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Research paper

Distribution and habitat suitability of species *Altiphylax stoliczkai* (Steindachner), Baltistan gecko, or Karakorum gecko of Ladakh.

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Abstract: The distribution of saurian species in Ladakh is not documented extensively compared to mammals and avian species. Four specimens of *Altiphylax stoliczkai* (Steindachner), Baltistan gecko, or Karakorum gecko, a species endemic to South Asia were reported from Ganglaas, Leh, Ladakh. The locality of the species is new for the species. The habitat of the species was described based on observation during surveys. Habitat suitability was also determined for the area other than the area surveyed by using Maxent software, which is based on the maximum-entropy approach for modeling species niches and distributions. Since the region is ecologically very sensitive and fragile, thus for conservation of species special strategies need to be adopted, hence described. This study is a first step in updating the databases of the species and its habitat in Ladakh, the Union Territory of India with the goal to make scientific biodiversity data available for the species for use in conservation of the species.

Keywords: Ladakh, sauria, habitat, conservation

Introduction:

Bohm *et al.* 2013, Cox and Temple 2009 and Gibbons *et al.* 2000 noted the decline of reptiles influenced by a variety of threats such as habitat loss, degradation and fragmentation, pet trade, invasive species, pollution, diseases and climate change. Thus there is an urgent need to take necessary steps for their conservation as mentioned by Gibbons *et al.* in 2000. Bohm *et al*. 2013 noted that nearly one of five reptilian species are threatened with extinction and one of five classified as Data Deficient. It was also noted by Primack in 2010 that data of population of reptilian species is lacking globally for their conservation, which could be utilized for the conservation of the species of reptiles. The

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present study focuses on the distribution of saurian species *Altiphylax stoliczkai* (Steindachner), Baltistan gecko, or Karakorum gecko, in Ladakh "the land of high mountain passes" which is situated in the northwestern part of India, on the slopes of the Great Himalayas. Ladakh is the highest altitude plateau region in India (much of it being over 3,000 m), incorporating parts of the Himalayan and Karakoram mountain ranges and the upper Indus River valley. The species is endemic to South Asia. The flora and fauna of Ladakh was first studied by Ferdinand Stoliczka, an Austrian Czechpeople Czechpaleontologist, who carried out a massive expedition in the region in the 1870s. The fauna of Ladakh have much in common with that of Central Asia generally and especially those of the Tibetan Plateau. An exception to this is the birds, many of which migrate from the warmer parts of India to spend the summer in Ladakh (Khan 2015,Pfister2004, https://en.wikipedia.org/wiki/Wildlife_of_Ladakh). But very few information is available about the distribution of lizards and their habitat in the area. The study is based on the survey conducted by in from 10th August to 24th August 2019. The study on the distribution and morphometry of the species was published along with distribution of other saurian species by Bahuguna *et.al.* in 2024.GIS tools were used to prepare the distribution map and habitat suitability maps of the species of lizards.

Material and Methods:

Many specimens of the species were sighted based on extensive survey of Ladakh (from 10th August to 24th August 2019) from Gangalaas , Leh near stream. Most of them were present under stone. Habitat of the species of lizards from Ladakh was also examined during extensive survey of 15 days (from 10th August to 24th August 2019). Habitat suitability test was done using MaxEnt (Phillips *et al.*, 2006) software. Species distribution models (SDMs) are basically used to assess the relationship between species locations at study area and the environmental and/or spatial characteristics of that particular study area (Elith *et al.*, 2010). They are implemented for studies in the field of biogeography, conservation biology and ecology (Elith *et al.*, 2010). The published literatures were also used for getting the information of other localities not covered by us during present survey. Maxent software is based on the maximum-entropy approach for modeling species niches and distributions. The model provides an output as a probability distribution where each grid cell has a predicted suitability of conditions for the species by using a set of environmental (e.g., climatic) grids and georeferenced occurrence points. Figure 1 indicates Flowchart depicting methodology for habitat suitability modeling. Data sources and layers used for the preparation of the layers for habitat suitability of the species includes SRTM DEM (USGS Earth Explorer) and Bioclimatic variables (WorldClim-www.worldclim.org). The bioclimatic variables for prediction of the future habitat were also used for modeling.
The layers that were used in the suitability modeling included:

- Sample layer (presence data/occurrence data)
- Elevation
- Slope
- BIO1 = Annual Mean Temperature
- BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
- BIO3 = Isothermality (BIO2/BIO7) (×100)

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- BIO4 = Temperature Seasonality (standard deviation ×100)
- BIO5 = Max Temperature of Warmest Month
- BIO6 = Min Temperature of Coldest Month
- BIO7 = Temperature Annual Range (BIO5-BIO6)
- BIO8 = Mean Temperature of Wettest Quarter
- BIO9 = Mean Temperature of Driest Quarter
- BIO10 = Mean Temperature of Warmest Quarter
- BIO11 = Mean Temperature of Coldest Quarter
- BIO12 = Annual Precipitation
- BIO13 = Precipitation of Wettest Month
- BIO14 = Precipitation of Driest Month
- BIO15 = Precipitation Seasonality (Coefficient of Variation)
- BIO16 = Precipitation of Wettest Quarter
- BIO17 = Precipitation of Driest Quarter
- BIO18 = Precipitation of Warmest Quarter
- BIO19 = Precipitation of Coldest Quarter

