

## Predicting Seasonal Variation in Habitat Distribution of Himalayan Newt (*Tylototriton verrucosus*) in Darjeeling District, India

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### ABSTRACT

The Crocodile newt (*Tylototriton verrucosus*) is the only Urodel present in India and the Indian Wildlife Protection Act 1972 lists it as an endangered category. In West Bengal, India it is confined to the Darjeeling Himalayan foothills only. For appropriate management strategies, wildlife supervisors need to diagnose the extent of their appropriate habitat and consider its distribution outlines across the landscape. MaxEnt modeling was used in this analysis to assess the effective habitat and seasonal distribution of Crocodile newts'. The results showed that minimum temperature and precipitation are the best predictors of suitable habitat for both year-round and breeding seasons. The breeding season model showed a highly suitable habitat of 66.66 Km<sup>2</sup>, while the year-round model estimates a highly suitable environment of 56.25 Km<sup>2</sup>. Our results suggest an increase an increase of around 18.51% landscape area as highly suitable during the breeding season, and minimum temperature regulates such distribution pattern of the newt. These findings can be used to determine the suitable habitat available and to introduce conservation and management action plans so as to increase the desirable habitat and protect the species in the foothills of the Darjeeling Himalayas.

**Keywords:** Maximum Entropy; Species Distribution; Breeding Season; Modeling; Conservation; Amphibia

### INTRODUCTION

The genus *Tylototriton* is a group of newts, commonly known as the crocodile newts. The genus consists of nearly 24 species, distributed throughout the Eastern Himalayas, China, Nepal, India, Bhutan, Thailand, Myanmar and Vietnam (Nussbaum et al. 1995, Phimmachak et al. 2015, Qian et al. 2017). Among the 24 species, India is marked for the presence of *Tylototriton verrucosus*, often called the Himalayan newt. Reports of its occurrences are found in Darjeeling district of West Bengal (Dasgupta 1990), Manipur (Selim 2001) and Arunachal Pradesh (Mansukhani et al. 1976). Although the species is least concerned in the IUCN list, Indian wildlife protection act 1972 has enlisted it with an endangered category status (Seglie et al. 2003). A number of factors can be respondent for such a threatening scenario. The decrease of the Himalayan newt population has all been caused by natural phenomena such as UV-B radiation, climate change, pathogen infestation, human impacts such as habitat

fragmentation, pollution, excessive agricultural processes (Duellman 1999).

One vital reason for the decline of a species is the fragmentation of its habitat, particularly of the breeding territories. The disintegration of habitats into patchy reinforcements adversely affects the population structure (Smith and Hellmann 2002) in many ways, such as, reproduction, growth, migration, survival (Harris 1984) etc. The overall fitness of an organism to achieve its survival needs like feeding, reproduction, and movements; needs to be much higher in regions with low connectivity as compared to high connectivity regions. These scenarios in turn affect the dynamics, geographic orientation and the tenacity of the population. However, the impact of habitat fragmentation for a species might possibly change in due course of time, especially from one season to the other. The migratory treks for resource biomass, reproduction, and associated biotic relationships all are influenced by change in the climate. Connecting the use of habitats during the breeding and non-breeding season can be of great

help to comprehend the movement patterns in this aspect (Rubenstein and Hobson 2004). With increased urbanization demands of more lands for human habitation, crop production and procurement of lands has resulted in drastic reduction of forest cover and ultimately leading to habitat fragmentation. These anthropogenic events have affected the biodiversity significantly, particularly in population decline.

Knowledge regarding inclination towards specific habitats and likewise distribution range can be key information for conservation strategy making. Since food and other resources increase during the breeding season, it is quite obvious that movement towards breeding grounds will be higher during this time frame. Throughout this period the newts' may exploit their niche more effectively, allowing their own survival in a potential broad distribution range. As a result of this niche expansion, the significance of certain habitats would definitely be higher during breeding season from the rest of the year.

To assess seasonal variation in the distributional range of Himalayan newt, we employed the MaxEnt (Maximum Entropy) modeling method (Phillips 2005, Phillips *et al.* 2006). The MaxEnt algorithm has been extensively used in conservation and management practices (Cowley *et al.* 2000, Pearce and Ferrier 2000, Stockwell and Peterson 2002, Gibson *et al.* 2004). MaxEnt models can be of great help for wildlife managers in identifying hitherto unrevealed regions of wild species and can direct the creation of successful management and policies (Baldwin 2009, Braunisch *et al.* 2011). MaxEnt is preferred over other model building techniques for generally two reasons: first, it utilizes presence only data, no absence or pseudo absence data is needed, and second, it offers best results for small sample sizes when compared to other similar methods (Elith *et al.* 2006, Hernández *et al.* 2006, Pearson *et al.* 2007). MaxEnt predicts the distribution range of a species by combining its occurrence data in terms of geographic locations and environmental variables (e.g. temperature, precipitation, elevation etc.).

In compliance to this context, the objective of this work is to evaluate how Crocodile newts exploit the landscapes, aiming the variations in distribution pattern during breeding season (May-July) and the year-round (annual) via its environmental

inclinations. Specifically, the concern is on the evaluation of reasonable breeding habitats during May-June-July and the environmental variable that may control seasonal movements along the study region.

