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New sightings and habitat suitability mapping of *Platyceps gracilis* (Günther, 1862), an endemic snake species of India

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SUMMARY

This study presents updated observation data and mapping of habitat suitability for *Platyceps gracilis* the snake species endemic to India. The objective is to improve understanding of its distribution patterns and conservation needs. Observations from field surveys supplemented by literature reviews and citizen science contributions were used in mapping the habitat suitability using Maxent software across Indian subcontinent. Our findings enhance the extent of its known distribution and provide insight into its preferred habitat. Regions with a high potential for *Platyceps gracilis* occurrence were identified by habitat suitability mapping, emphasizing priority regions for conservation efforts.

INTRODUCTION

India is one of the nations with the highest degree of endemism when it concerns amphibians and reptiles (Deuti et al. 2022). Endemic species usually evolve in isolation within specific environments, producing unique adaptations and genetic diversity (Losos and Ricklefs 2009).

Platyceps gracilis (Günther, 1862) (formerly as: *Coluber gracilis*) also known as Slender racer, Graceful racer or Günther's racer is a rare, non-venomous snake endemic to India (Whitaker and Captain 2004) and listed under Data Deficient category as per IUCN Red List Assessment (Srinivasulu et al. 2013). *Platyceps gracilis* is known from Maharashtra, Rajasthan, Gujarat, and Madhya Pradesh (Smith 1943; Whitaker and Captain 2004; Chandra and Gajbe 2005; Sharma and Nagar 2007; Vyas et al. 2011; Sharma et al. 2012; Walmiki et al. 2012; Patel and Vyas 2019), where it occurs in scrubland, dry deciduous forests, rock fissures, and recently urbanized areas.

Knowledge on species occurrence (both historical and present) and habitat preference is critical for conservation (Pollock et al. 2020). Because of their limited distribution, conservationists lack biological data on endemic species and small range and distribution instinctively exposes them to a high risk of extinction (Işik 2011). As a result, reliable biological and ecological information is essential to establish effective monitoring and conservation initiatives. Habitat suitability and geographic variation in abundance are crucial indicators for determining and assessing species' conservation status (Nagendra et al. 2013).

SDMs (Species Distribution Models) use occurrence and environmental data to define possible distribution ranges and identify suitable natural conditions within a specie's range and can also help in assessment of conservation status for potentially vulnerable taxa (Pacifici et al. 2015). Maxent (machine learning maximum entropy modeling) is one of the most widely used tools for SDM (Phillips et al. 2006; Philips and Dudík 2008). While this appears to be a simple concept, species occurrence is the result of an array of ecological processes, including the environmental variables that create suitable habitats (Tikhonov 2017), species behavior and dispersal ability (Guisan and Thuiller 2005), the evolutionary processes that led to modern distributions (Ricklefs 2006), and, more recently, how these variables are affected by a growing human-dominated landscape (Williams et al. 2020).

In this note, we use modeling, primary and secondary field data to better understand the slender racer's ecology and distribution. Habitat modeling can help us understand how the species respond to broad-scale variations in environmental factors, therefore providing new information on the habitats that are better favorable for the target species.

MATERIALS AND METHODS

Study Area

The study area encompasses the different geographical regions of the Indian subcontinent, with a focus on the distribution range of *Platyceps gracilis*, which is endemic to the subcontinent. *Platyceps gracilis* distribution spans multiple administrative divisions and biogeographic zones (Ashaharraza 2007; Sharma et al. 2012; Walmiki et al. 2012; Ghadage et al. 2013; Patel and Patel 2023), includes India's northwest region, which ranges from harsh deserts to semi-arid plains in Rajasthan. Gujarat features coastal plains, hilly regions, and fertile plains. Forests, plateaus, and river basins spread over Madhya Pradesh and the Western Ghats of Maharashtra. The entire region experiences a dry period from December to June, followed by a wet season from July to November. The Western Ghats and parts of Maharashtra receive extreme precipitation, averaging about 400 cm per year, followed by moderate rainfall of 100-200 cm per year in Madhya Pradesh, and less than 50 cm per year in Arid and Semi-Arid regions of Rajasthan. Thorny bushes, drought-resistant trees such as *Acacia* and *Prosopis* species of Thorn scrub forests, and scattered grasslands characterize the vegetation of Arid and Semi-Arid regions. Mangrove forests enrich the coastal regions, while dry deciduous forests, scrublands, and grasslands dominates inland. The scrublands are dominated by *Acacia* and *Butea* species, whereas teak, sal, and bamboo are common in hilly terrain. The region also has parts with tropical dry forests and thorn woods. The Western Ghats, coastal plains, and Deccan Plateau have all had an impact on the vegetation of the western peninsula. The Western Ghats have a rich biodiversity, with tropical evergreen forests, semi-evergreen forests, and moist deciduous forests prevailing at higher elevations. The Plateau is distinguished by its dry deciduous forests, scrublands, and grasslands. The Aravalli Range influences the topography in northen region of distribution, rising to heights of around 1,700 meters above sea level. The authors recorded the observations of *Platyceps gracilis* from Ajmer region falling at ecotone of Arid and Semi-Arid biogeographic zones, away from its northernmost distribution and observations.