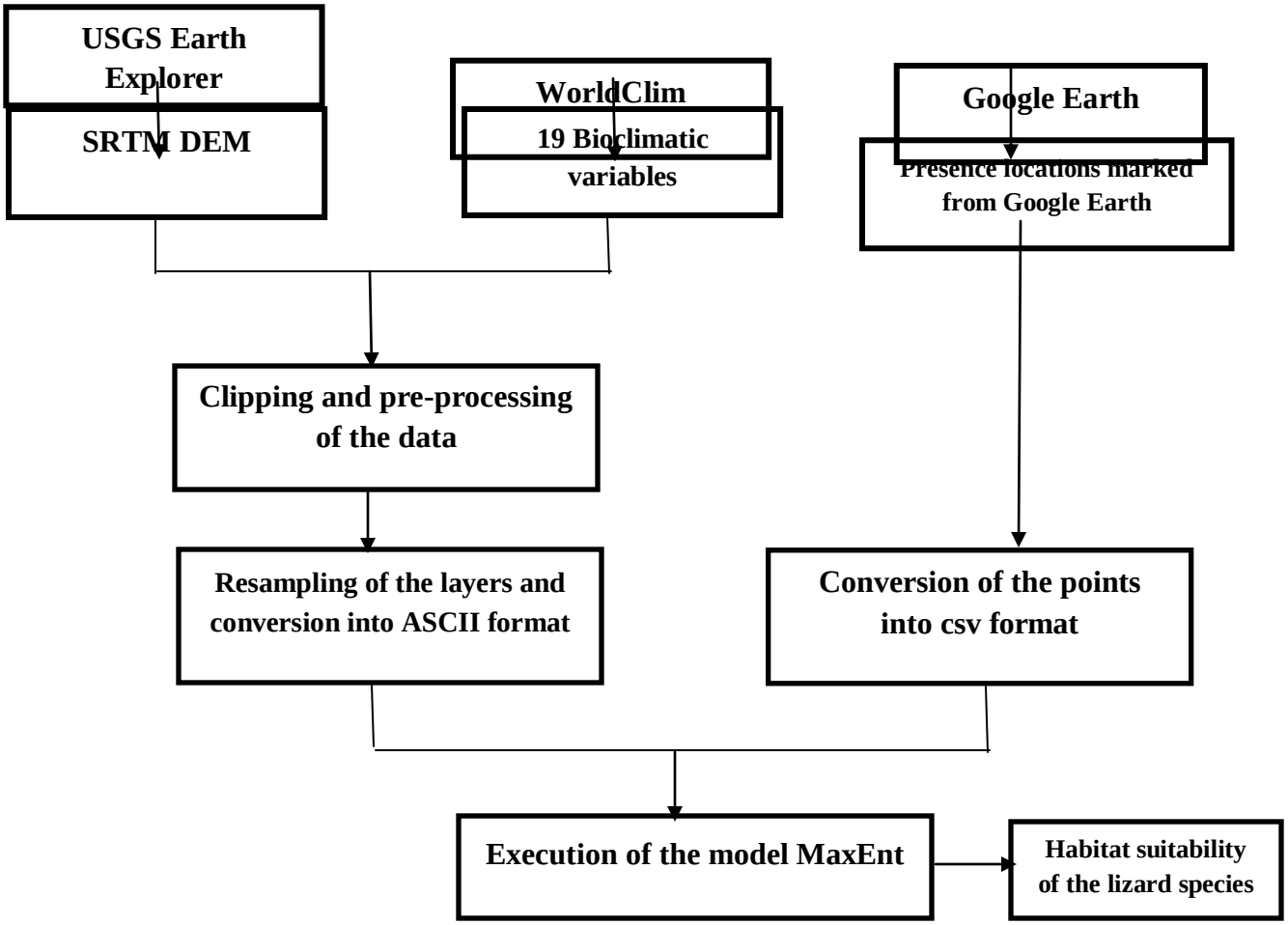

Figure 1. Flowchart depicting methodology for habitat suitability modeling

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In the modeling, all the nineteen bioclimatic variables were used for habitat suitability. The resolution of each of the bioclimatic variables used were 30s (i.e., 1 km). Future prediction of the habitat for the species was also done. Future and past climate are often data produced with Global Climate Models, also known as General Circulation Models (WorldClim). There is number of different GCMs, and each of them provide different results (WorldClim). The weather replicated by these models particularly depends in part on the assumption of the atmospheric concentration of greenhouse gasses (WorldClim). "Emission scenarios" are often used to define projected future atmospheric concentrations of greenhouse gasses (WorldClim). Thus, weather projected for a given period in the future depends on the climate model and the emission scenario used in the study, as well on the model run (WorldClim). The resolution for the climatic variables used for the time period 2021-2040 is 2.5 minutes. Climate models are distinctive tools to examine the characteristics and behavior of the climate system (Boucher et al., 2020). The climate models and their components are developed progressively over the years, the sixth phase of the Coupled Model Intercomparison Project (CMIP6) acted as an opportunity for the Institut Pierre-Simon Laplace for developing, testing, and evaluating a unique configuration of its climate model, which is called IPSL-CM6A-LR (Boucher et al., 2020).The IPSL-CM6A-LR model performance has pointedly improved over IPSL-CM5A-LR and IPSL-CM5A-MR and compares well with other published CMIP6 models for a number of metricsused to analyse efficiency of the model (Boucher et al., 2020). Multi-collinearity has been reduced among the 19 bioclimatic variables and highly correlated variables ($r \geq 0.85$ Pearson correlation coefficient) were removed from further models (Qin *et al*., 2017).