## MATERIALS AND METHODS

### Study area

The study area comprises the entire area of Darjeeling district. Situated in the Himalayan foothills; it is the northernmost district of West Bengal, India (Fig.1). The geographical extensions of the study area lies between Latitude: 27° 01' 48.00" N and Longitude: 88° 09' 36.00" E. The total area covered under the study region is 2,092 km<sup>2</sup> (District Census Handbook, Darjeeling 2011). The climate in this area depends mostly on the altitude and slope. The elevation of the area lies between 15m - 3602 m above mean sea level. The region enjoys significant amount of rainfall. The monsoon period experiences continuous rainfall. However, the winters, especially December and January is too cold and unpleasant. The temperature sometimes falls below zero degrees. According to Indian meteorological department, 2019, the area receives an overall precipitation ranging from 1877mm - 2333 mm (Roy *et al.* 2019).

Despite being one of the smallest geographic areas, the density of vegetation is very high in Darjeeling. Darjeeling houses a total of four protected areas, one national park (NP) and three wildlife sanctuaries (WLS). The only National Park in Darjeeling is the Singalila National Park, initially founded as a wildlife sanctuary in 1986 and later converted to a national park in 1992. Darjeeling also has three sanctuaries: Jorepokhri Salamander WLS, Mahananda WLS, and Senchal WLS.

### Data collection and selection of environmental variables

We obtained 25 species occurrence points through regional survey of the entire Darjeeling area and online database (GBIF) for *Tylotriton verrucosus* presence. Along with these presence records we used three environmental variables from WorldClim website (<http://www.worldclim.org/current>) (Hijmans *et al.* 2005). These variables; minimum temperature, maximum temperature and precipitation

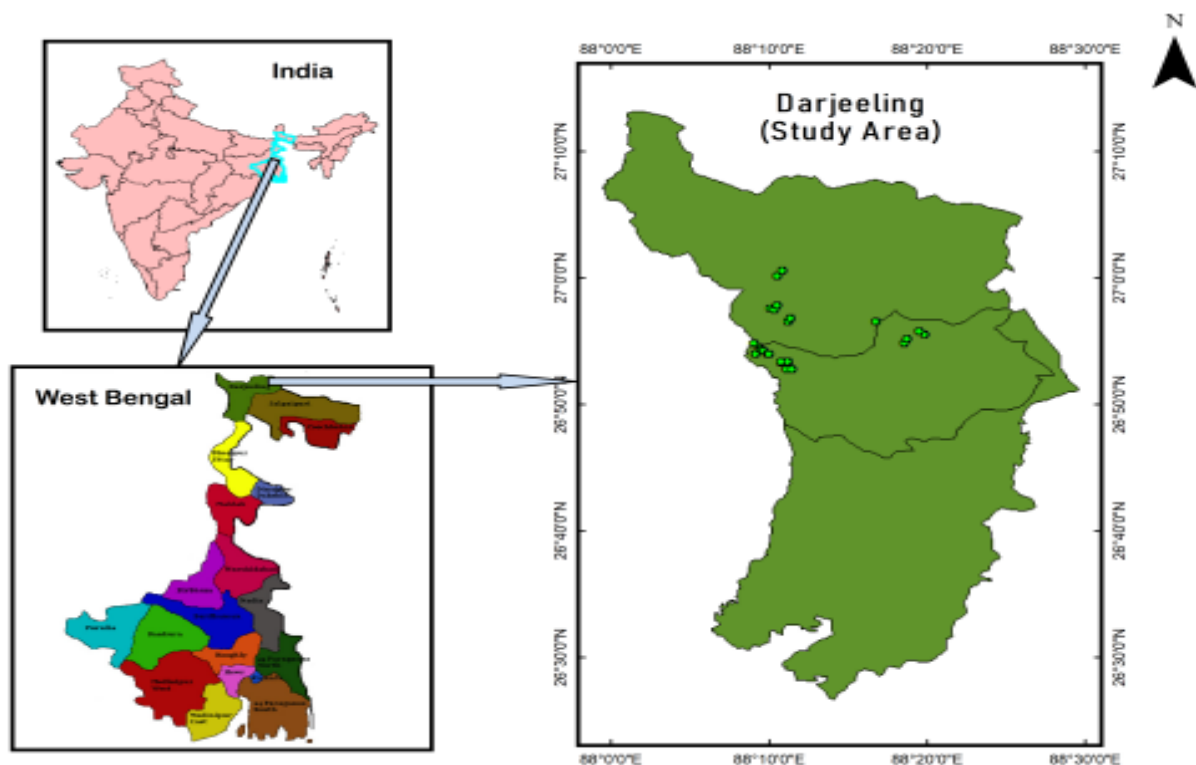


Figure 1. Location of the study area with occurrence points of *Tylototriton verrucosus*

were downloaded as 30 arc seconds spatial resolution (1 Km<sup>2</sup> grid size) and were further clipped in ArcGIS 10.1 according to the range of the study area before use. The occurrence points were plotted using ArcGIS software. The fact that, both temperature and precipitation are ecologically highly significant with amphibian biology, especially for their breeding season being active during the monsoon, justifies their selection. We approached for two different models, the first one being the model for year-round composed of the annual average of all the selected environmental variables, and the second one for the breeding seasons only. For the breeding season, averages of three months (May, June and July) environmental data were taken.