Habitat Modelling

We incorporated observations from published literature (Chandra and Gajbe 2005; Sharma and Nagar 2007; Ashaharraza 2007; Vyas et al. 2011; Sharma et al. 2012; Walmiki et al. 2012; Ghadage et al. 2013; Patel and Vyas 2019; Patel and Patel 2023), Global Biodiversity Information Facility (GBIF.org, 2024), and new field observations made by the authors beyond the northernmost limit of *Platyceps gracilis* known range. We used Maxent (Maximum Entropy) Modelling (Philips et al. 2006) to create species distribution models that correlated the occurrence of *Platyceps gracilis* to variables from three categories: bioclimatic, elevation, and land cover data. To eliminate spatial autocorrelation and overrepresentation in densely sampled areas, only a subset of presences separated by at least 1 km is selected and retained. The distribution dataset comprised of 40 presence reports from 2004 to 2024.

All of the essential bioclimatic variables were obtained from the WorldClim database version 2.1. The database included 19 bioclimatic variables averaged from 1970 to 2000 (Fick and Hijmans 2017). Elevation was chosen as the topographic variable since it is the most important factor determining habitat selection for many species (Wani et al. 2023). Before running the Maxent models, we did substantial data preparation to address concerns such as spatial autocorrelation and linearity among environmental variables.

In our approach, the model was tested using 10-fold cross-validation, which means it was ran with 10 replicates to obtain its optimal results. 80% of the location point data was used to train the Maxent model, with the remaining 20% having been used to validate it. The replication type was bootstrap. The jackknife test was used to determine the factors' relative relevance (Phillips et al. 2006; Pearson et al. 2007; Zhang et al. 2018). The output was in logistic format.

The logistic outputs of habitat suitability were transformed to binary outputs of habitat suitability values, and maps were generated using the threshold to illustrate the highest and lowest suitability. We obtained the area under the curve of the receiver operator plot (AUC), and averaged over 10 runs to assess model performance. When the value of AUC is < 0.7, 0.7-0.9 or >0.9 the prediction accuracy of model is considered average, high and excellent respectively (Di Pasquale et al. 2020). Along with AUC we employed True Skill Statistics (TSS) for evaluation of output.

RESULTS

During herpetological fieldwork conducted from 2018 to 2023 in Ajmer, Rajasthan, we recorded five individuals (Table 1) of *Platyceps* *gracilis* (Figure 1: a-c) beyond the northernmost distribution limits. Previously, the species was reported in Udaipur, Rajsamand, and Dungarpur Districts (Sharma and Nagar 2007; Sharma et al. 2012) in Rajasthan. The present sightings increase the known presence of *Platyceps gracilis* farther north (Figure 2). The region of occurrence in new sightings is at the border of the Arid and Semi-Aird biogeographic zones (Choudhary et al. 2022) and is influenced by the rocky terrain of the Aravalli hills (Sharma et al. 2023).

Table1. New recorded observations of *Platyceps gracilis*.

Observation Record	Year	Location	Coordinates
1	2018	MDS University, Ajmer	26°30'19.4"N 74°40'44.5"E
2	2019	Madar Hills, Ajmer	26°27'47.3"N 74°40'26.0"E
3	2019	Taragarh Hills, Ajmer	26°25'28.3"N 74°36'39.9"E
4	2023	Naseerabad, Ajmer	26°26'38.1"N 74°46'01.2"E
5	2023	MDS University, Ajmer	26°30'08.3"N 74°40'49.5"E

Figure 1. Photographs of observed *Platyceps gracilis*.