Results and Discussion:

The species *Altiphylax stoliczkai* (Steindachner),frontier bow-fingered gecko, Baltistan gecko, or Karakorum gecko was collected from Ganglas (Figs. 9-11), GPS co-ordinates N 34.20247; E 77.61617 Alt : 3906 m asl, temp 17.1 C, humidity 19%).Ganglas is a village between Leh and South Pullu. (registration no of three specimens of the species HARC-ZSI /R ZSI256, Fig 9). Ladakh is situated in northwestern Indian subcontinent, administratively, as Ladakh Union Territory (until October 31, 2019, part of Jammu and Kashmir state). Ladakh covers about 45,000 square miles (117,000 square km) and constitutes Ladakh Range, which is a southeastern extension of the Karakoram range and the upper Indus river valley. Ladakh is one of the highest regions of the world. Its natural features consist mainly of high plains and deep valleys.The climate of Ladakh is cold and dry. Average annual precipitation is roughly 3 inches (80 mm); fine, dry, flaked snow is frequent and sometimes falls heavily. Vegetation is confined to valleys and in sheltered spots. Ladakh is one of those places where climate change is more evident than elsewhere (Gray *et al.* 2013).

The existence of the habitat of the species *Altiphylax stoliczkai* (Steindachner), reported in the present study depends on the climatic condition of the area since the study by Chevuturi *et al.* 2018 shows that the climate over Leh has a warming trend with reduced precipitation in the current decade. The reduced average seasonal precipitation might also be associated with some indications of reducing number of days with higher precipitation amounts over the region. The genus is endemic to Central

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Asia. The collection was done undertone near to the stream. The area was surrounded by the village with backyard farming. It has lush green agriculture field along with huge plantation of popular trees. Several streams pass through the village, providing sufficient water for irrigation This habitat of *Altiphylax stoliczkai* (Steindachner) is very fragile and sensitive to climate condition of the area as this is the only green patch present in Ganglas and area around it has a grass land with fragmented habitat because of road construction. Thus in future for conservation of this species special strategies need to be adopted and also awareness programmes also need to be initiated for the villagers and local people of Ganglas so that the habitat of the species will be maintained and conserved. The species is endemic to South Asia.

The preliminary species distribution maps (Fig.1) provided in this study allow, nevertheless, for further analysis on distribution patterns of abundance, rarity, richness and assemblage composition at larger spatial scales (Elith *et al*.2010). As it is evident from the habitat suitability maps (Fig 2) for the species, the lizard species mainly favor rocky terrain with surrounding grass and scrub lands, vegetated slopes, near cultivated areas. Species distribution modeling has proved to emphasize on the point that bioclimatic models are useful in predicting distribution of amphibians and reptiles because of their ectothermic nature (Nasrabady *et al.* 2016). In this study, the percent contribution of the variables slope, BIO15, BIO18 and BIO9 showed the maximum percent contribution (Table 2, Figs 5, 6). The altitude as well as humidity has some remarkable influence on clinal change in certain morphological and physiological characters of lizard species (Borkin *et al.* 2018). The species have found to inhabit areas such as stones on roadsides, in villages and at the forest edges (Borkin et al. 2018). Precipitation increases the vernation of grass and these species are often found in grassland and shrubby vegetation near streams. It seems that seasonal rains cause increased growth and the presence of grass and other plants in habitat will eventually turn out to be the reason to stay safe from competitors and predators (Nasrabady*et al.* 2016).The regions that have high suitability are those that have all ecological requirements, like precipitation which is important for feeding and temperature that is important for basking and capturing energy (Sanchooli. 2016). This can be correlated with the results obtained as BIO9 which is variable for mean temperature in the driest quarter and BIO18 which is the variable of precipitation of warmest quarter also have shown significant percentage of contribution in the analysis. Also, moisture climate has a direct impact on the growth of plants and that eventually leads to increase in the insect prey density. The results for the jackknife test of variable importance depicts that the environmental variable with highest gain when used in isolation is slope, which therefore appears to have the most useful information by itself (Tables 1). The environmental variable that decreases the gain the most when it is omitted is slope, which therefore appears to have the most information that isn't present in the other variables. The prediction of the habitat suitable in future for the lizard species was also modeled using MaxEnt. Some important locations that was found to be suitable in the study area other than the areas already explored, included Hemis National Park, Tungri, Hamiling, Akshu, Naltar valley, Deosai Park, Harong, Merak, Sasakul, Erad and many other places as well. The percent contribution of the variables slope, BIO15, BIO9, BIO1 and

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BIO17 showed the maximum percent contribution in future prediction (Tables 2, Figs 7,8). It is evident from the results that again temperature, precipitation and altitude have shown remarkable influence in future prediction of the habitat. The map for the future prediction also shows some important locations that needs to be looked upon when conservation of the habitat comes into play. Also, the AUC value for the future prediction is 0.90 and value above 0.70 indicate good fit for the model (Fig6).

