidance of JAK. JAK is also the PI of the project under which the present study was conducted.

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INTRODUCTION

Amphibians and reptiles play integral roles in food webs as herbivores, predators and prey, and they also connect aquatic and terrestrial ecosystems (Schenider et al. 2001; Ahmed 2010). Unlike birds and mammals, herpetofauna in India have not been studied in detail (Vasudevan et al. 2001), with most studies restricted to the rainforests of the Western Ghats (Myers 1942; Inger et al. 1984; Vasudevan et al. 2006; Naniwadekar & Vasudevan 2007; Chandramouli & Ganesh 2010; Venugopal 2010; Murali & Raman 2012; Balaji et al. 2014; Bhupathy et al. 2016; Garg & Biju 2017; Chaitanya et al. 2018; Ganesh et al. 2018; Harikrishnan et al. 2018; Malik et al. 2019; Ganesh & Achyuthan 2020) and northeastern India (Ahmed et al. 2009; Das et al. 2009; Chhetri et al. 2010; Purkayastha et al. 2011; Pan et al. 2013; Vogel & Ganesh 2013; Roy et al. 2018). Sporadic studies have described or recorded new species for the western Himalaya (Murthy & Sharma 1976; Saikia et al. 2007; Negi & Banyal 2016; Santra et al. 2019).

Gibbons et al. (2000) enumerated six causes of global decline in herpetofauna: habitat loss and degradation, introduced invasive species, environmental pollution, disease and parasitism, unsustainable use, and global climate change. These causes are present in India where conservation strategies are mostly based on glamorous taxa such as birds and mammals, and thus may neglect smaller and less conspicuous vertebrates such as amphibians and reptiles (Vasudevan et al. 2006). The inclusion of smaller vertebrates in management plans for any particular region is necessary for the overall conservation of biodiversity at local as well as landscape-level (Pawar et al. 2007). Information on the herpetofauna species constellation appears to be largely neglected regionally. Moreover, the information available mostly restricted to some protected areas, and there is a need to study amphibians and reptiles, particularly at watersheds, which are ecological islands of these species.

In the present study, we present and discuss the species composition and abundance of the herpetofauna of the two watershed areas in northern India. The paper investigates species diversity and abundance of reptiles and amphibians in watersheds on mountains in northern India. For the first time ecological and distributional data are provided for the herpetofauna of Kumaon Himalaya, particularly the watersheds. Due to little or no herpetological information in this region, this work can be essential for understanding the ecosystem in this region. The data collected is valuable not only to

assess current biodiversity and abundance scientifically, but also to estimate them in the future, which will aid efficient conservation.

STUDY AREA

The Khulgarh Watershed Area (KWA) lies between 29.575–29.683 °N and 79.537–79.616 °E in Almora District of Kumaon Himalaya, Uttarakhand, northern India (Fig. 1). The area spreads over 32km² and represents middle Shiwaliks. It is situated 15km west of Almora Town and encompasses 34 villages. There are three distinct seasons: summer, winter, and monsoon. The average annual temperature of the watershed is 20°C and the elevation of the area ranges 1,100–2,200 m. The most dominating tree species in the study area was *Pinus roxburghii* both in forested and outside forest areas. Other dominant tree species found in the area were *Quercus incana* and *Lyonia ovalifolia*.

Dabka Watershed Area (DWA) has an area of about 69.06km² and lies between 29.505–29.402 °N and 79.298–79.427 °E in the region of lesser Himalaya in the state of Uttarakhand (Ahmed 2010) (Fig. 1). The climate of the area is cold and temperate with temperate vegetation. The monsoon starts at the end of June and ceases by the middle of September. This area falls in different altitudinal ranges of 500–2,600 m. In the lower elevations of 600–900 m near Kotabagh, the mean annual temperature varies from 18.9°C to 21.1°C with a mean annual rainfall of 2,860.3mm. In the warm temperate zone of 900–1,800 m, the mean annual temperature varies from 13.9 to 18.9°C with mean annual rainfall of 3,623.33mm. In the cold temperate zone of 1,800–2,500 m, the mean annual temperature varies from 10.3 to 13.9°C with an annual rainfall of 1,750mm. DWA is a reserve forest, which is divided into forest ranges, Vinayak and Naina. Most of the study area was located under Vinayak forest range of Kumaon division with dominating *Quercus leucotricophora*, and a few patches of *Pinus roxburghii*, *Taxus baccata*, and *Cedrus deodara* trees are also present. *Rhododendron arborium* trees are common throughout the area because both KWA and DWA were present in similar ecological conditions and KWA has more disturbed habitat than DWA (Ahmed 2010), so, we compared them based on their elevation pattern and disturbance factor.