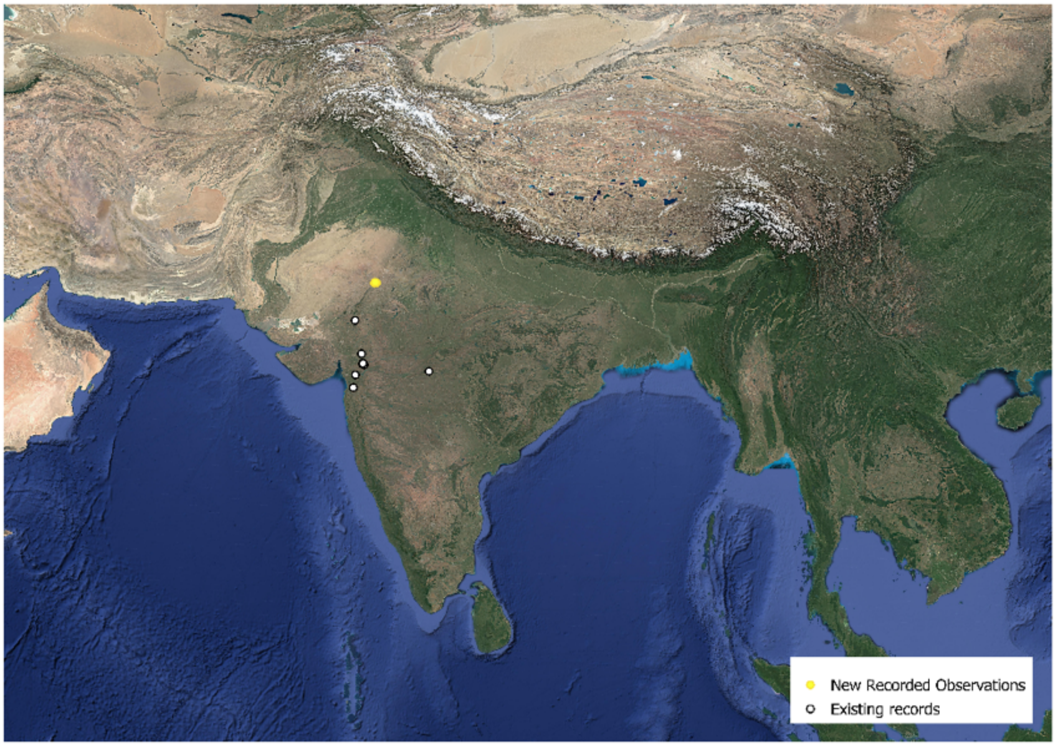

Figure 2. Distribution of *Platyceps gracilis* in India.