The distribution data are also valuable for conservation planning and modeling species distribution at regional and global level (Sillero *et al.* 2005). As already mentioned the decline of reptiles has been influenced by a variety of threats such as habitat loss, degradation, fragmentation, pet trade, invasive species, pollution, diseases and climate change (Bohm *et al.* 2013, Cox and Temple 2009, Gibbons *et al.*2000) and Ladakh has very fragile ecosystem, thus special attention need to be given for restoring and maintaining the ecosystem of the area hence the habitat of lizards.

Conservation strategies for the species:

More data of population of reptilian species is required for their conservation and also the information of the potential impacts caused by human activities in the region due to tourism and road construction and also due to climate change. The rapid development of a road network, to provide access to all main settlements within the region, has come with an environmental cost mainly for the areas of high natural value. It is estimated that some 11 tons of wood are used for each kilometre of road being constructed in the Himalaya (Burman 1990). Most comes from local sources and is used for asphalt production and for cooking and heating by construction workers. These laborers live on the construction site and use the resources of the land. Tree and bush cutting as well as wildlife poaching are thus common problems around such sites. Impacts particularly severe in fragile and biodiversity rich areas like wetlands, riverine shrub land and areas of juniper forest where destruction of natural woodland and wildlife population decline have been reported. (Fox, 1994, Humbert-Droz, 2001). These losses have been partly offset by plantation by private land owners and the Forest Department and wood production appears to have increased in the past decades especially in the Indus Valley. Still, such plantations comprising mostly of exotic willows and poplars, do not seem to have reduced biomass extraction in natural woodlands or shrub land and are actually often developed at their expense. Neither do they harbour the varied flora and fauna typical of natural woodlands (Ahmed 2002). According to the study done by Thayyen of India's National Institute of Hydrology that winter temperatures are rising and glaciers are losing mass adding to the evidence that global warming is disturbing water cycles on the roof of the world, and that too in an unpredictable ways. Snow cover is shrinking, glaciers are melting, the monsoon season changing and permafrost is at risk, all with drastic consequences for a region whose ice fields hold the largest freshwater reserves outside the poles (http://www.bloomberg.com/features/2020-indus-river/).The Nubra valley was once a part of the ancient Silk Road trading route that connected Asia with Persia and Europe. Now it's a staging post in the inexorable advance of climate change. Nubra and Shyok rivers both of which feed the Indus are having flash floods almost every year for the past decade and this pattern will accelerate in future. A study published by Columbia University's Lamont Doherty Earth Observatory reported that Himalayan

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glaciers melted twice as quickly in 2000 2016 as they did from 1975 to 2000 (http://www.bloomberg.com/features/2020-indus-river/). It indicates that the habitat of the lizards dwelling in this region particularly in Nyoma, Indus valley area are under threat. Thus, more awareness programmes need to be initiated for the region alongwith the control and regulation of tourists and their vehicles. All nearby places of Ladakh like Himachal Pradesh and Jammu & Kashmir have to control and regulate vehicles numbers. Afforestation programs need to be strongly implemented in Himachal Pradesh and Jammu & Kashmir to keep the temperature under control.

Conclusion:

The distribution maps presented in this paper provide visualized occurrence records to fill a gap in the knowledge of biodiversity of saurians in Ladakh, the Union Territory of India and will help the prioritization of conservation efforts and the identification of important conservation areas for lizards. *Altiphylax stoliczkai* (Steindachner), frontier bow-fingered gecko, Baltistan gecko, or Karakorum gecko was collected from Ganglas. The habitat that are mapped to be suitable for the species harbors some of the ideal conditions favorable for them. Such ideal habitats include vegetated slopes, grasslands and scrublands, rocky terrain. The study could provide better understanding of the ecological requirements of the lizard species and can be correlated with data regarding habitat and threats to develop strategies for management and conservation of these habitat that are found to be suitable through the study. This could provide an insight into the importance of the fragile habitat of Ladakh that is very sensitive. The presence of these species even enhances the significance of such landscapes and eventually would lead to conduction of further studies on lizard species that are often focused less compared to species like Snow Leopard, wild ungulates etc. This study is a first step in updating the databases of lizards and habitat of Ladakh, the Union Territory of India with the goal to make scientific biodiversity data available and useful for the international community. Special efforts need to be done by policy makers for effective conservation strategies for flora and fauna.

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Table 1. The percent contribution of variables that showed significant impact on suitability analysis

S.NO	VARIABLE	PERCENT CONTRIBUTION
1.	Slope	42.8
2.	BIO15 (Precipitation Seasonality) (Coefficient of Variation)	24.8
3.	BIO9 (Mean Temperature of Driest Quarter)	18.2
4.	BIO18 (Precipitation of Warmest Quarter)	7.1

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Table 2. The percent contribution of variables that showed significant impact on suitability analysis-for future prediction

S.NO	VARIABLE	PERCENT CONTRIBUTION
1.	Slope	55.7
2.	BIO15 (Precipitation Seasonality) (Coefficient of Variation)	26.7
3.	BIO9 (Mean Temperature of Driest Quarter)	12
4.	BIO1(Annual Mean Temperature)	2.8
5.	BIO17(Precipitation of Driest Quarter)	2.7

