

Predicting Impressions of Climate Change on the Distribution of Crocodile Newt (*Tylototriton verrucosus*), A Rare Amphibian in the Darjeeling Himalayan Sub-region, India

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ABSTRACT

In view of a proper action plan on conservation and management of a species, particularly the rare ones with special ecological interest, comprehensive knowledge on its geographic distributions is a must. *Tylototriton verrucosus* is one such species with special ecological importance, being the lone representative Urodel in India. Information on its distribution is there but scarce. In West Bengal, India, the distribution of *T. verrucosus* is restricted in the northern section. The preliminary goal of this work is to (i) recognize and predict the present and future distribution range of *T. verrucosus* on the basis of species incidence data and 19 environmental variables, (ii) define the most significant climatic variables regulating the distribution of the species in the Darjeeling Himalayan sub-region. We accomplished our goal utilizing maximum entropy algorithm, species occurrence data of *T. verrucosus* and environmental predictor variables. The AUC Value 0.859 with a s.d of (X value) was considered statically significant compared to null value is 0.5 in Maxent based model. The potential present optimal distribution area covers nearly 26.98 Km² areas. Our findings depicted that Annual Mean Temperature (46.6%), Isothermality (29.5%) and Precipitation of Driest Quarter (11.6%) promises to be the key environmental variables for predicting current and future potential distribution. Our results suggest (i) an increase in optimal suitable area in both 2050 and 2070 for the RCP scenarios of 4.5 and 8.5, respectively and (ii) Annual mean temperature regulates the overall distribution of the newt. The findings could be used in a variety of ways, including the identification of additional territories where newts may already exist but have not yet been detected; the popularity of areas where it's more likely to spread; the concern choice location for creation and refinement; and the preservation and protection of such rare species.

Key words: Climate change, Modeling, MaxEnt, RCPs, Amphibia, Conservation.

INTRODUCTION

The global climate has been witnessing the human impact on it since the last few decades. Apart from the high amounts of greenhouse gas emissions, the rise in world temperature is also a serious concern. During the last century the world temperature showed an increase by 0.078 degrees (Hansen et al. 2010), and predictions suggests it can rise up to 4.8°C by 2099 (Priti et al. 2016). Drastic change in the environmental factors leads to the disruption of tolerance level eventually forcing an organism to rehabilitate in new area (Pearson and Dawson 2003) and for some species, especially the amphibians (Araújo et al. 2006) the possible habitat will likely be wiped off absolutely (Malcolm et al. 2006, Coetzee et al. 2009, Anderegg et al. 2015). Climate

change is answerable for the range shift and decline of many species in the past (Chen et al. 2011, Dobrowski et al. 2013). Thus to make an effective conservation plan it is quite important to consider the prediction of probable habitat distribution of an organism comprising the environmental change and human impact on it (Dawson et al. 2011).

The crocodile newt, *Tylototriton verrucosus* (Anderson 1871), is the lone member of the order Urodela (Class: Amphibia) in India. It is noteworthy to mention that the species is listed under Schedule I of the Indian Wildlife (Protection) Act-1972. Having a limited distribution in India, records of its occurrences have been reported from Darjeeling (Dasgupta 1983, 1984, 1988, 1990, Dasgupta and Dasgupta 1990a, b; Dasgupta et al. 1989), Manipur (Selim 2001), Arunachal Pradesh (Mansukhani et al.

1976). Besides, the species has also been known to inhabit the mountain regions of Southern China (Zhao and Adler 1993), Bhutan, Burma, Thailand, and Vietnam. Studies regarding behavior, viz. breeding (Annandale 1908, Chaudhuri 1966, Dasgupta 1983), habitat (Shrestha 1984, 1989, 1994), life cycles present (Hegde and Deuti 2007) has been conducted previously, but only a few works addresses the species distribution modeling aspect of this species. The recent most work in this regard predicted the occurrence of Crocodile newts in distinct mountain regions of South Eastern sections of Asia (Sengupta 2012).

To comprehend the probable response of a species to climate change, it is important to model its habitat, both the present and the future potential ones as well. Species Distribution Models (SDMs) are supposed to be empirical tools for conservational planning and practices of a species (Whittaker et al. 2005; Williams et al 2009). SDMs can be helpful in deducing the potential habitat distribution and the bioclimatic factors (Raxworthy et al. 2003, Anderson and Martinez-Meyer 2004, Franklin and Miller 2009, Thorn et al. 2009, Elith and Leathwick 2009, Peterson et al. 2011, Wilson et al. 2011) shaping such distribution and habitat suitability, especially for rare and cryptic species (Santos et al. 2006) like *T. verrucosus*. Among many SDM algorithms, MaxEnt (Maximum Entropy, Phillips 2004) is mostly relied upon, especially in the cases of rare organisms as it relies on presence-only data collection method of species occurrence (Phillips et al. 2006, Elith et al. 2006, Pearson et al. 2007, Wisz et al. 2008, Rebelo and Jones 2010, Elith et al. 2011, Sardà-Palomera et al. 2012, Garcia et al. 2013, Marcer et al. 2013). Thus the practice of MaxEnt modeling since the past few decades seems quite obvious to investigate the shifts in species range, calculate possible threats under present and future Climates and fluctuation in the species diversity (Franklin 2009, Peterson et al. 2002, Duckett et al. 2013, Gallagher et al. 2013).