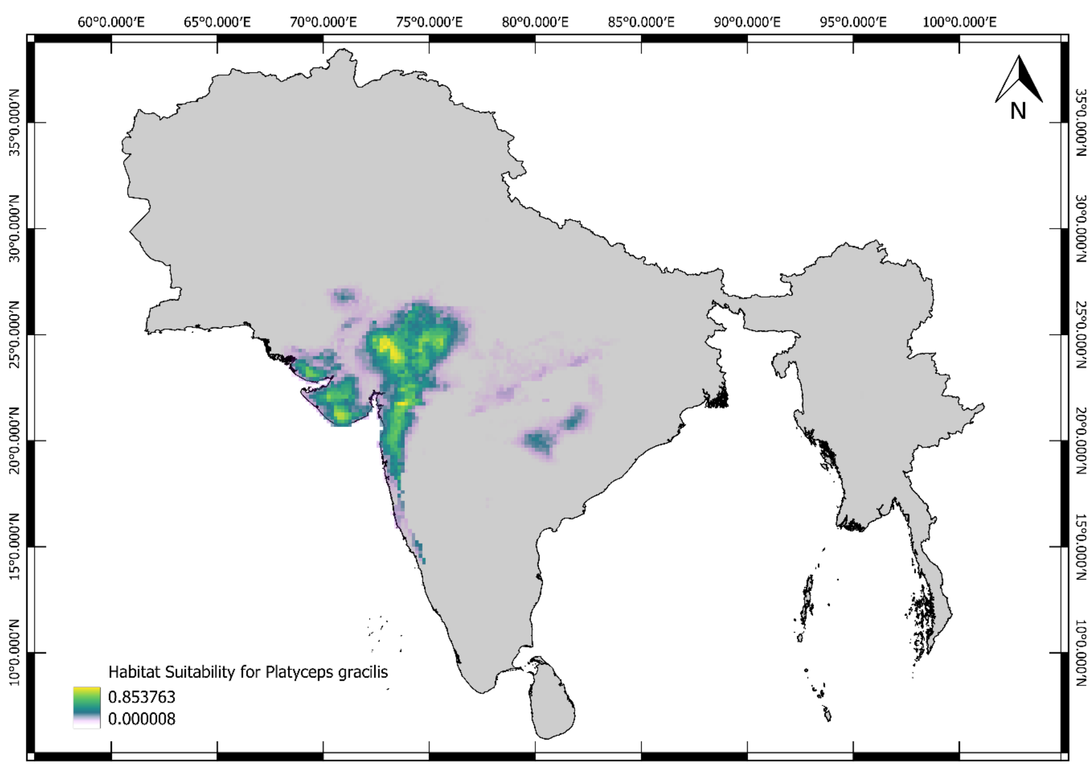

Figure 3. Predicted habitat for *Platyceps gracilis* in India.

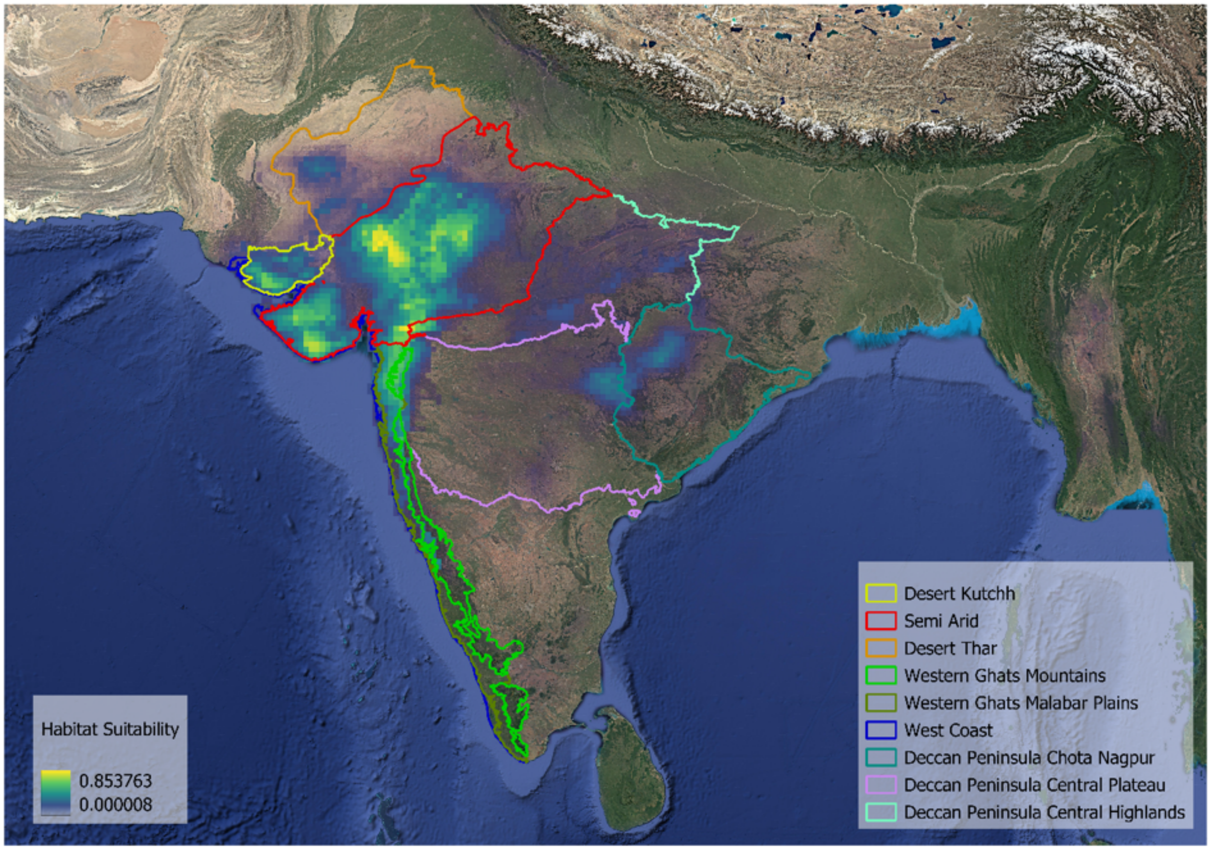

Figure 4. Suitable habitat in different biogeographic provinces of India.