### Model Development

MaxEnt (maximum entropy) version 3.4.1 (source: <http://www.cs.princeton.edu>) algorithm (Phillips *et al.* 2006, Elith *et al.* 2011) was employed to assess the probable suitable range for *T. verrucosus* in Darjeeling district. The MaxEnt algorithm requires presence only data to predict the suitable habitats. Depending on environmental layers, MaxEnt compares the possibility of presence in a particular cell with other such cells in the area. The model as a

result obtained exhibits the relative chances of species distribution towards all of the grid cells inside a pre-described geographic area, wherein a high-quality predictive-value associated with a selected grid designates the opportunity of the grid cell with favorable climatic settings. In addition to making excellent performance paralleled to other models, the MaxEnt model also produces best results with smallest aggregate of sample numbers. Finally MaxEnt was run on the default settings mode with 10 replicates. The MaxEnt algorithm used 75% of the data for training purpose and the rest 25% data for model evaluation. The regularization multiplier value was 0.5, and background points were set to be 5000. The model performance was evaluated by area under the curve (AUC) separately for training and test data, both. The AUC value varies from 0-1. A value of 0.5 means the model is no more accurate than a random one, while AUC > 0.8 means good and AUC > 0.9 denotes excellent performance (Manel *et al.* 2001). Fig.2 depicts the predicted habitat suitability models for year-round and breeding season models.

The habitat suitability of the predicted map ranged from 0.0-1.0. We further reclassified them into five suitability classes; unsuitable (0–0.2); low suitable

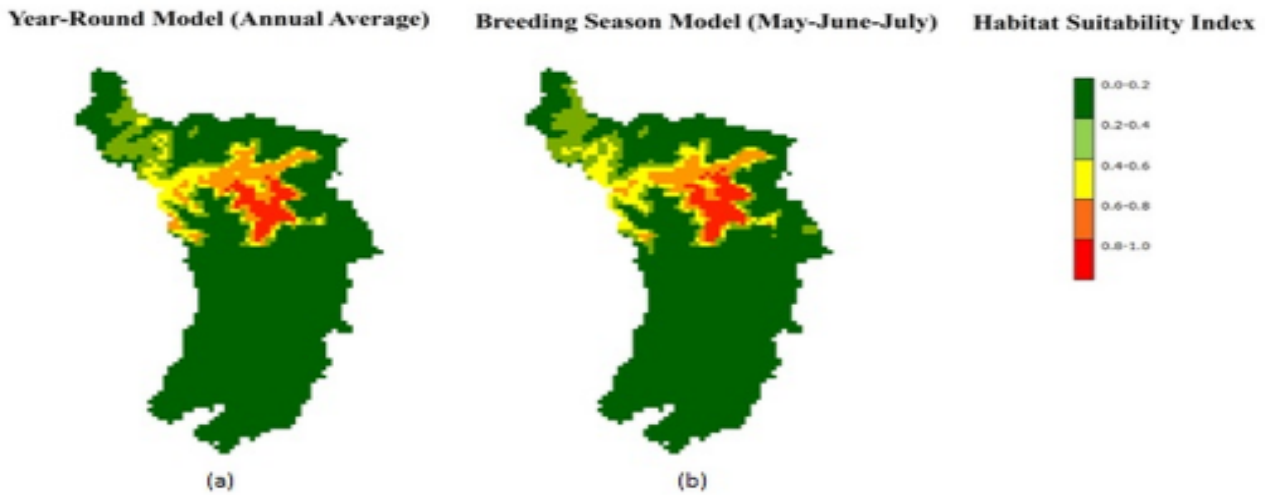


Figure 2. Predicted habitat suitability models for (a) Year-round model and (b) Breeding season model

(0.2–0.4); suitable (0.4–0.6); moderately suitable (0.6–0.8); highly suitable (0.8–1.0). The area calculation for each suitability class was done by ArcGIS environment. All the statistical analyses were done in MS Excel.

RESULTS

As a whole, both the models displayed decent predictive ability and performance. As per the AUC values, the breeding season model was more predictable and explanatory. Altogether, newts accepted a slender range of environmental setup throughout the year in comparison to the breeding

season. However in the breeding season, the newts stood by the areas with lowest tolerable minimum ambient temperature with higher precipitation. It was estimated that during the breeding season, the newts can be found more regularly as the suitable areas increased in this timeframe by a significant proportion.