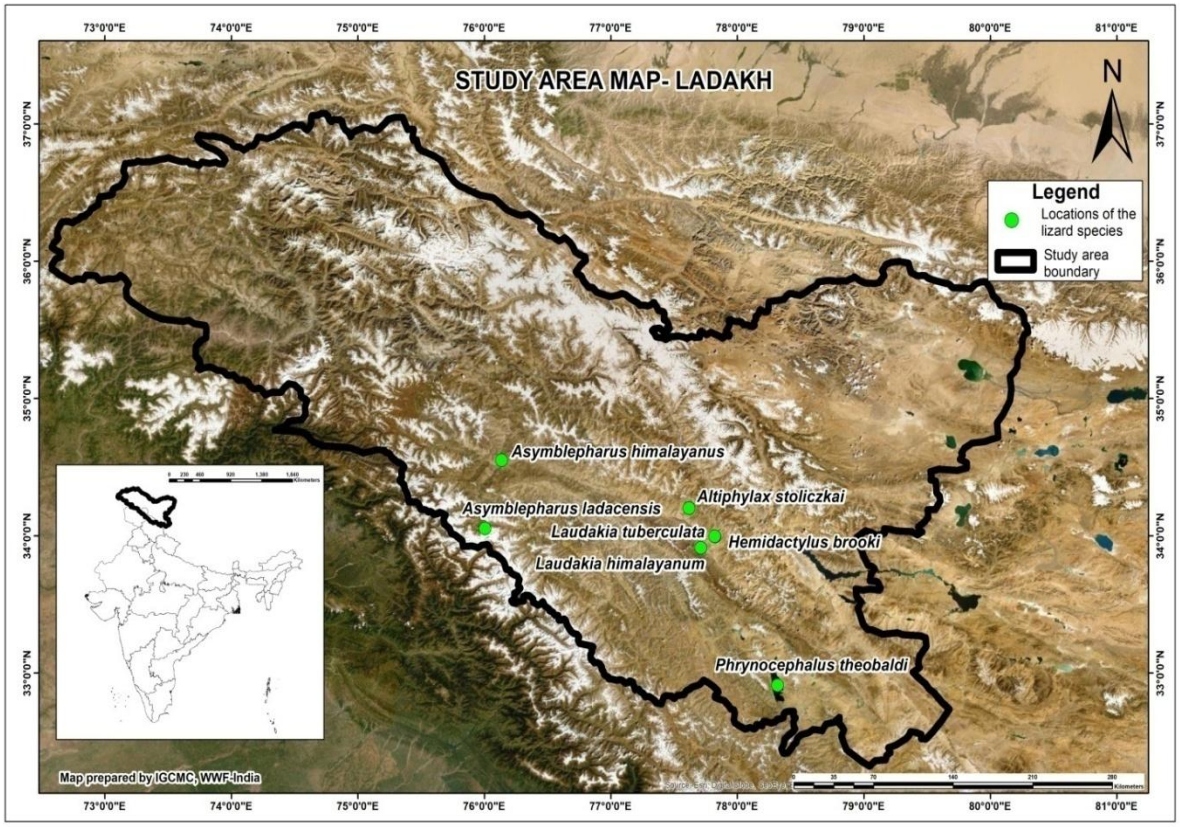

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Figure 1. Study area map showing the locations of the species of lizards in Ladakh