We used MaxEnt algorithm to assess the key environmental factors followed by mapping the likely distribution of *T. verrucosus* in the Darjeeling and Kalimpong districts of west Bengal, India. *T. verrucosus* is listed as least concerned on the red list of The International Union for Conservation of

Nature (IUCN). Our study also emphasized in the prediction of suitable climatic regions under the future climatic scenarios of two separate time periods, viz. 2050 and 2070 depending on the Representative Concentration Pathways (RCP 4.5 and 8.5).

MATERIALS AND METHODS

Study area and its significance

Eastern Himalaya, an area with diverse physiography and environmentally rich biodiversity, has been illustrated by Biodiversity Hotspots, Mega Diversity Zones, Endemic areas of Bird and International Eco-regions (Brooks et al. 2006). The Eastern Himalayas encompass Nepal, in India the mountain strips of Darjeeling, Sikkim, North Eastern states viz. Arunachal Pradesh, Manipur, Mizoram, Assam, Meghalaya, Nagaland and Tripura; and eastern Bhutan. The area homes a range of distinctive flora and fauna of global significance with endemism in species richness (Myers et al. 2000, Dhar 2002). However, being somewhat recent, the Eastern Himalayas offer low endemism, particularly among higher taxa. Regardless of the overall low endemism, it shares numerous species with globally substantial populations.

Our field of study comprises the Darjeeling Himalayan Sub-region, i.e., districts of Darjeeling and Kalimpong, located in the northernmost part of West Bengal, India, within the Eastern Himalaya. The area principally comprises of alpine and rough mountainous terrain. Together, these two districts involve 3149 sq.km of area (Fig. 1). The study area is geographically stretched between latitudes from 26° 27" to 27° 13" N and longitudes from 87° 59" E to 88° 53" E. Elevation of the study region varies between 15 m to 3602 m from the mean sea level. The slope ranges around flat to 80°. The area is affected climatically receiving a heavy rainfall by south-western and north-eastern Indian monsoon. According to the District portal, Darjeeling, the average annual precipitation of this region is 3092 mm. The region experiences very wet summer and a dry and cold in winter season. Sometimes, the temperature falls down near zero degrees in the study area.

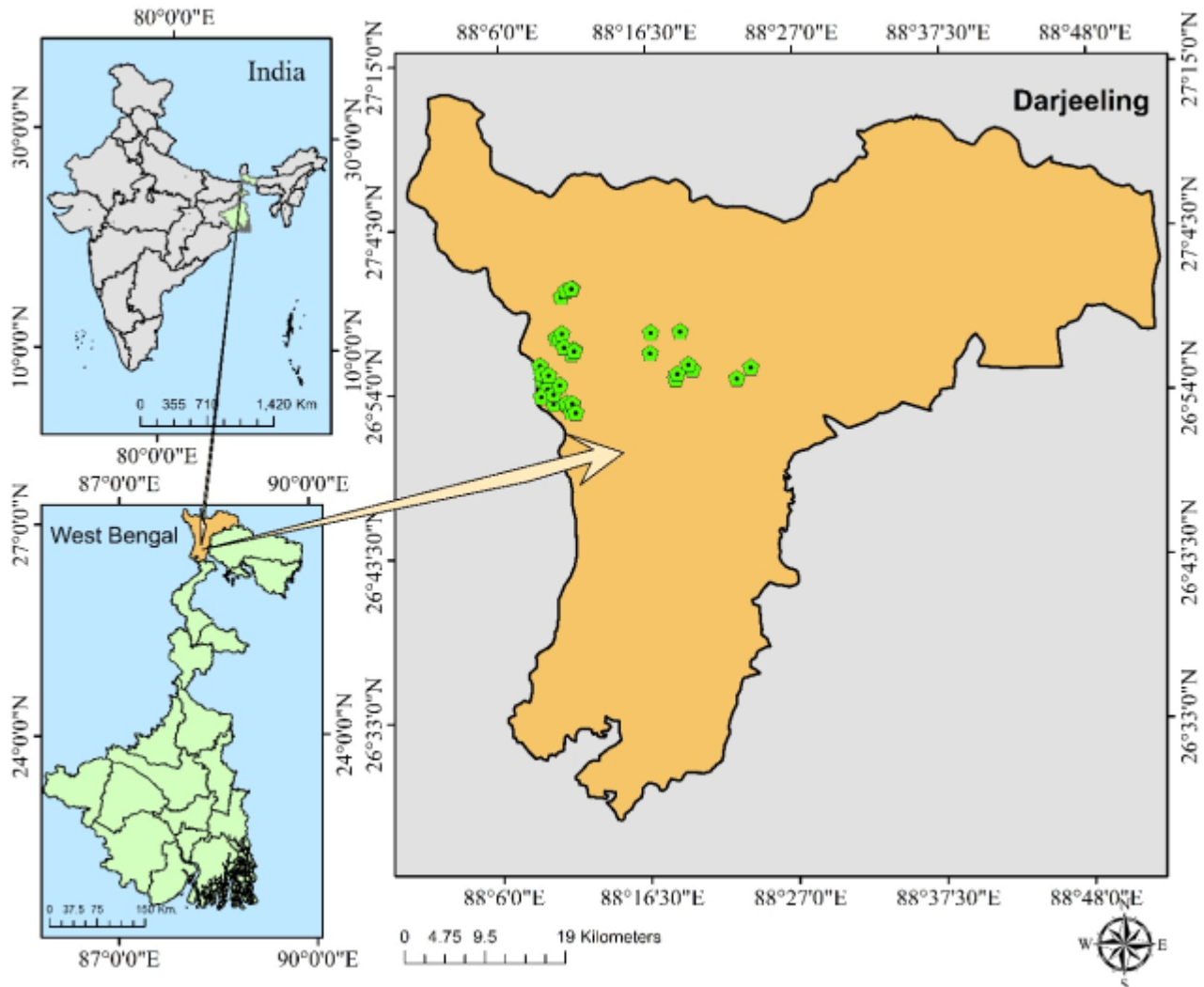


Figure 1. Location map of the study region. Green point showing location of species occurrence