The average AUC values for the models are 0.931 (year round model) and 0.918 (breeding season) respectively, ensuring high model performance. The standard deviation was 0.032 and 0.048. From the three selected variables minimum temperature turned out to be the most significant one contributing more than 70% in both models, followed by precipitation

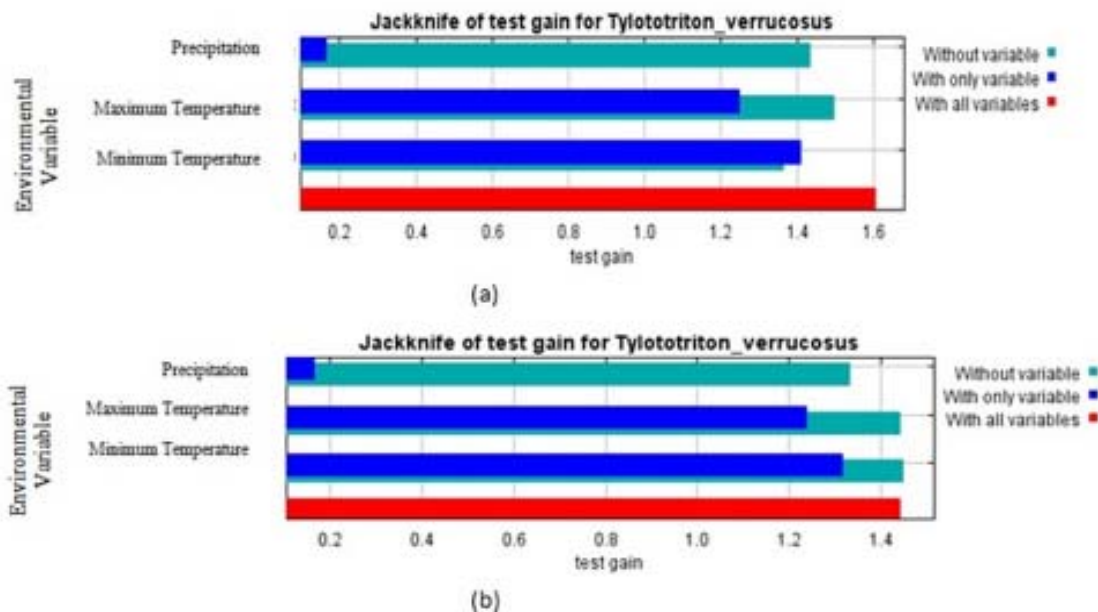


Figure 3. Jackknife test gain plots for (a) Year-round model, and (b) Breeding season model