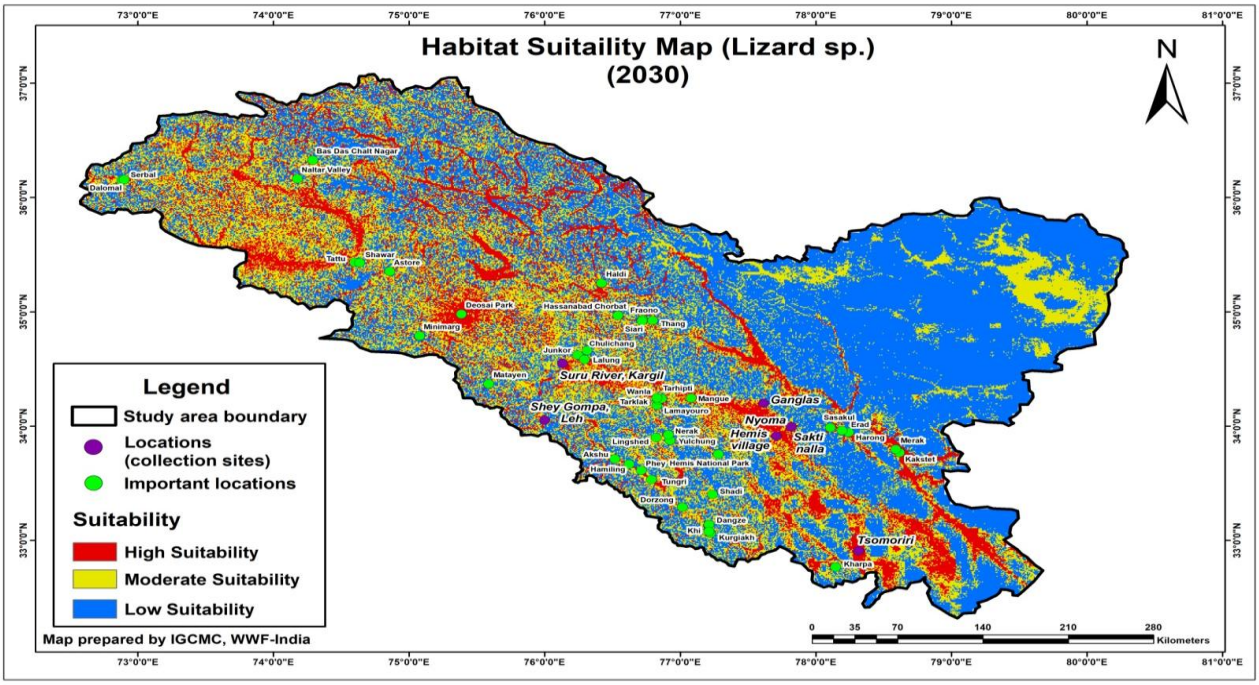

Figure 2. Habitat suitability map depicting the predicted suitable habitat in future for the lizard species

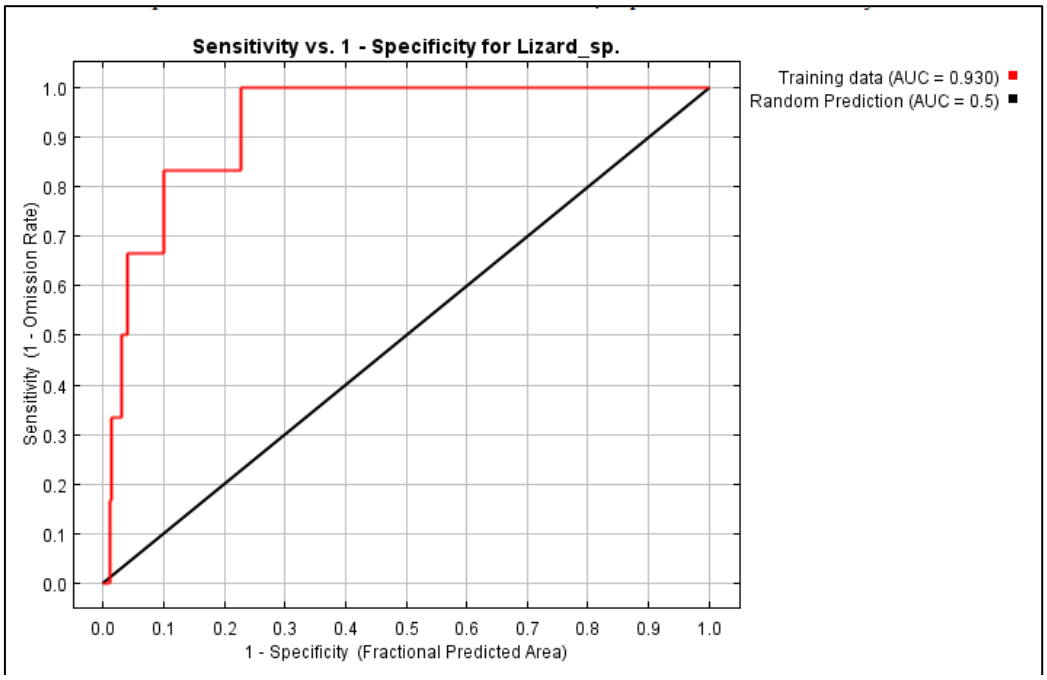

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Figure 3. showing ROC Curve (Receiver Operating Characteristic)

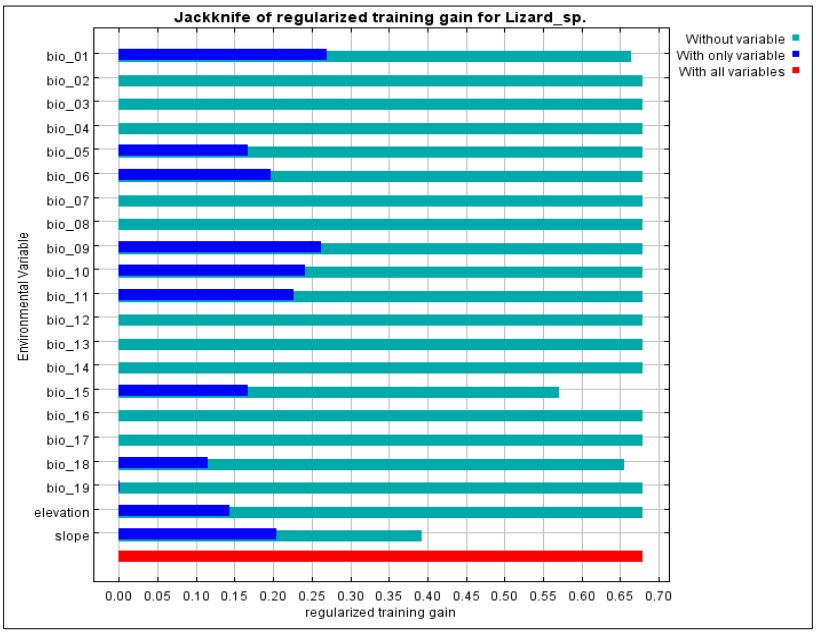

Figure 4. The figure shows the results of the jackknife test of variable importance