Data collection and present distribution of *T. verrucosus*

Our study encompassed the use of presence – only data of species occurrences. The presence-only method of data collection has been preferred against the presence-absence method as it prompts pseudo-absence information of species event. A comprehensive review of literature was done to order every single accessible data for the presence of *T. verrucosus* in the Darjeeling Himalayan sub region. To reduce the potential inaccuracies in species occurrence data, we eliminated duplicate records using SDM toolbox (Brown et al. 2017). Finally, a total of 37 *T. verrucosus* presence points were identified and incorporated into this study to model the species' potential distribution, both current and future. The species occurrence data was collected through regional surveys to ascertain the presence

of newts in the study region and finally tallied with published literature(s) (Hegde and Deuti 2007), and online databases (global Biodiversity Information Facility <http://www.gbif.org/> and VertNet <http://portal.vertnet.org/>). We used ArcGIS 10.1 software to plot the distribution points in GIS environment.

Selection of environmental variables

Our study included 19 environmental variables for *T. verrucosus* habitat suitability analysis and species distribution. As of their predictive value, these environmental variables are more subtle in delineating the tolerance level of a habitat both physiologically and ecologically (Thompson et al. 2009) than just temperature and precipitation indicators (Graham and Hijmans 2006, Kumar et al. 2009). We obtained environmental predictors data from World Clim (<http://www.worldclim.org/current>)

as raster layers with a spatial resolution of 30 arc seconds (~1 km). The dataset was prepared by the interpolation of the historical records (1970–2000) of monthly precipitation and monthly temperature. The current bioclimatic variables (raster) have been spatially interpolated and represents the climatic standards from 1970–2000. These environmental variables are highly significant as they are obtained from monthly rainfall, and minimum, maximum and mean temperature and point towards an overall trend of rainfall and temperature depending on the monthly values of these variables.

For habitat suitability model under future climatic conditions, Global Climate Model (GCMs) data of spatial resolution 30 arc seconds (~1 km) resolution were selected from CMIP5 (IPPC Fifth Assessment) for the years 2050 and 2070 (<http://www.worldclim.org/CMIP5>). Species distribution projections under a single or restricted number of climatic scenarios can lead to ambiguity to an unknown extent (Beaumont et al. 2008). Thus, we incorporated two different global climate models (GCMs) and two greenhouse gas (GHG) concentration pathways (RCPs) (RCP 4.5 and RCP 8.5). Among the GCMs/ we used BCC-CSM1.1 (Beijing Climate Centre, China Meteorological Administration) as it has a better suitability to regions with greater extent of monsoon precipitation (Jena et al. 2016, Raju and Kumar 2016). RCP 4.5 infers that annual global GHG emissions will peak nearby 2040, and then decline and in RCP8.5, emissions will continue to increase all the way through the 21st century (Meinshausen et al. 2011).

We assessed the multiple correlation of all the 19 environmental predictor (Remya et al. 2015, Yang et al. 2013) using correlation coefficient (r) in ArcGIS desktop (version 10.1) using SDM toolbox and removed the ones with low projecting capability (i.e., jackknife training gain and percent contribution). To remove highly correlated variables the correlation coefficient was set on a value of $(r) \geq 0.70$ (see Appendix). The selection of environmental variables was also supported by Principal component analysis (PCA). Finally, the model was run with a set of five selected variables, these are Annual Mean Temperature (Bio1), Isothermality (Bio3), Minimum Temperature of Coldest Month (Bio6), Precipitation Seasonality (Bio7), and Precipitation of Driest

Quarter (Bio 14).

Development of species distribution models

In our study, we used MaxEnt software version 3.4.1 (Maximum Entropy, <http://www.cs.princeton.edu>) to generate species distribution models to map both present and future geographical distribution of newts in the Darjeeling Himalayan sub-regions. MaxEnt provides species distributions depending on presence-only data by searching the distribution of maximum entropy, concern to the limitations that the predicted value of every bioclimatic variable below this anticipated distribution ought to fit its empirical average (Phillips et al. 2006). The model thus acquired reveals the comparative likelihood of species distribution against all the grid cells within a pre-defined geographical area, where a great predictive-value related to a specific grid cell designates the possibility of the cell with favorable bioclimatic conditions for the species to be modeled (Elith et al. 2006). The MaxEnt model not only provides better outcomes when compared to other methods, moreover achieves best results under smallest quantity of sample incidences (Pearson et al. 2007, Elith et al. 2006, Kumar et al. 2009).