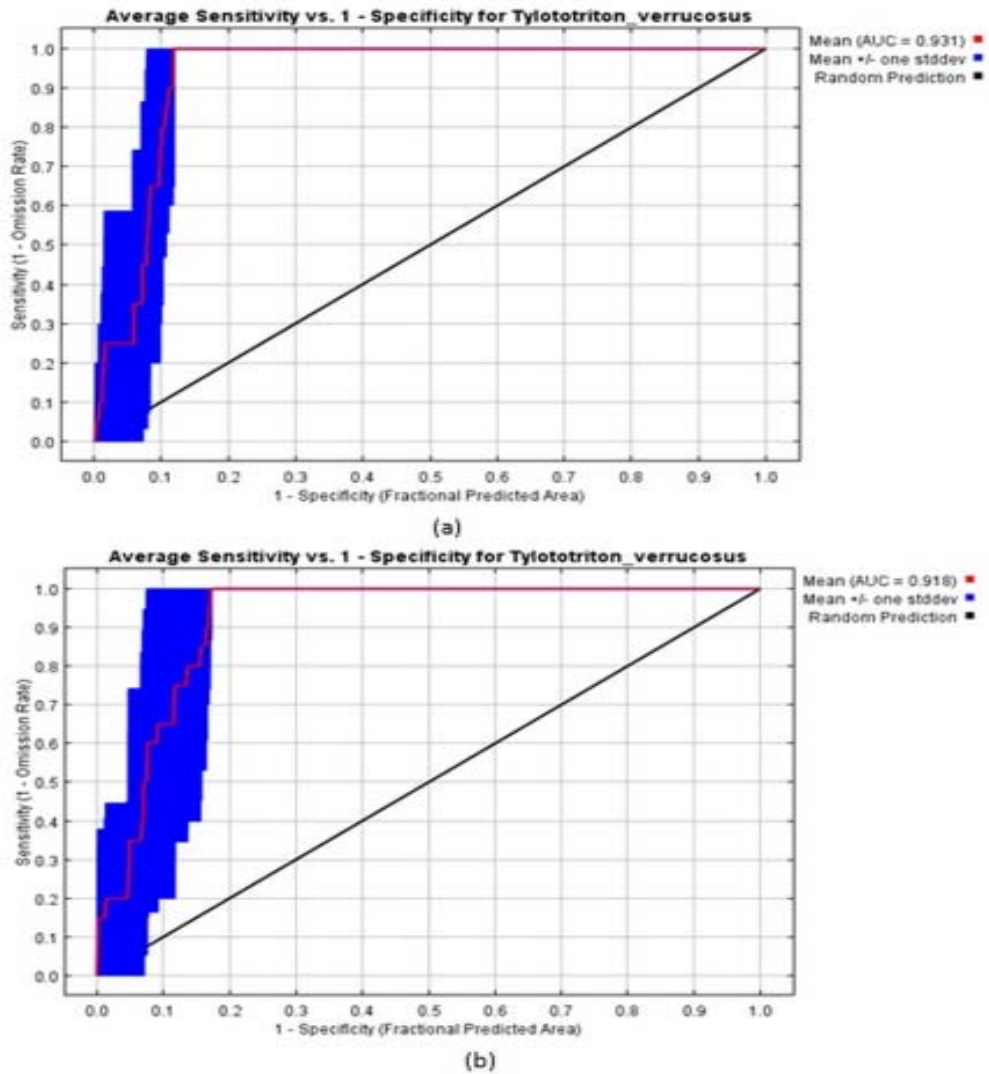


Figure 4. ROC plots for (a) Year-round model, and (b) Breeding season model

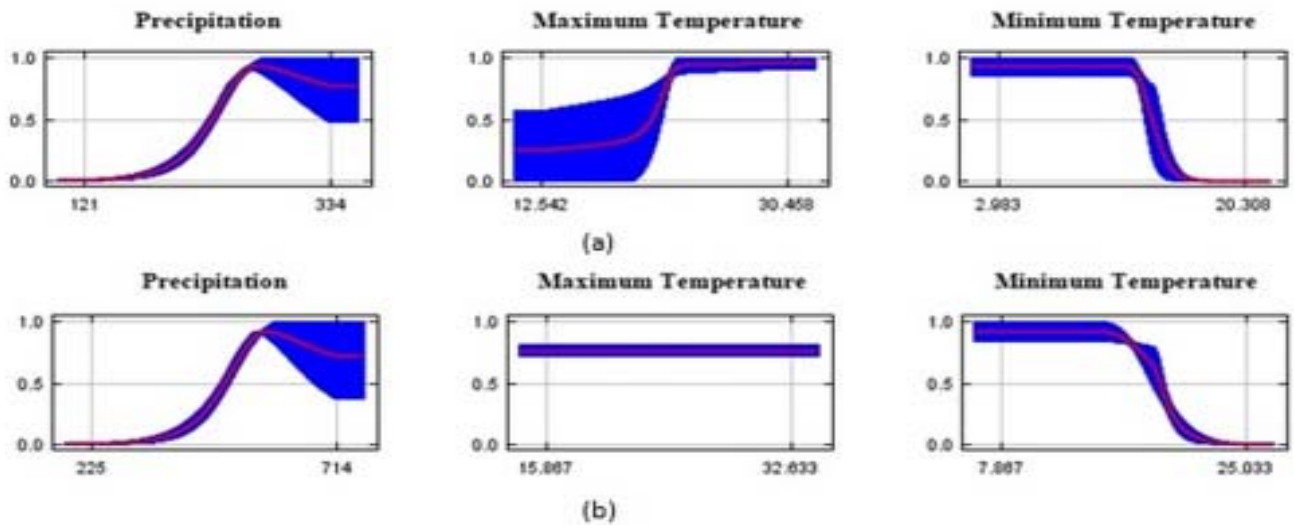


Figure 5. Response curves showing relationships of environmental variables and species suitability (a) Year-round model, and (b) Breeding season model

and maximum temperature. The jackknife output, ROC plots and response curves of the variables are depicted in Figs.3, 4 and 5.

The models suggested that the newt's overall suitable habitat range in the breeding season (442.33 Km<sup>2</sup>) is higher than year around model (408.32Km<sup>2</sup>). Thus, during May-July the newts experience an overall 8.32% increase in their habitats. In either cases, MaxEnt predicted potential habitats beyond the present locations. Availability of sufficient water in temporary or semi-temporary areas lead to the construction of water bodies for breeding, thus the previously defined unsuitable areas loses a significant portion (34.03 Km<sup>2</sup>) and becomes somewhat suitable during breeding seasons.

The calculated area for moderately suitable (103.47 Km<sup>2</sup>) and highly suitable (56.25 Km<sup>2</sup>) habitats together constituted 159.72 Km<sup>2</sup> in case of year around model. On the contrary, the breeding season model depicted 84.02 Km<sup>2</sup> areas for moderately suitable and 66.66 Km<sup>2</sup> for highly suitable (Table 1 and Fig. 6).

Among the three variables selected, minimum temperature and precipitation come to be the key regulators with percent contributions of over 72% and 25%, respectively. Alongside, Jackknife tests also attributed minimum temperature with the maximum AUC gain for both year-round and breeding seasons, signifying it as a greatest predictor of the three variables when measured individually. The contributions of the variables are represented in Table 2.

Table.1 Predicted area (Km<sup>2</sup>) of different suitability classes

Habitat Type	Model Type		Area Change	Change
	Year-Round	Breeding Season		
Unsuitable	1440.88	1406.85	-34.03	Decreased by 2.4%
Low Suitable	147.91	172.91	25	Increased by 17%
Suitable	100.69	118.74	18.05	Increased by 18%
Moderately Suitable	103.47	84.02	-19.45	Decreased by 18.8%
Highly Suitable	56.25	66.66	10.41	Increased by 18.5%