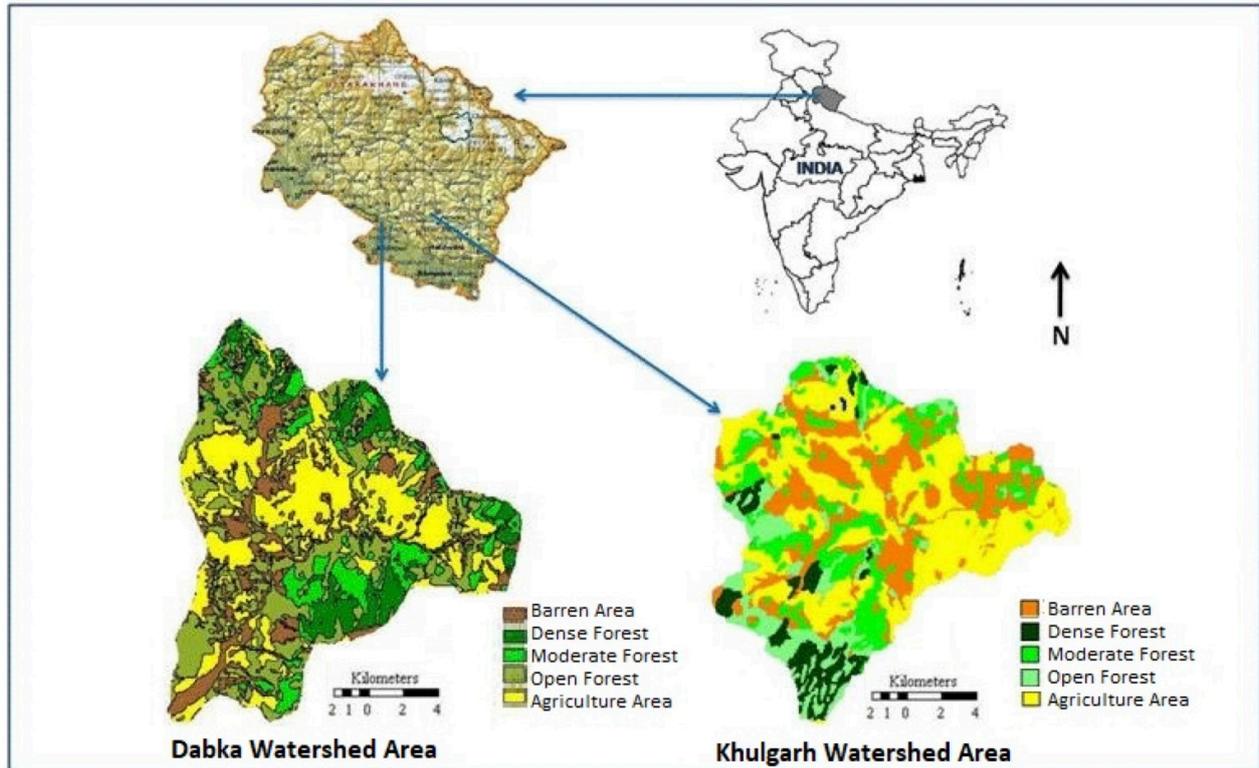


Figure. 1. The location of Dabka and Khulgarh watershed areas.