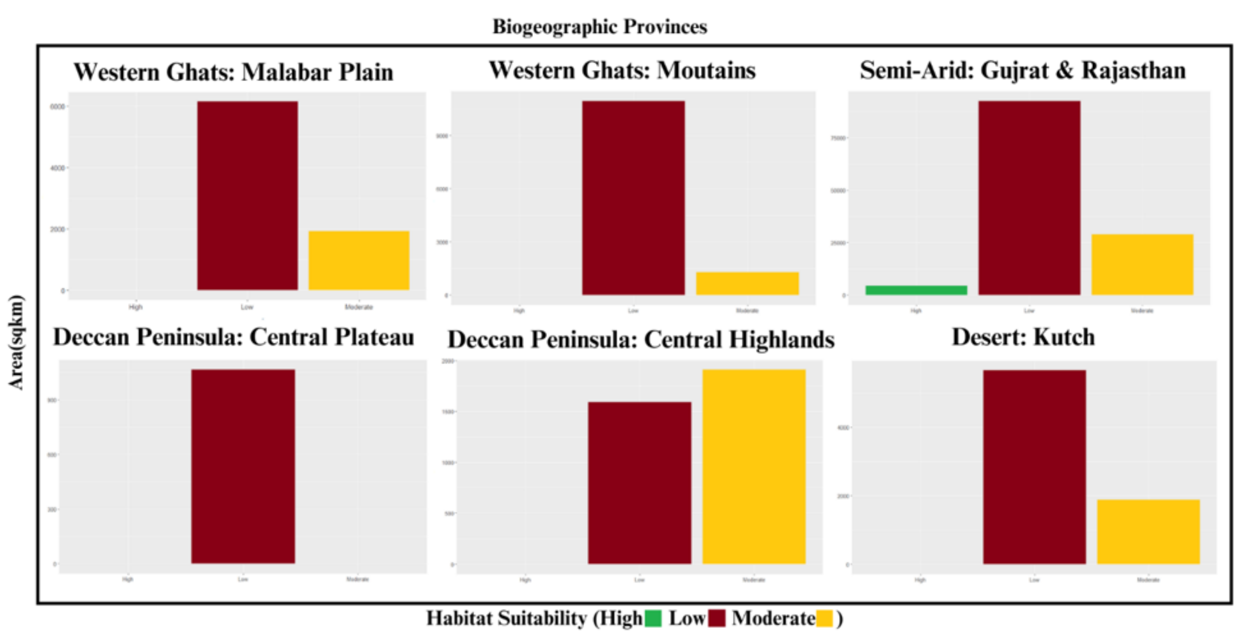

Figure 5. Graphs depicting the area of suitable habitat categories in different biogeographical provinces of India.

Habitat Suitability map was generated from the output of Maxent model (Figure 3). The total suitable habitat was estimated to be 15,855.9 square kilometers spread across 5 biogeographic zones: Arid, Semi-Arid, Deccan Peninsula, Western Ghats, and Coastal Region, and 9 biogeographic provinces: Thar Desert (Arid), Kutch Desert (Arid), Parts of Gujarat and Rajasthan (Semi-Arid), Central Highlands (Deccan Peninsula), Eastern Highlands (Deccan Peninsula), Central Plateau (Deccan Peninsula), Mountains (Western Ghats), Malabar Plains (Western Ghats), and West Coast (Coasts) (Figure 4).

The highly suitable habitat for *Platyceps gracilis* is estimated to be 4,381.7 square kilometers, followed by 35,917.6 square kilometers of moderately suitable habitat and 118,258.6 square kilometers of barely suitable habitat. The majority of suitable habitats are in the Semi-Arid zone, followed by the Western Ghats (Figure 5).