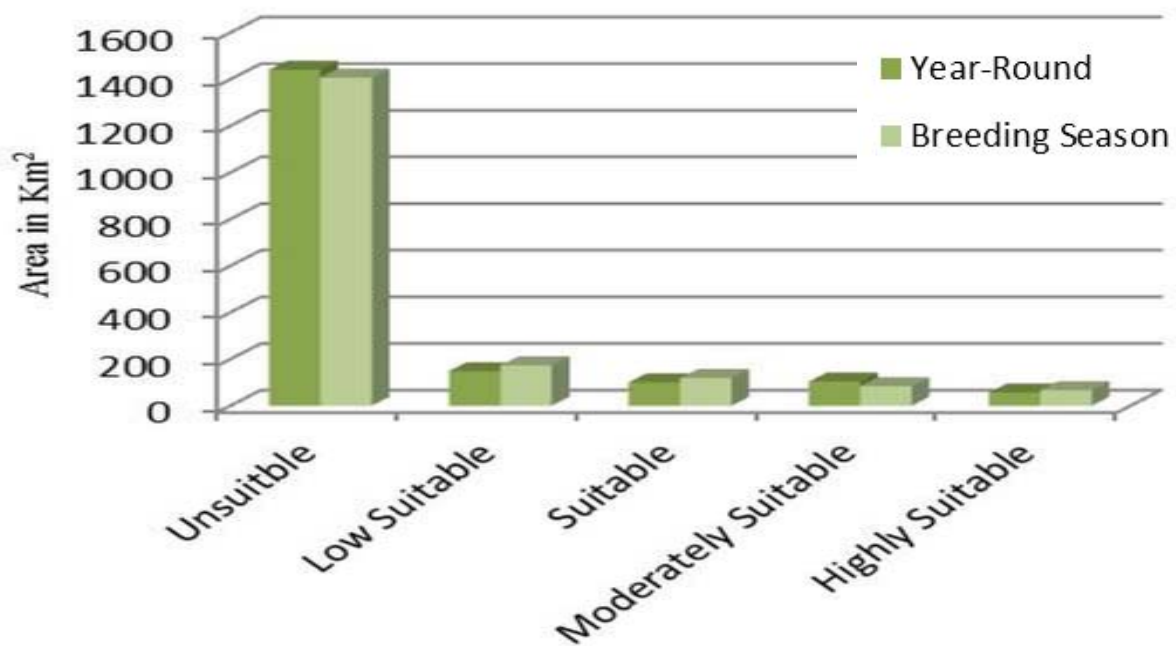


Figure 6. Area comparisons of different suitable habitats

Table 2. Percentage contribution of environmental variables

Environmental variables	Percentage Contribution (%)	
	Year-Round	Breeding Season
Min. Temp. ( $T_{\min}$ )	72.0	72.2
Precipitation	25.5	27.8
Max. Temp. ( $T_{\max}$ )	2.4	0.0

## DISCUSSION

According to Seglie *et al.* (2003), 40% of the newt's population is diminished, and thus his demand for a threatened category from the existing Least Concerned status in IUCN category seems to be justified. Moreover, being endemic to the Himalayan region this species is of special ecological interest, and as a result, the government and other policy maker bodies need to focus on specific breeding programs both in and ex-situ. Action plans on conservation and management of *Tylototriton verrucosus* must be based on location-specific reintroduction and breeding. Our model points out the fact that there might be more suitable habitats in Darjeeling region apart from their present residences. More field surveys can be helpful in this respect. The potential extended suitable localities can be of great ecological significance from the conservational point of view. However, survival of an organism in a swiftly shifting environment depends on its ability to mitigate effects of climate change and searching for buffer areas.

Our results indicate MaxEnt to be an effective tool in modeling the distribution range of a species with, small sample size (Elith *et al.* 2006, Hernández *et al.* 2006). The intention of using MaxEnt modeling approach is not to predict the true limits of the newts, but to recognize habitats having similar environmental surroundings to the occurrence neighborhoods (Pearson *et al.* 2007). According to the theory of ecological niche, the distribution range of a species is mostly regulated by precise environmental needs (Hutchinson 1957). Depending on the climatic variables, our models showed fair estimation of the newts' distribution in the study area, both for the year round model and the breeding season model as well. Thus our models can be

ascribed as the newts possible distribution range in the study area based on its fundamental niche. Nevertheless, to achieve more accurate results, other factors like competition, anthropogenic impacts should be included. Consequently, the impact of those interactions may have ultimately resulted in the range difference exhibited by the two models due to alterations in the newts' fundamental or realized niche (Broennimann *et al.* 2007). The present work can be utilized for habitat preferences of the newts.

The expected breeding season and year-round predicted suitable localities for *T. verrucosus* are crucial figures for the documentation and application of ideal management methods. The AUC values suggested that MaxEnt performed remarkably well in predicting *T. verrucosus* habitat. Our results have shown that *T. verrucosus* has a broad distribution range in the breeding season as compared to the rest of the year. The breeding season model is less illustrative and quite more predictable as compared to the year-round model. The minimum temperature of the study area took utmost control of the breeding season distribution, suggesting the newts' stringent choice of climatic factors during breeding. This may be due to the availability of water in ponds and pools due to precipitation, and food. The minimum temperature becoming the greatest predictor among the variables indicates the newts' preference towards a low temperature region. Rainfall during the breeding season helps in overall decrease in ambient temperature, making the environment soothing, furthermore favorable for breeding, even in temporary water bodies too. High degree of rainfall makes temporary pools, puddles etc. a good breeding site, especially for small sized population. Again, for some amphibians, migration towards area of favorable ecological conditions is of no exception (Sinsch 2014).