METHODS

Reptiles were sampled using the adaptive cluster sampling method (Ishwar et al. 2001). The basic sampling unit used was 5m x 5m randomly laid quadrats. If a reptile was sighted in one of these quadrats (hereafter referred to as primary quadrats), additional quadrats (secondary quadrats) of the same dimension were searched on the four sides of the primary quadrat. There was a gap of one meter between the primary and secondary quadrats. If any of these four quadrats had reptiles, further quadrats were laid around them until the quadrat with reptiles was surrounded by the quadrats without reptiles. The whole network of quadrats with reptiles then becomes a cluster. If the primary quadrat did not have any reptile, the sampling was carried out in the next, randomly selected quadrat. In order to minimize the chances of missing animals during search efforts, two observers searched the quadrat from opposite sides towards the center. We also searched study sites opportunistically to confirm the record of species that are rare and may not be recorded by the standard methods. We identified all species whenever possible and released them back into their natural habitats.

In addition to the adaptive cluster sampling method,

three quadrats of 5m x 1,000m along the streams were established. Stream was considered as center of quadrat, and sampling was carried on both sides of the stream simultaneously. Loose rocks and leaf litter was carefully turned, and cavities were prodded for reptilian species. In DWA, 40 permanent quadrats were laid and monitored for two seasons (summer and winter), amounting to 300 quadrats (both primary and secondary). In KWA 30 permanent quadrats were laid amounting to 250 quadrats (both primary and secondary) in two seasons (summer and winter). Data were collected from September 2007 to June 2009 except monsoon for stream transects.

The amphibian community was sampled using the methods described by Vasudeven et al. (2001). Amphibians were sampled using a combination of the adaptive cluster sampling method and visual encounters. Opportunistic records were also maintained. The adaptive sampling was done along streams on the forest floor with the same procedure as reptiles. In DWA 4 streams and in KWA 3 streams transect were established and monitored (Table 3). During monsoon the stream became flooded, therefore, sampling was abandoned. Herpetofauna were surveyed during mid-day as mostly the species come out from their refuge for basking when



the ambient temperature turns warmer (Hill et al. 2005).

Analysis

Data were summarized, and density was calculated for each species. Shannon-Weiner index (H') was used for measuring diversity, and Simpson's diversity index (D) was used for calculating evenness. Margalef's diversity index (RI) was used to measure richness of species on different transects and in different seasons. Pearson's product moment correlation coefficient was used to examine the correlation of reptile and amphibian density with different habitat variables.

RESULTS

Reptiles

Dabka Watershed Area: In DWA, 15 species of reptiles were recorded (Appendix I). Overall reptile density was 87.52 individuals/ha. Overall diversity, richness, and evenness of reptiles were 1.519, 0.932, and 0.759, respectively. Density of reptiles was higher in summer (127/ha) than in winter (50.4/ha). The diversity, richness, and evenness of reptiles were higher in summer than in winter (Table 1). In terms of species, *Asymblepharus ladacensis* density was highest (43.75/ha), followed by *Eutropis carinata* (27.22/ha), *Laudakia tuberculata* (25/ha), *Calotes versicolor* (12.5/ha), and *Eutropis macularia* (12.5/ha).

Khulgarh Watershed Area: In KWA, nine species of reptiles were recorded (Appendix I) with overall density of 77.71/ha. Overall diversity, richness and evenness of reptiles were 1.227, 0.733, and 0.659, respectively. *Lygosoma punctatus* density was highest (110.37/ha), followed by *Eutropis macularia* (35.57/ha), *Laudakia tuberculata* (30.76/ha), and *Calotes versicolor* (10.12/ha). Reptilian density, diversity, richness, and evenness were found to decrease with the increase of elevation in both watersheds (Figs. 2–5). Reptile density showed weak positive correlations with soil moisture in both watersheds (Table 2). Density was positively correlated with litter cover and litter depth weakly to moderately (Table 2).