The MaxEnt algorithm was run following the “default settings” manner as recommended by Phillips and Dudik (2008). The explanation of using the inbuilt settings being the fact that it has been in practice for studies of a wide array of organisms, ecological conditions, distinct species records, even in instances with sample bias. One reason for error prone prediction results while using presence-only data is sampling bias (Fourcade et al. 2014). Therefore we generated a bias file to bind the background points of species occurrences so as to isolate the preferred localities inside the study region (Phillips et al. 2009). We configured MaxEnt algorithm to employ 75% of data for training and 25% for analyzing the model. Furthermore, the logistic output design was chosen because it is robust to unidentified incidence, and it is also easier to conclude as the projected likelihood of occurrence of species subject to the limitations imposed by the bioclimatic variables (Phillips et al. 2008). This approach suggests that the grid cells having smaller logistic outputs are ascribed to be unfavorable or minimal favorable ecological niche for the species

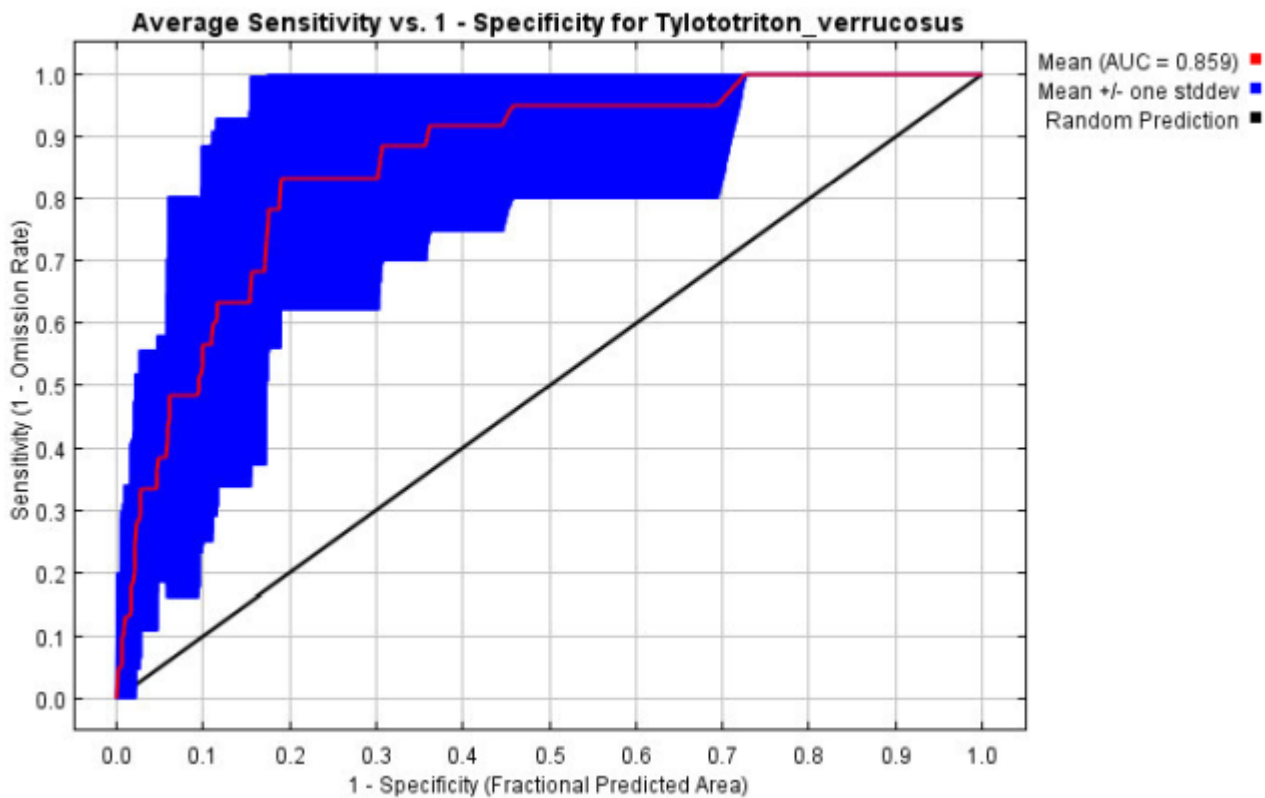


Figure 2. ROC curve plot for *T. verrucosus* under current climatic conditions

under study. Principal Component Analysis (PCA) was carried out to minimize dimensionality and to decide the percentage contribution of each environmental variable, using R studio.

As the sample size is relatively small, the final MaxEnt model engaged quadratic, linear and hinge feature only (Kumar et al. 2014). Upon testing with regularization multiplier, the value 0.5 provided best demonstration of the current and future habitat distribution of *T. verrucosus* species without being an over-fit. The background points were taken up to 5,000.

The suitability range of the habitat distribution maps of present and future times varied from 0 to 1. These potential habitats were regrouped into five classes of suitability (Yang et al. 2013), unsuitable (0–0.2); barely suitable (0.2–0.4); suitable (0.4–0.6); highly suitable (0.6–0.8); very highly suitable (0.8–1.0). We calculated the area of each identified classes in ArcGIS environment. For easy understanding, both the highly suitable and very highly suitable classes can be added together to form optimum suitability class (suitability index 0.6–1.0).