In different circumstances, the year round model exhibits a slender niche as compared to the breeding season one. This might be due to robust biotic and anthropogenic interactions. Availability of food and other rationale during summer, overwintering of the larvae during the winter, chances of severe encounter with predators can also accumulate to such narrowing of the distribution. Anthropogenic events like, land use for cultivation, trespassing and disturbing the newts' niche for forest product

collection may restrict the species from habitat expansion and landscape migration. The swing in the distribution can be related to poor suitability of habitats during the other seasons of the year and proper managements of the land on specific habitats by the local people and/or the conservation practitioners.

Our model is built on the climatic data available in Worldclim database. Besides, data from Waterportal (<https://www.indiawaterportal.org>) was also collected to analyze the trends of precipitation and temperature in the study region. The patterns of temperature and precipitation show that there is a continuous rise both in minimum and maximum temperature since the last 100 years and the trend line suggests that it will keep on rising. Figures 7 and 8 shows the pattern of upward shift of maximum

and minimum temperature. Being an ectotherm, *T. verrucosus* needs external heat to accomplish its physiological demands. The rise in temperature thus may be of help considering the body physiology to a certain extent. However, an abnormal increase in ambient temperature may lead to physiological and anatomical anomalies and the species may ultimately perish. Seebacher *et al.* (2015) has found some ectotherms with elevated heart rate and foraging demand in response to increased temperature. Besides temperature, precipitation too plays a key role, especially in the breeding seasons. Our findings suggest that there has been a steady downfall in the amount of rainfall in the study area (Fig.9), and the graph is still trending downwards. Although not alarming, the decrease of rainfall is a matter of serious concern, as with the first rain in the hills, the newts

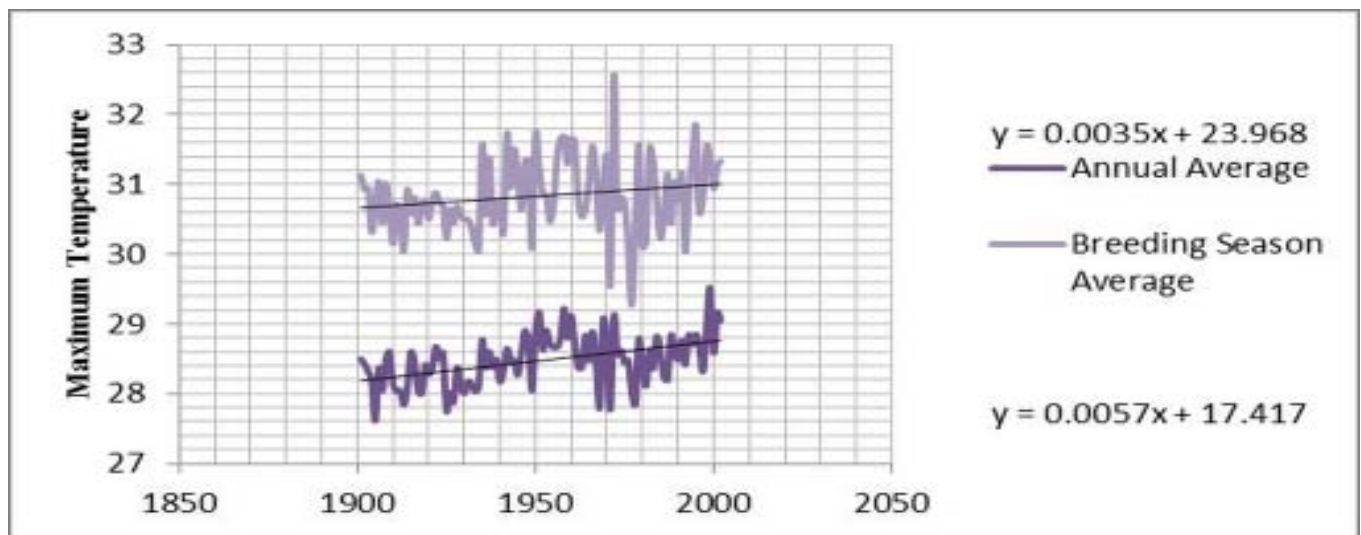


Figure 7. Trends of annual maximum temperature and breeding season maximum temperature (1901-2002)