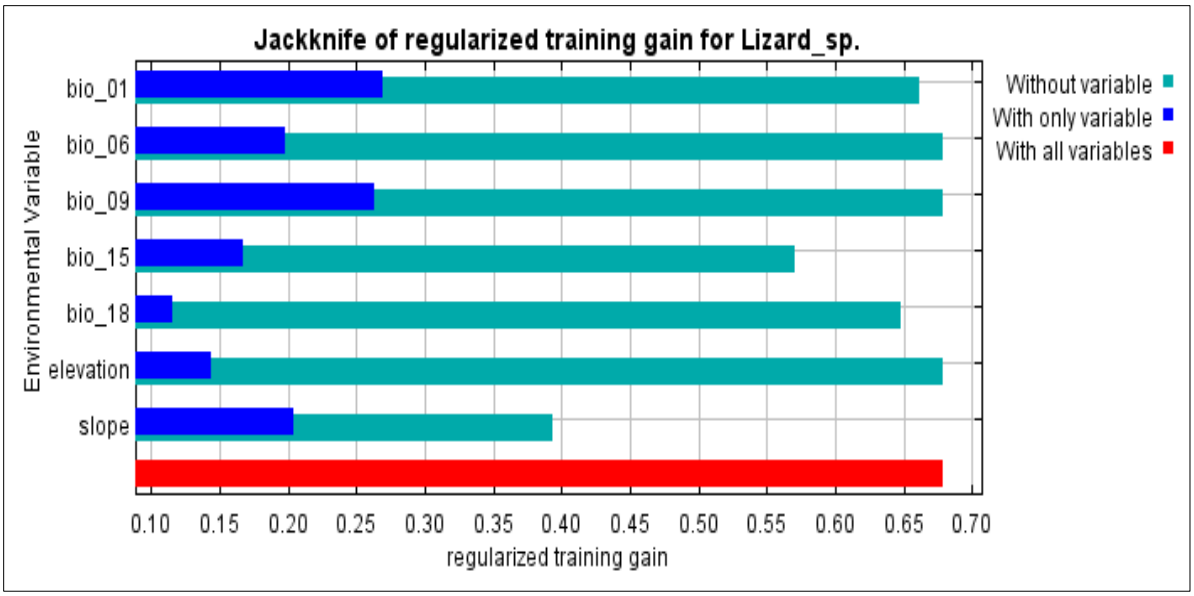

Figure 5. The figure shows the results of the jackknife test of variable importance (excluding the highly correlated variables)

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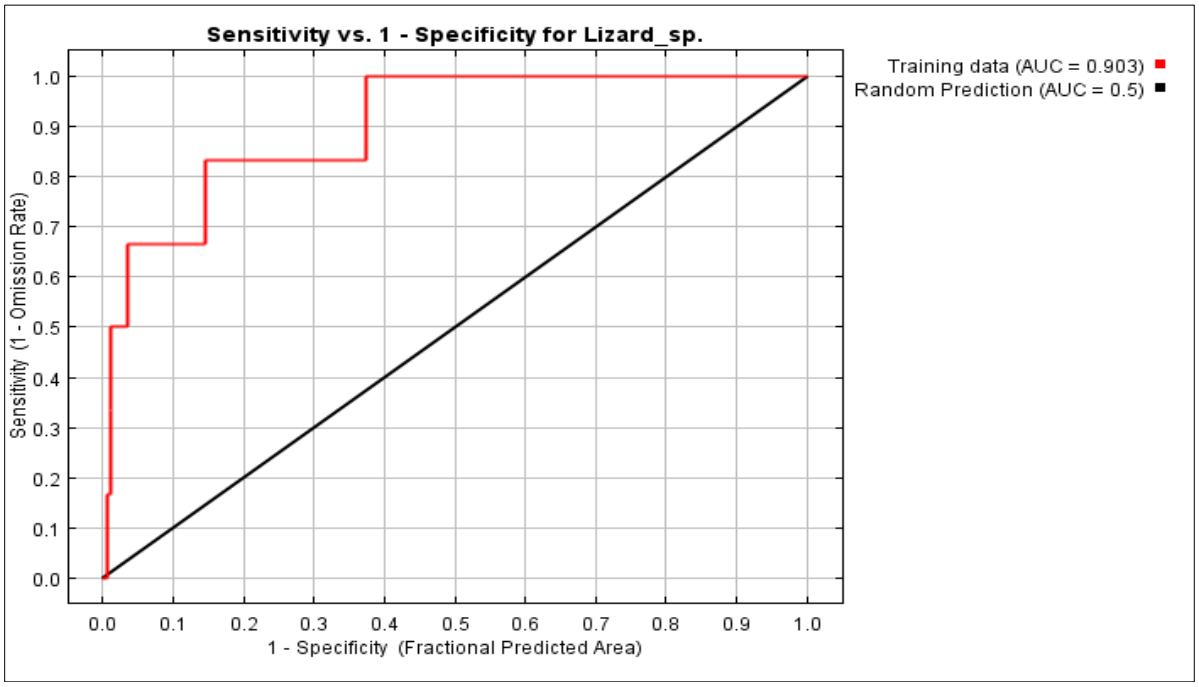

Figure 6. Figure showing ROC Curve (Receiver Operating Characteristic) for future prediction of habitat