Model evaluation and authentication

We evaluated the fitness of the final model by means of area under the curve (AUC). The area under the curve (AUC) is the threshold-independent practice of model performance that distinguishes existence from nonexistence (Thuiller et al. 2005) by means of specificity and sensitivity (Phillips et al. 2006). The threshold of the precision was determined by the AUC of the ROC (receiver operating characteristic) plots delivered by MaxEnt (Baldwin 2009). The AUC value for our current distribution model was 0.859, with a standard deviation of ± 0.114 (Fig. 3). The area under the curve plots illustrates both sensitivity of the degree on prediction of presence and specificity on the prediction accuracy of absences (Fielding and Bell 1997). The AUC values range from 0 to 1; a value of 0.5 designate that the models success was not better than that anticipated by random, while a score of 1.0 specify a perfect fit. A value less than 0.5 shows that the model is a worse fit (Engler et al. 2004). An AUC value > 0.90 can be inferred as of excellent performance, while AUC > 0.80 can be ascribed as very good (Araujo et al. 2005).

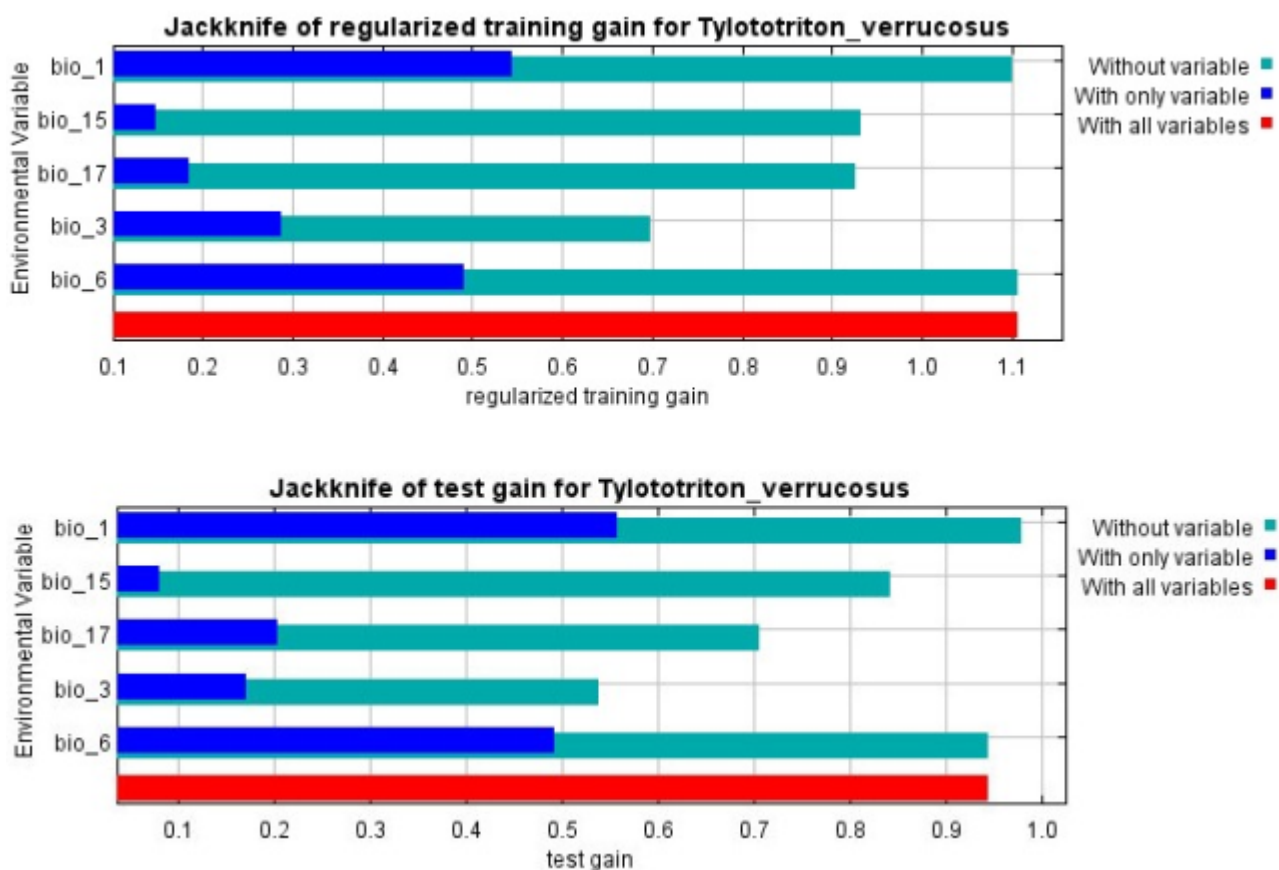


Figure 3. Jackknife plots for training and test gains showing contribution of variables for the current distribution.

RESULTS

Model results

Among the environmental predictors, Annual Mean Temperature (Bio1) contributed highest with 46.6%, Isothermality (Bio 3) 29.5%, the contributions of the last three variables altogether was : Precipitation of Driest Quarter (Bio 17) 11.6% , Precipitation Seasonality (Bio 15) 10.9%, and Min Temperature of Coldest Month (Bio 6) only 1.3%. Thus, Bio 1,

Bio 3, Bio 17 and Bio 15 collectively contributed up to 98.6% in model building (Table 1). Figure 3 displays jackknife test outputs alongside significance of selected environmental variable’s and Figure 4 demonstrates the response curves for the environmental variables.