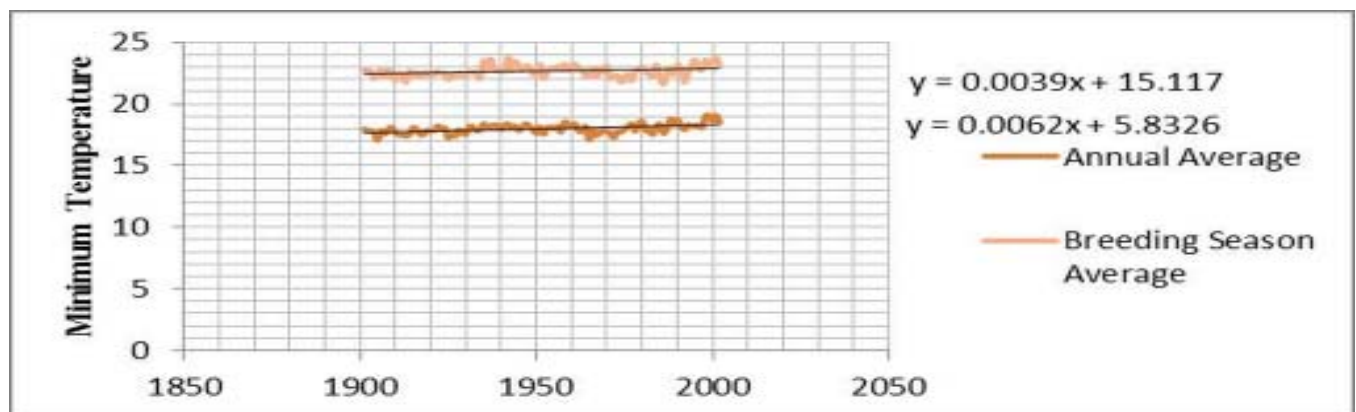


Figure 8. Trends of annual minimum temperature and breeding season minimum temperature (1901-2002)

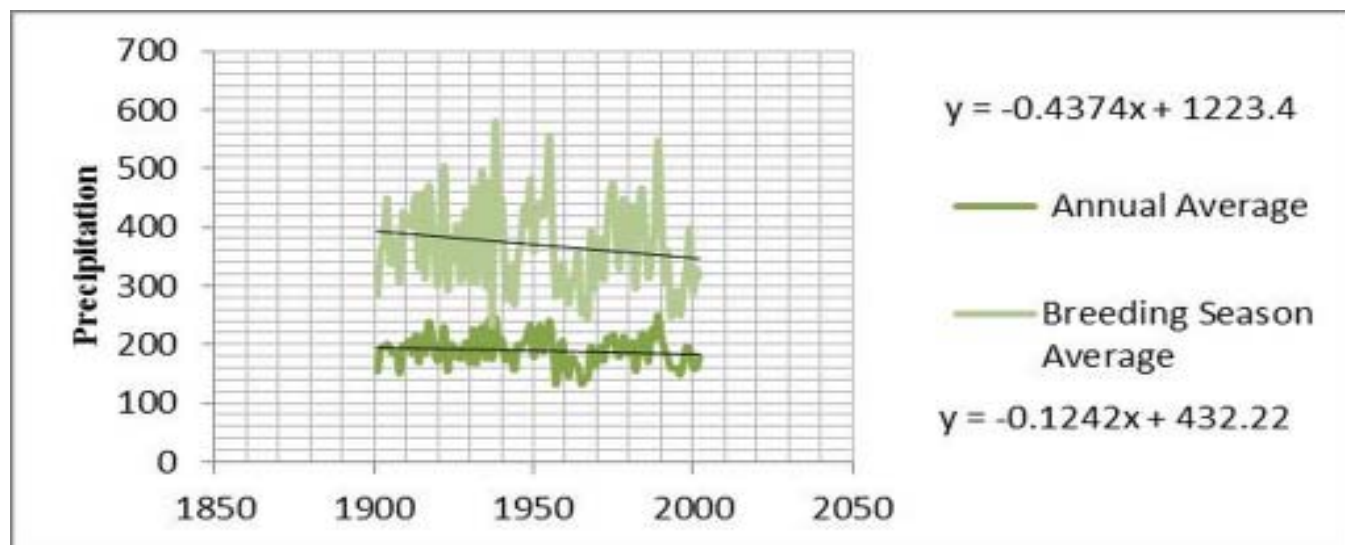


Figure 9. Trends of annual average precipitation and breeding season precipitation (1901-2002)

break their hibernation and prepares for breeding. Lack of rainfall may eventually lead to unfilled or semi filled breeding ponds, leaving the newly hatched eggs, larva and metamorphs surrender to the predators. Thus, it can be said that impact of change in the environment may ultimately affect the newt's population in the study region slowly but steadily.

Again, it must be highlighted that, although the distribution models provide significant intuitions regarding conservational approaches, still there are major theoretical reservations to be addressed in the study of environmental niches of organisms, such as the definition of fundamental interactions between spatial distribution and variables, and how those orientations affect model performance (McPherson and Jetz 2007, Tsoar *et al.* 2007).

## CONCLUSIONS

We assume our findings will support the policymakers and conservation enthusiasts by enabling them in making more precise decisions to protect the species. Apart from environmental factors, topography and human impacts also play crucial role in designing the habitat distribution of a certain species. Thus, more investigation and data assemblage could help to improve the results, particularly those concerned with connectivity, breeding sites, topography and anthropogenic impact. The MaxEnt model outputs can be of great significance for in-situ conservational process if the population is really approaching threatened category

in near future. We hope that our findings can be allocated to classify areas for the protection of this rare species that call for precise organization and supervisions.

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**Authors' contributions:** B.D and A.D. designed the work. B.D and D.S executed the study, composed the draft manuscript. A.D. perceived the idea and tailored the final manuscript.

**Conflict of interest:** The authors declare no conflict of interest.

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