Amphibians

Dabka Watershed Area: In DWA eight species of amphibians were recorded (Appendix II). Overall, amphibians density was 9.38/ha. Diversity, richness, and evenness were 0.426, 0.674, and 0.278, respectively. In total, 221 individuals were encountered in DWA. In Baghjala transect, 111 individuals contributing to six

Table 1. Diversity, richness, and evenness of reptiles in different seasons in Dabka and Khulgarh watershed areas.

Index	DWA		KWA	
	Winter	Summer	Winter	Summer
Diversity	0.413	0.981	0.213	0.589
Richness	1.325	2.513	1.542	1.653
Evenness	0.931	1.431	0.831	1.00

Table 2. Correlations of reptile density with nine microhabitat variables in Dabka and Khulgarh watershed areas (* $p < 0.01$).

Microhabitat variables	DWA	KWA
Slope	-0.026	0.030
Soil moisture	0.122*	0.160*
Canopy cover	0.018	0.089
Shrub cover	0.085	0.068
Herb cover	0.020	-0.098
Presence of logs	0.414	-0.049
Presence of rocks	0.052	-0.147
Litter cover	0.216*	0.330*
Litter depth	0.318*	0.536*

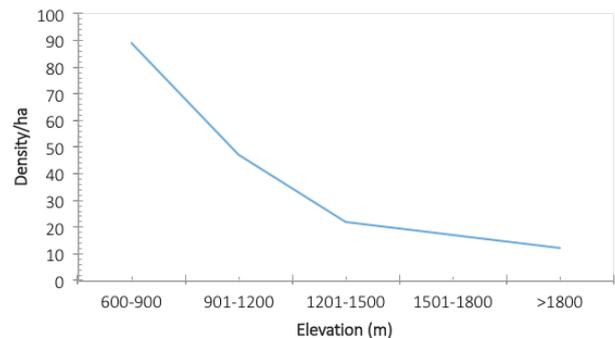


Figure 2. Reptile density along altitudinal gradients in Dabka Watershed Area.

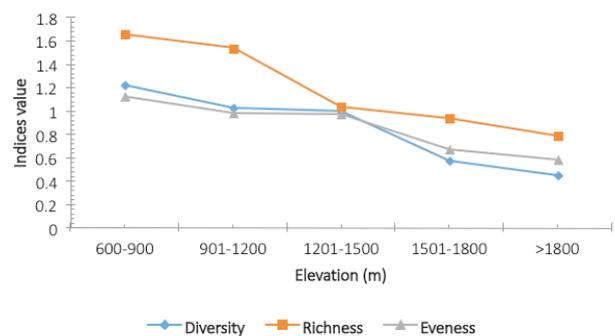


Figure 3. Reptile diversity, richness, and evenness along the altitudinal gradients in Dabka Watershed Area.

Table 3. Density of amphibians (individuals/ha) on different stream transects in Dabka and Khulgarh watershed areas.

DWA		KWA	
Stream Transect		Stream Transect	
Chand	1.21	Sayhedeви	2.43
Mahadav	4.12	Kosi	5.10
Baghjala	22.21	Kovodov	10.22
Gugukhan	3.11		

Table 4. Amphibian density (individuals/ha) in Dabka and Khulgarh watershed areas.

Species	DWA	KWA
<i>Duttaphrynus melanostictus</i>	2.22	0.023
<i>Duttaphrynus himalayanus</i>	1.11	1.04
<i>Euphlyctis cyanophlyctis</i>	23.34	11.23
<i>Hoplobatrachus tigerinus</i>	0.24	-
<i>Hoplobatrachus crassus</i>	1.21	-
<i>Nanorana liebigii</i>	2.23	0.87
<i>Limnonectes limnocharis</i>	0.91	-
<i>Amolops marmoratus</i>	10.22	-

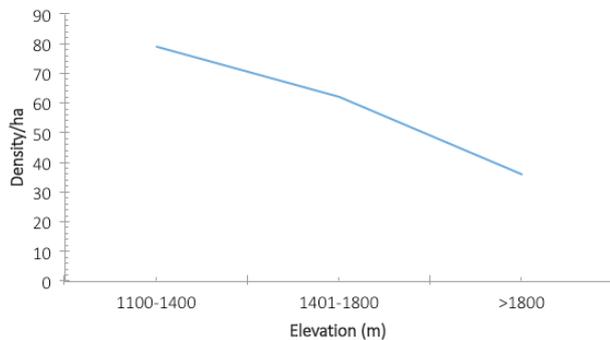


Figure 4. Reptiles density along altitudinal gradients in Khulgarh Watershed Area.