The AUC varied from 0.953 to 0.976 for ten replicated models, with an average of 0.964 ± 0.008 and TSS value of 0.619 suggesting good performance. Figure 6 shows the variation in habitat suitability of *Platyceps gracilis* based on individual response curves for high-contributing variables. The variables with the highest contribution to the final ensemble model include precipitation seasonality (Bio 15; 46.9%), precipitation in the coldest quarter (Bio 19; 19.5%), elevation (Elev; 7.7%), and precipitation in the wettest quarter (Bio 16; 7.7%) (Table 2). The probability of suitability increases with rising temperature in the warmest and wettest quarters, mean diurnal range, and precipitation seasonality, but decreases as elevation and precipitation in the coldest and warmest quarters increases.

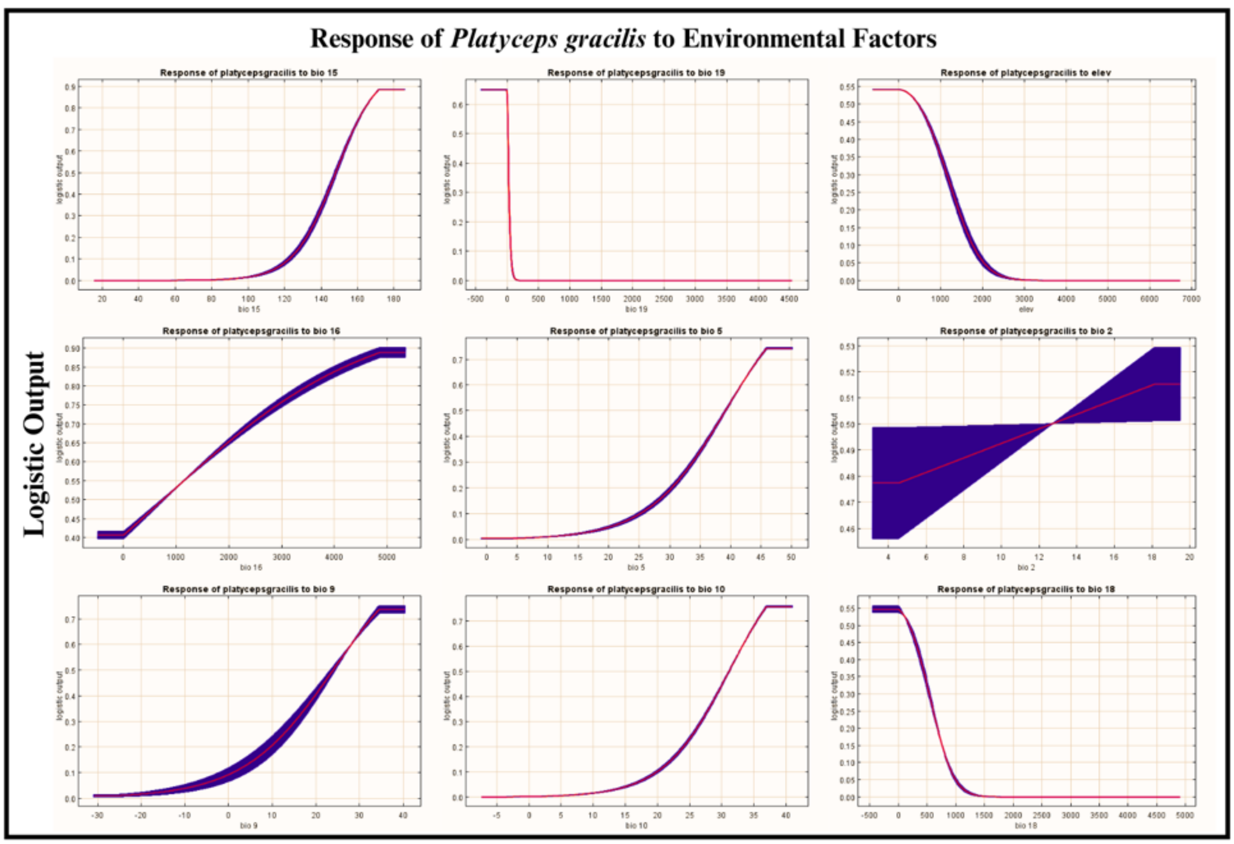

Figure 6. Graphs depicting the area of suitable habitat categories in different biogeographical provinces of India.

Table2. List of Environmental variables used for modeling the habitat suitability for *Platyceps gracilis*.