Predicted current potential distribution

Our model predicted the current range for *T. verrucosus* in Darjeeling and Kurseong, where the

Table 1. Selected environmental variables and their contribution to each climatic scenario

Code	Environmental variables	Percent contribution				
		Current Climate	2050		2070	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Bio1	Annual Mean Temperature	46.6	43.1	44.6	44.4	44.1
Bio3	Isothermality	29.5	32.9	32.5	32.6	32.6
Bio17	Precipitation of Driest Quarter	11.6	15	15.1	15	15.1
Bio15	Precipitation Seasonality (CV)	10.9	8.3	7.3	7.4	7.5
Bio6	Min Temperature of Coldest Month	1.3	0.7	0.6	0.6	0.7

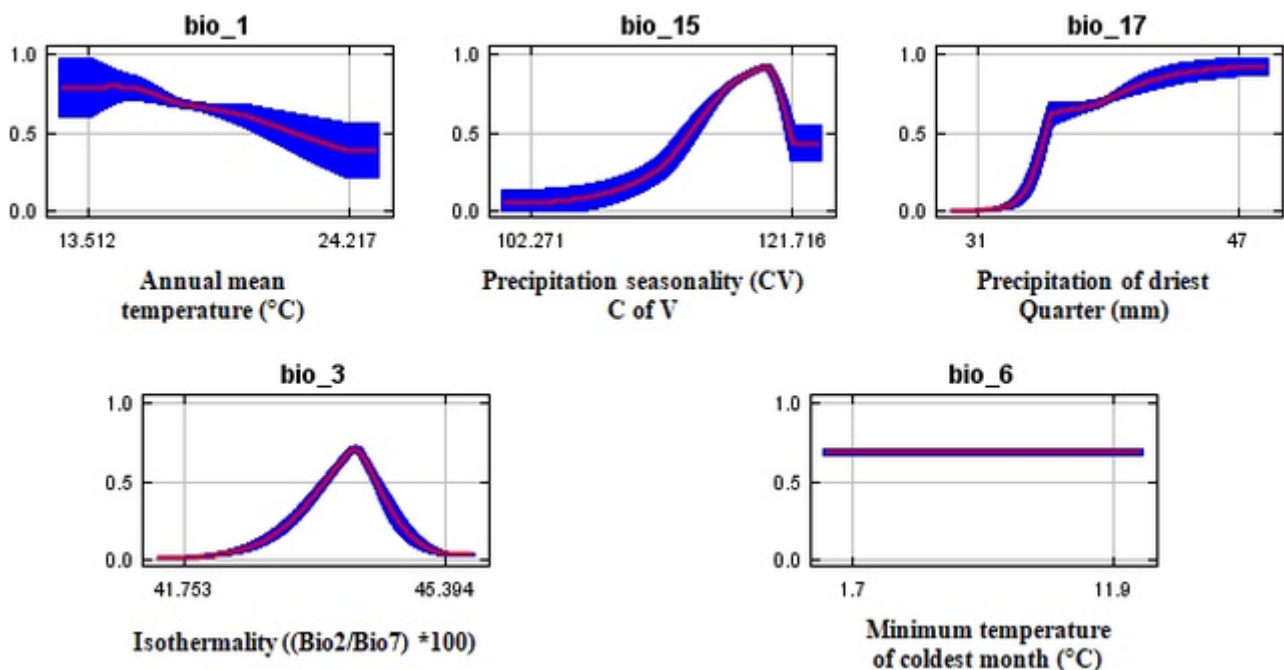


Figure 4. Relationships between the selected environmental variables and probability of *Tylototriton verrucosus* species suitability