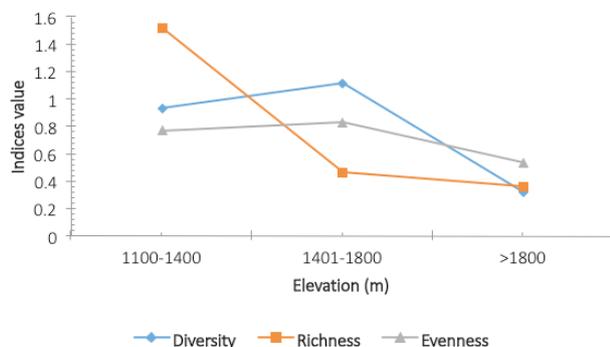


Figure 5. Reptiles diversity, richness, and evenness along altitudinal gradients in Khulgarh Watershed Area.

Table 5. Correlations of amphibian density with nine microhabitat variables in Dabka and Khulgarh watershed areas (*p<0.01).

Habitat variables	DWA	KWA
Slope	0.019	-0.360
Soil moisture	0.621*	0.485*
Canopy cover	-0.077	-0.015
Shrub cover	0.175	0.149
Herb cover	-0.067	-0.044
Presence of logs	-0.061	0.061
Presence of rocks	0.017	0.061
Litter cover	0.170*	0.299*
Litter depth	0.202*	0.316*

species were encountered with a density of 22.21/ha, followed by 61 individuals of three species in Mahadav, 29 individuals of two species in Gugukhan, and 20 individuals of two species in Chand transect (Table 3). In terms of species, the density of *Euphlyctis cyanophlyctis* was found highest (23.34/ha), followed by *Amolops marmoratus* (10.22/ha) and *Duttaphrynus melanostictus* (2.22/ha) (Table 4).

Khulgarh Watershed Area: Four species of amphibians were recorded in KWA, which were also present in DWA. Overall amphibian density was 5.23/ha. Diversity, richness, and evenness were 0.234, 0.174, and 0.025, respectively. Density in Kovodov transect was found highest (10.22/ha), followed by Kosi (5.10/ha) (Table 3). In terms of species, overall density of *Euphlyctis cyanophlyctis* was found highest (11.23/ha), followed by *Duttaphrynus himalayanus* (1.04/ha) (Table 4).

A total of 151 individuals were encountered in KWA. Of these 84 individuals of three species were encountered in Kovodov transect, followed by 36 individuals of two species in Kosi transect and 31 individuals of two species in Sayhedeви transect.

Amphibian density showed weak positive correlations with litter cover and litter depth in both watersheds (Table 5). Amphibian density had moderate to relatively high positive correlations with soil moisture in both watersheds (Table 5).

DISCUSSION

Reptiles

The overall reptilian density in DWA and KWA was 87.5/ha and 77.7/ha, respectively, during the entire study period. These values are much lower than 154/ha



recorded in Panama (Inger 1980) and 108/ha recorded in KMTR in Western Ghats (Kumar et al. 2001), but they are similar to the 66.5/ha recorded in the Garhwal Himalaya (Dar et al. 2008). The higher density recorded in Panama and the Western Ghats can be attributed to these studies being conducted in tropical rainforests, whereas the present study was conducted in subtropical areas of the Himalaya. Kumar et al. (2001) reported 54 species from KMTR, and Inger et al. (1984) and Dar et al. (2008) reported 33 and 10 species, respectively, in Garhwal Himalaya. In our study, 15 species were recorded. Fewer species in the two watersheds may be due to small study sites located in sub-tropical areas of Kumaon Himalayas (Dar et al. 2008)