Code	Variable	Percent contribution
Bio 15	Precipitation Seasonality (Coefficient of Variation)	46.9
Bio 19	Precipitation of Coldest Quarter	19.5
Elev	Elevation	7.7
Bio 16	Precipitation of Wettest Quarter	7.7
Bio 5	Max Temperature of Warmest Month	3.0
Bio 2	Mean Diurnal Range (Max Temp-Min Temp)	3.0
Bio 9	Mean Temperature of Driest Quarter	2.1
Bio 10	Mean Temperature of Warmest Quarter	2.0
Bio 18	Precipitation of Warmest Quarter	1.7
Bio 6	Min Temp of Coldest Month	1.2
Bio 14	Precipitation of Driest Month	1.1
Bio 7	Temperature Annual Range (Bio5-Bio6)	0.9
Bio 8	Mean Temperature of Wettest Quarter	0.7
Bio 11	Mean Temperature of Coldest Quarter	0.6
Bio 4	Temperature Seasonality (SDx100)	0.5
Bio 3	Isothermality ([Bio2/Bio7]x100)	0.5
Bio 1	Annual Mean Temperature	0.3
Land Cover	Land Cover	0.3
Bio 12	Annual Precipitation	0.2
Bio 17	Precipitation of Driest Quarter	0.2
Bio 13	Precipitation of Wettest Month	0.0

DISCUSSION

Platyceps gracilis is one of the least-known snake species in India (Ashaharraza 2007). It is reported to feed on rodents, lizards, and skinks (Patel and Patel 2023) and can be found in a variety of microhabitats including urbanized areas, dry deciduous vegetation, boulders, rock fissures, and rocky terrain. Many researchers proposed studying the species' habitat and distribution to better understand its ecology (Sharma et al. 2012; Walmiki et al. 2012). Biological and ecological investigations are critical for rapid assessment of the state of data-deficient species (Borgelt et al. 2022). We provide a significant contribution to understanding the endemic, Data Deficient *Platyceps gracilis* by integrating distribution information with ecological models and frequent surveys.

In India, seasonal variability (i.e., summer, monsoon, and winter) in temperature is greater than daily temperature variation in most parts of the country (except the colder regions), and this variation is expected to affect species growth and distribution (Dubey et al. 2021).

We used Maxent as it is effective at reconstructing a species' distribution in specific locations because it maintains its strong predictive power even when the sample size is limited, which is useful when dealing with rare species (Peterson et al. 2007) and needed fewer variables to attain high AUC values.

Species distribution models showed that *Platyceps gracilis* distribution is influenced by topographic, climatic, and habitat characteristics. Winter conditions are a key element influencing reptile distribution (Gregory 1984), and climatic variables such as temperature seasonality can play an essential influence on niche divergence among species (Ahmadzadeh et al. 2016). Previous research indicates that *Platyceps gracilis* selects open habitats with higher temperatures (Average yearly temperature ranging between 28-30 °C) as part of its home range (Walmiki et al. 2012;

Ghadge et al. 2013; Ashaharraza 2017; Patel and Patel 2023). Reptiles are ectothermic, which means they depend entirely on surrounding warmth to raise their body temperature and become active; as a result, they frequently have limited climatic tolerance and are highly dependent on climatic conditions (Luo et al. 2012; Hosseinzadeh et al. 2014).

In an era of rapidly changing climate, our findings may contribute to the development of an accurate framework for predicting conservation areas for this species, as well as a model-based framework for future sampling and conservation assessment. Given financing constraints when conserving threatened species, the habitat map developed in this study may help conservation authorities better prioritize conservation initiatives. Several limitations like coarse resolution of environmental data, absence of climate change projections and exclusion of anthropogenic factors like urbanization, agricultural expansion and habitat fragmentations might influence the generalizability of the results and provides a scope for further enhanced research.

CONCLUSIONS

The current study exhibited the use of habitat modeling to estimate *Platyceps gracilis*' climatic and ecological suitable zones in India and neighboring countries like Afghanistan, Nepal, Pakistan & Sri Lanka. Temperature and precipitation have been identified as important bioclimatic elements in defining the distribution of this poikilothermic species. The semi-arid regions followed by the Western Ghats provide the highest and moderate suitable habitats for the species. Along with the Habitat suitability modeling for *Platyceps gracilis* we have documented five new records of the species beyond its recorded distribution indicating there is still scope and emphasis can be given on field surveys in to properly document the occurrence across its suitable habitats. Thus, good wildlife management, planning, and construction of core zones for target species belonging to wildlife are critical for safeguarding and maintaining sustainability.

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