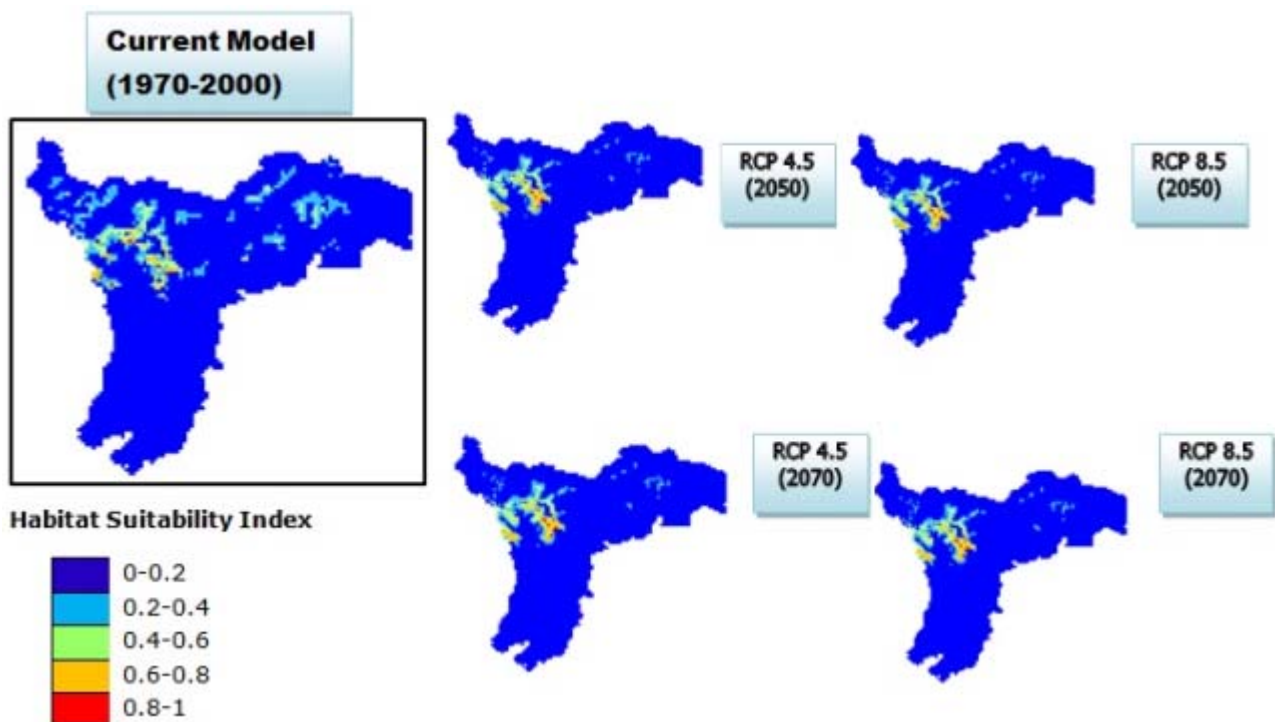


Figure 5. Predicted current and future habitat suitability map of *Tylototriton verrucosus*

species is known to be present already. However, it also predicted suitable territories in the Kalimpong district, where no known records of *T. verrucosus* occurrence is available. Places, namely Deolo, Silery Gaon, Rishop, Pedong, Kolakham, Lava, Loley gaon in Kalimpong can be suitable for introduction and

rehabitation as far as conservational aspects are concerned. Interestingly, the present potential distribution is substantially greater than the existing occurrence of *T. verrucosus*. The model expected that the optimal suitable area would be 26.98 Km².

Predicted future potential distribution for 2050 and 2070

While the territories of the future potential newt distribution are very similar to those of the present potential newt distribution, our MaxEnt model results demonstrated that the geographical distribution would then extend below the expected range of climatic variation. The projections for 2050 and 2070 using the Rcp4.5 and Rcp8.5 climate models suggested a significant increase in optimal suitable area compared to the predicted current distribution of newts (Fig. 5). For 2050, our model predicted an optimal suitable habitat of 47.22 Km² areas for the RCP 4.5 scenario and 46.53 Km² of optimal suitable habitat for RCP 8.5 scenario. The model estimates 47.90 Km² of optimal suitable habitat for RCP 4.5 scenario and 47.88 Km² of optimal suitable habitat for RCP 8.5 scenario, for the year 2070.

DISCUSSION

Although significant, research on the geographical distribution of *T. verrucosus* is little, especially in India. The MaxEnt model suggests the need of more field survey for *T. verrucosus* distribution, as there are more suitable areas present in the study region (Table 2). Two most important climatic parameter, temperature and precipitation shape key processes like habitat selection and dispersal. The newt’s life cycle is exemplified by periodic migrations among terrestrial and aquatic habitats for foraging and breeding respectively (Hegde and Deuti 2007). Annual Mean Temperature, Isothermality, and Precipitation of Driest Quarter turn out to be the key predictive environmental factors collectively contributing 87.7 %.

Our findings suggest that climate change scenarios will affect the *T.verrucosus* distribution, but interestingly in a positive way. It is obvious that the newt’s distribution region and population would alter, yet the extent of that change relies upon the scenario of climate change. Comparable investigations performed on this species in Thailand also proposes that climate change is one of the most significant factors influencing habitat change and reasonable territory expansion (Pongpattananurak et al. 2013).The predicted increase in the suitable habitat might be of great relief for the management strategists and policymakers to make effective conservation action plans. All models predicted that habitat suitability will increase nearly twice as of current suitable area in all four; RCP4.5 and RCP8.5 of 2050, and RCP4.5 and RCP8.5 of 2070 climatic change scenario. However, the adaptive capabilities of a species to cope up with climate alteration will rest on the pace of climate change and its own dispersal efficiency (Moritz et al. 2008, Loarie et al. 2009). Still increasing habitat suitability points out towards the possibility of truncated connectivity in near future. Nevertheless, some amphibians using both terrestrial and aquatic habitats are known to migrate significant distances for suitable habitats (Smith and Green 2005, Sinsch 2014). Species distribution models relying on environmental variables do not essentially illustrate the significance of topography. It affects a species’ distribution with regard to microclimate (Dobrowski 2011). Suitable habitats with similar topography may be found in adjacent states like Sikkim and Meghalaya.

In a fast changing environment, survival will rely on a species’ ability to find shelters buffering beside extreme circumstances (Scheffers et al. 2014).

Table 2. Changes in suitable habitats from current to future climate scenarios (all area units in Km²)

Habitat Suitability Classification	Current Area (1970-2000)	Future							
		2050				2070			
		RCP 4.5	Area Change	RCP 8.5	Area Change	RCP 4.5	Area Change	RCP 8.5	Area Change
Unsuitable	2528.98	2609.51	80.53	2606.77	77.79	2606.07	77.09	2605.48	76.50
Barely suitable	215.67	117.34	-98.33	119.43	-96.24	119.42	-96.25	119.97	-95.70
Suitable	83.68	81.24	-2.44	82.58	-1.10	81.92	-1.76	81.98	-1.70
Highly suitable	23.42	41.66	18.24	40.97	19.55	42.34	20.92	42.33	20.91
Very highly suitable	3.56	5.56	2.00	5.56	2.00	5.56	2.00	5.55	1.99

Alongside many ectotherms can reprogram their physiology and patterns of behavior according to the environment (Abram et al. 2017). Owing to the drastic change in climate, especially the temperature some ectotherms have been found with increased physiological rates, such as metabolic rate, cardiac cycle rate and dispersal, leading to a higher food requirement (Seebacher et al. 2015).