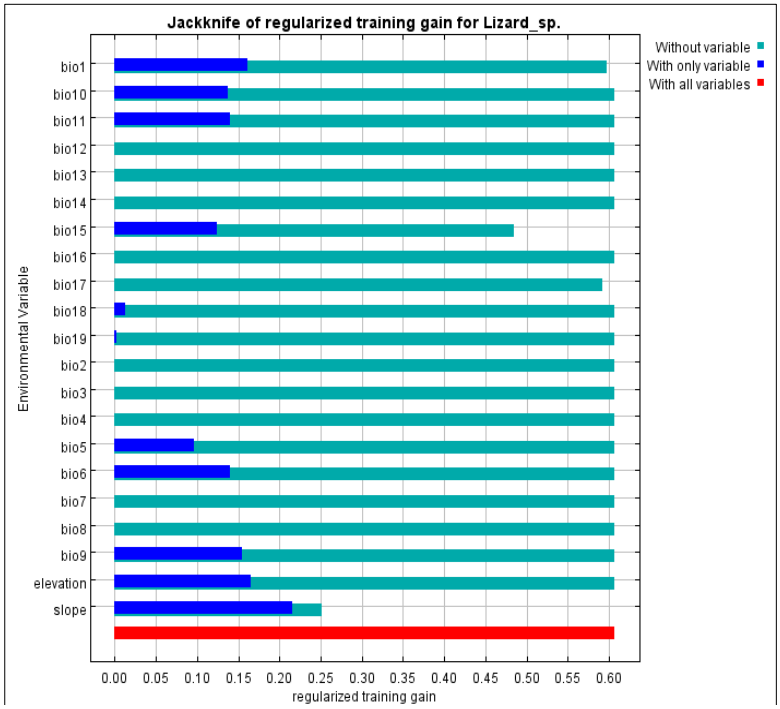

Figure 7. The figure shows the results of the jackknife test of variable importance for future prediction of habitat

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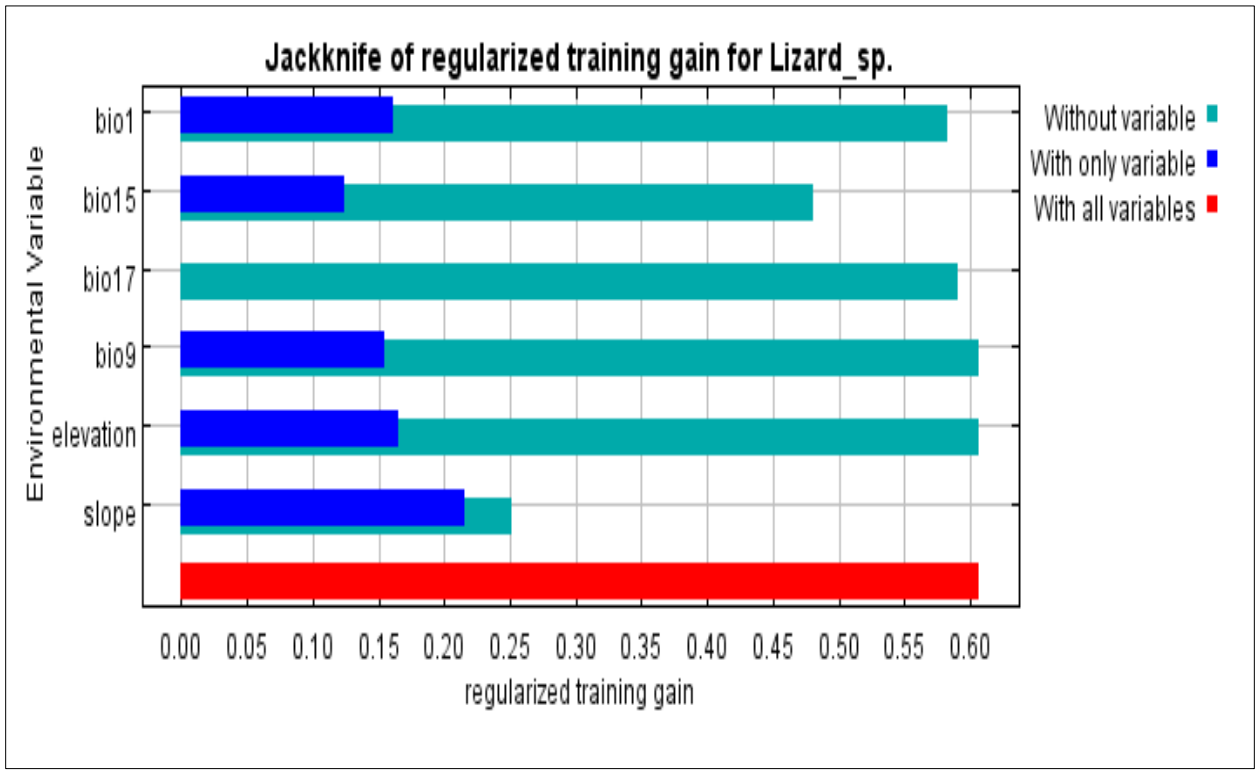

Figure 8. The figure shows the results of the jackknife test of variable importance(when the model was executed without taking the bioclimatic climatic variables that showed zero contribution)for future prediction of habitat

Fig 9. .*Altiphylaxstoliczkai* (Steindachner)

Fig 10. Locality Ganglas: habitat of *Altiphylaxstoliczkai*

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Figure 11. Locality Ganglas, fragmentation of habitat due to road construction.

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