In both DWA and KWA, the density of reptiles was higher in summer than in winter. Lower density in winter may be due to harsh climatic conditions in both sites, however, the high density in summer may be also due to high density of non-snake reptiles including geckos and agamids (Dar et al. 2008). There were some differences in abundance in both watersheds. Overall, a higher number of species was recorded in DWA with more diversity and richness than KWA. This may reflect the general topographical condition of DWA starting from 500 to 2,600 m, thus representing the species of both lower and higher altitudes. Skinks and agamids formed dominant groups in both watersheds. Snakes were more abundant in DWA than in KWA, but contributed to a small portion of forest floor reptiles in both sites. Low abundance of snakes could be due to their secretive nature, and thus they escape detection during sampling (Ahmed 2010).

Change in reptilian abundance along altitudinal gradients has been documented in previous studies (Fauth et al. 1989; Bhupathy & Kannan 1997; Dar et al. 2008; Chettri et al. 2010; Gautam et al. 2020). The results of both the study sites showed a decline in density with altitude. Porter (1972) believes that this might be primarily due to the decline in temperature. Atmospheric temperature is considered as dominant factor for the elevational zonation of life in Himalaya (Mani 1974) and terrestrial reptiles respond more strongly to temperature than moisture (Hofer et al. 1999). It seems logical because reptiles are ectothermic, and thus, temperature plays a vital role in their ecology.

Reptile density showed a positive correlation with leaf litter cover, litter depth, and soil moisture. This was particularly demonstrated by skinks and agamids. There was also a preference for certain structural diversity in the ground vegetation characters. This association of geckos, skinks has already been shown by Kumar et

al. (2001) and Dar et al. (2008). Agamids, which were dominated by *Calotes*, preferred more rocky and open canopy than skinks. The specific habitat features are essential for leaf litter reptiles as they can meet the conflicting demands of thermoregulation, predator avoidance, and participation in other activities (Lima & Dill 1990). It might also be possible that a cool and humid environment below litter provides good microclimatic conditions for arthropods, which are major prey animals for the forest floor reptiles (Kumar et al. 2001). Because snakes are predatory in nature, their local distribution might be influenced by the distribution of their prey abundance such as lizards and frogs (Dar et al. 2008).

Amphibians

Amphibian density in both areas showed positive correlations with litter cover and litter depth. Deep litter may provide a wider range of microhabitat, allowing more individuals and species to coexist in the litter microhabitat (Fauth et al. 1989), or provide refuge from predation (Lieberman 1986). Lieberman & Dock (1982) argued that litter may sustain large arthropod prey population. Block & Morrison (1998) found that litter depth is an important factor in habitat selection in amphibians and reptiles. In addition, various biotic and abiotic factors are also reported to influence the distributions of amphibians. Anuran activity temperature can also be predicted accurately from environmental temperature; therefore, ambient temperature is a crucial factor that limits their distribution (Navas 2003). In the present study, amphibian density showed a positive correlation with soil moisture in both watersheds. Naniwadekar & Vasedevan (2007) also found that Increase in soil moisture and decrease in soil temperature were associated with increase in amphibian species richness. This correlation is reasonable because amphibians have soft skin and are sensitive to temperature and precipitation, and thus prefer moist habitat. Moreover, Khatiwada et al. (2019) found among all the environmental variables, elevation, surface area and humidity were the best predictors of species richness, abundance and composition of amphibians, and high elevations in the tropics are also characterized by greater soil moisture and abundant perennial running or stagnant water that provides suitable microhabitats for anurans (Navas 2003).

Baghjalla in DWA and Sayadevi in KWA were found with the highest density of amphibians. It might be due to the presence of water till late winter, less rocky and width of the stream (Kaleem Ahmed personal observation). In addition to these, streams were wide as compared to others, as a result, slowing the flow

and creating stagnant pools for species like *Euphylyctis cyanophlyctis* to flourish. The low density of amphibians was recorded in Kosi and Sayadevi streams in KWA and Gugukhan and Mahadav streams in DWA. These streams were perennial but quite deep, and amphibians like water seem to avoid deep water (Dar et al. 2008). Hecnar & M'Closkey (1998) also found a negative correlation of amphibian density with water depth. Low density in Chand stream may be due to the fast flow of the water; amphibians are known to avoid fast-flowing streams (Dar et al. 2008).