CONCLUSIONS

The favorable environmental variables and predicted present and future suitable habitat can be of a great value for creating conservation and management action plans for both the government and non-government agencies. In this aspect, MaxEnt algorithm has reflected as a convenient tool for assessing the climatic requirements and impacts of climate change on the newt in the study area compiling occurrence information, geographic information system (GIS) tools, and species distribution model (SDM). The model proposes expansion in the newt's distribution range towards currently unsuitable regions of the study area. In particular, the modeling outputs help conservation initiatives to identify appropriate ecosystems under the future climate scenario in the Darjeeling Himalayan sub-region.

While the established model reveals admirable predictive command, it is also important to consider the concern of species ecology. Our findings indicate the presence of adequate amount of suitable area for the newt to eventually expand to the Kalimpong region than its current distribution. However, the absence of newts in those areas despite having suitable environment may be due to additional factors like soil, allopatric barriers, anthropogenic disturbances, competition with others species and other parameters. Insufficiencies of satisfactory data lead to the exclusion of such factors in our study and provide a gap for new areas of research.

The species may be endangered due to habitat fragmentation, as they now exist in small and dispersed subpopulations. Their habitats, however, must be preserved as an organized network; failure to preserve the species' core distribution typically means that the population is threatened by various environmental and genetic progressions such as

inbreeding depression, population chaos, and genetic drift. Wide-scale initiatives, such as connectivity restoration, may need to support site-scale efforts in the near future for the species to be successfully conserved.

ACKNOWLEDGEMENTS

The authors are indebted to the native people of the Darjeeling district for giving us species information by questionnaire means that facilitated us in recognizing the sites of the newts.

Authors' contributions: BD developed the theoretical background, designed the model and the computational framework. AD and BD analyzed the data. AD and KKB drafted the manuscript. All authors read and approved the final manuscript.

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

Funding: the authors did not receive any funding for this study.

Appendix: Correlation matrix among environmental predictors (Highly correlated predictors($r \geq 0.70$))

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Received: 31st October 2021

Accepted: 8th November 2022

Appendix A.1 Different Greenhouse gas scenario and description (Moss et al. 2008).

Scenarios	Description
RCP 2.6	A stable scenario where GHGs will be steadied by green technologies and the radiative force will be rise up to 2.5 W/m ² by 2100 relative to pre-industrial values
RCP 4.5	A stable scenario where GHGs will be steadied due to green technologies and the radiative force will be extended up to 4.5 W/m ² by 2100 relative to pre-industrial values.
RCP 6.0	A moderate scenario where GHGs will moderately increase, and radiative force will be rise up to 6.0 W/m ² by 2100 relative to pre-industrial values
RCP 8.5	A comparably extreme scenario where GHGs will gradually rise, and radiative force will be extended up to 8.5 W/m ² by 2100 relative to pre-industrial values.

Appendix A.2 Selected 19 bioclimatic variables for the preliminary model

Code	Bioclimatic variables	Unit
Bio1	Annual mean temperature	°C
Bio2	Mean diurnal temperature range (mean of monthly (max temp - min temp))	°C
Bio3	Isothermality ((Bio2/Bio7)*100)	
Bio4	Temperature seasonality (standard deviation*100)	C of V
Bio5	Maximum temperature of warmest month	°C
Bio6	Minimum temperature of coldest month	°C
Bio7	Temperature annual range (Bio5 - Bio6)	°C
Bio8	Mean temperature of wettest quarter	°C
Bio9	Mean temperature of driest quarter	°C
Bio10	Mean temperature of warmest quarter	°C
Bio11	Mean temperature of coldest quarter	°C
Bio12	Annual precipitation	mm
Bio13	Precipitation of wettest period	mm
Bio14	Precipitation of driest period	mm
Bio15	Precipitation seasonality (CV)	C of V
Bio16	Precipitation of wettest quarter	mm
Bio17	Precipitation of driest quarter	mm
Bio18	Precipitation of warmest quarter	mm
Bio19	Precipitation of coldest quarter	mm

Appendix A.3 Cross-correlation matrix (r) among the group of selected bioclimatic predictors calculated by principal components (PC).

Variables	BIO1	BIO 15	BIO 17	BIO 3	BIO 6
BIO 1	1.00000	0.47251	-0.65406	0.45126	0.95935
BIO 15	0.47251	1.00000	-0.55948	0.09468	0.43288
BIO 17	-0.65406	-0.55948	1.00000	-0.73941	-0.43349
BIO 3	0.45126	0.09468	-0.73941	1.00000	0.22974
BIO 6	0.95935	0.43288	-0.43349	0.22974	1.00000

Appendix A.4 showing Eigen value and its percentage produced by principle components for the group of selected climatic predictors (PC).

PC	Eigen value	% of Eigen values
1	46.44910	76.1769
2	8.44915	13.8567
3	5.82819	9.5583
4	0.23620	0.3874
5	0.01266	0.0208

**Appendix A.5** Created bias layer for the *Tylototriton verrucosus* to limit the background points to the species occurrence areas