Higher density and diversity of amphibians in DWA than in KWA might be due to the general topography of the area starting from 550 to 2,600 m, representing the species of both Himalayan foothills as well as middle Himalaya. Another reason may be fewer disturbances and the larger area of DWA (69.06km²) compared to KWA (32km²). Overall, it is concluded that DWA is more diverse and richer in reptiles and amphibians than KWA. This study indicates that watersheds of Kumaon Himalaya is rich in herpetofaunal diversity, which decreases along the elevation gradients. This is because they can provide suitable habitats for herpetofauna (i.e., more humidity and food). Moreover, unequal distribution of different habitat types (more forested area and less barren and agriculture area in DWA as compared to KWA) may provide herpetofauna suitable habitat to flourish more in DWA. Overall, our results could provide important baseline information to design effective conservation and management strategies in the future.

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Appendix I. List of reptile species recorded in Dabka and Khulgarh watershed areas (P—present | A—absent).

Taxa	DWA	KWA
Family: Gekkonidae Gray, 1825		
<i>Hemidactylus flaviviridis</i> Rüppell, 1835	P	A
Family: Agamidae Gray, 1827		
<i>Calotes versicolor</i> (Daudin, 1802)	P	P
<i>Laudakia tuberculata</i> (Gray, 1827)	P	P
<i>Psammophilus dorsalis</i> (Gray, 1831)	A	P
Family: Scincidae Gray, 1825		
<i>Asymblespharus ladacensis</i> (Günther, 1864)	P	A
<i>Eutropis macularia</i> (Blyth, 1853)	P	P
<i>Eutropis carinata</i> (Schneider, 1801)	P	A
<i>Lygosoma punctata</i> (Gmelin, 1799)	A	P
Family: Colubridae Opperl, 1811		
<i>Ahaetulla nasuta</i> (Lacépède, 1789))	P	A
<i>Boiga trigonata</i> (Schneider in Bechstein, 1802)	P	A
<i>Coelognathus Helena</i> (Daudin, 1803)	P	A
<i>Ptyas mucosa</i> (Linnaeus, 1758)	A	P
Family: Natricidae Bonaparte, 1838		
<i>Amphiesma stotatum</i> (Linnaeus, 1758)		
Family: Elapidae Boie, 1827		
<i>Naja naja</i> (Linnaeus, 1758)	P	P
<i>Bungarus caeruleus</i> (Schneider, 1801)	P	P
Family: Pythonidae Fitzinger, 1826		
<i>Python molurus</i> (Linnaeus, 1758)	P	A
Family: Viperidae Opperl, 1811		
<i>Daboia russelii</i> (Shaw & Nodder, 1797)	P	P
<i>Gloydius himalayanus</i> (Günther, 1864)	P	A

Appendix II. List of amphibian species recorded in Dabka and Khulgarh watershed areas (P—present | A—absent)

Taxa	DWA	KWA
Family: Bufonidae Gray, 1825		
<i>Duttaphrynus melanostictus</i> (Schneider, 1799)	P	P
<i>Duttaphrynus himalayanus</i> (Günther, 1864)	P	P
Family: Dicroglossidae Anderson, 1871		
<i>Euphlyctis cyanophlyctis</i> (Schneider, 1799)	P	P
<i>Limnonectes limnocharis</i> (Gravenhorst, 1829)	P	A
<i>Hoplobatrachus crassus</i> (Jerdon, 1854)	P	A
<i>Hoplobatrachus tigerinus</i> (Daudin, 1802)	P	P
<i>Nanorana liebighii</i> (Günther, 1860)	P	A
Family: Ranidae Rafinesque, 1814		
<i>Amolops marmoratus</i> (Blyth, 1855)	P	A





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