IDENTIFYING HABITATS OF RED PANDA (*AILURUS F. FULGENS*) IN SAKTENG WILDLIFE SANCTUARY, BHUTAN IN MAXENT USING CLIMATE CHANGE SCENARIOS

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ABSTRACT

The red panda is a globally endangered species whose population is reported to be declining in the wild. It is a priority species for Sakteng Wildlife Sanctuary (SWS) since the frequency of disturbance from semi-nomadic inhabitants is relatively high in the landscape. Moreover, this landscape functions as an important connecting link between red panda habitats in state of Arunachal Pradesh (India) and Bhutan. Little research has been done on the spatial habitat distribution of the red panda in SWS. Lack of such information remains a challenge while implementing effective and holistic conservation initiatives. Therefore, this study attempts to identify the spatial distribution of potential habitats for red panda using the maximum entropy algorithm (Maxent 3.4.1). The mean temperature of the coldest quarter (Bio11) was the major predictor of habitat suitability for the red panda in SWS. The model predicted 226km^2 of potential habitat with the current climate scenario. Out of the total predicted habitats, less than 25 percent were within the core zones while the remaining 75 percent falls in multiple-use areas, timber extraction sites and buffer zone that are likely to experience a relatively high frequency of anthropogenic disturbances. With climate change, predicted potential habitats are likely to experience significant loss and an upward shift to a relatively higher elevation. The predicted shift towards higher elevation is likely to make red panda more vulnerable to disturbances from semi-nomadic communities who practice extensive grazing at higher elevations. Irrespective of any present or future emission mitigation endeavor, the natural system will probably experience the change as a consequence of already occurring climate change. Hence, the management of SWS should priorities on the identification and accomplishment of realistic goals that help the red panda adapt to predicted changes or new habitats in the landscape.

1. INTRODUCTION

Eastern Himalaya is home to diverse wildlife including several globally threatened species including the red panda. Mountainous topography with varying vertical climatic zonation of microhabitats and restricted species distribution makes the region known for many endemic species. The red panda or lesser panda is one of the globally endangered species (Glatston, 2015) endemic to eastern Himalaya (Roberts & Gittleman, 1984).

The red panda belongs to a monotypic family of Ailuridae (Duszynski, Kvičerová, & Seville, 2018) which feeds on bamboo leaves despite being categorized in the order of carnivora. The young leaves and shoots of bamboo comprise the primary diet for the red panda, supplemented with fruits, mushrooms, succulents, roots, and acorns according to the season (Yonzon & Hunter, 1991). It is mostly arboreal and has specialized habitat niche requirements related to forest types, elevation, availability of fallen logs and stumps, proximity to water sources and disturbances (Wei, Feng, Wang, & Hu, 1999; Yonzon & Hunter, 1991). They prefer Fir dominated mixed deciduous coniferous forest of the temperate zone with profuse bamboo undergrowth (Roberts & Gittleman, 1984).

The red panda occurs across the eastern Himalaya from western Nepal in the west to southwestern China in the east within the elevation range of 2200m to 4800m (Roberts & Gittleman, 1984). This distribution stretches across the temperate region of Nepal, India (Darjeeling, Sikkim and Arunachal Pradesh), Bhutan, northern Myanmar and part of Tibet, Sichuan and Yunnan province in China (Choudhury, 2001; Glatston, 2015; Wei et al., 1999). Two subspecies of the red panda are known to exist based on their morphology and geographic barriers. The Chinese subspecies *Ailurus f. styani* is restricted to Hengduan mountain in Sichuan and Nujiang River of Yunnan province in China while *Ailurus f.fulgens* is referred as Himalayan subspecies distributed across the eastern Himalayan range countries(Roberts & Gittleman, 1984; Wei et al., 1999)

Globally, less than 10,000 matured individuals of the red panda are estimated to exist in wild (Wang, Choudhury, Yonzon, Wozencraft, & Than, 2008) which are likely to further decline due to increasing anthropogenic and climate change induced threats (Glatston, 2015). Human population residing within the stretch of the red panda habitat across eastern Himalaya are known to be some of the poorest people whose dependence on natural resources is immense (Sandhu & Sandhu, 2015). This, in turn, elicits disturbances that are undesirable to the red panda (Acharya et al., 2018). Although, red panda is legally protected throughout the range countries and included in Appendix I of CITES (Glatston, 2015); habitat loss, degradation, fragmentation, mass flowering of bamboo, resource competition, attack by dogs and increased incidences of poaching and illicit trade of the species are threatening its survival (Bista et al., 2017; Dendup, Cheng, Lham, & Tenzin, 2016; Dorji, Rajaratnam, & Vernes, 2012; Glatston, 2015; Wei et al., 1999; Yonzon & Hunter, 1991).

Generally, the red panda in Bhutan occurs within the elevation range of 2400 to 3700 m in cool broadleaf to fir forest with good bamboo undergrowth preferably near water sources (Dorji et al., 2012). In 2011 red panda was reported to be present only in 13 districts (Dorji et al., 2012), but recently their distribution in 17 out of 20 districts was confirmed. Out of 10 protected areas and 9 biological corridors, the presence of red panda is documented from 7 parks and 8 biological corridors. Bhutan is predicted to have an estimated red panda habitat area of 8062.74km^2 (21% of the total geographic area), of which 62% are within the network of protected areas and biological corridors and only 21.4% were found to be moderate to highly suitable for the red panda (Dorji, 2011). Considering the average density of one red panda per 4.4 km^2 (Yonzon & Hunter, 1991); Bhutan is likely to have an estimated population of 442 individuals of red panda within the moderate to highly suitable habitats (Dorji, 2011). Though it is legally protected as Schedule I species (RGOB, 1995) and the majority of potential habitat in Bhutan falls within the network of park and biological corridors (Dorji, 2011); red panda is known to experience threats from the activities of humans residing in the same elevation range in and outside the protected areas. The threats include timber and fuelwood extraction, construction of roads, growth in tourism sector, people dependence on natural resource, extensive livestock grazing, accidental poaching and predation by dogs (Dendup et al., 2016; Dorjee, 2009; Dorji et al., 2012).

Sakteng Wildlife Sanctuary (hereafter SWS) is one of the ten protected areas in Bhutan (Figure 1). It is divided into three ranges; Merak, Sakteng and Joenkhar. SWS is home to indigenous semi-nomadic people known as Brokpa; a group of yak and cattle herder. More than 85% of the inhabitants' livelihood is dependent on yak and cattle rearing (SWS, 2019). They practice open grazing in meadows of the mountain and deep inside the forest based on the season. Their winter rangeland overlaps with the primary habitat of the red panda. Increasing herd size to maximize the

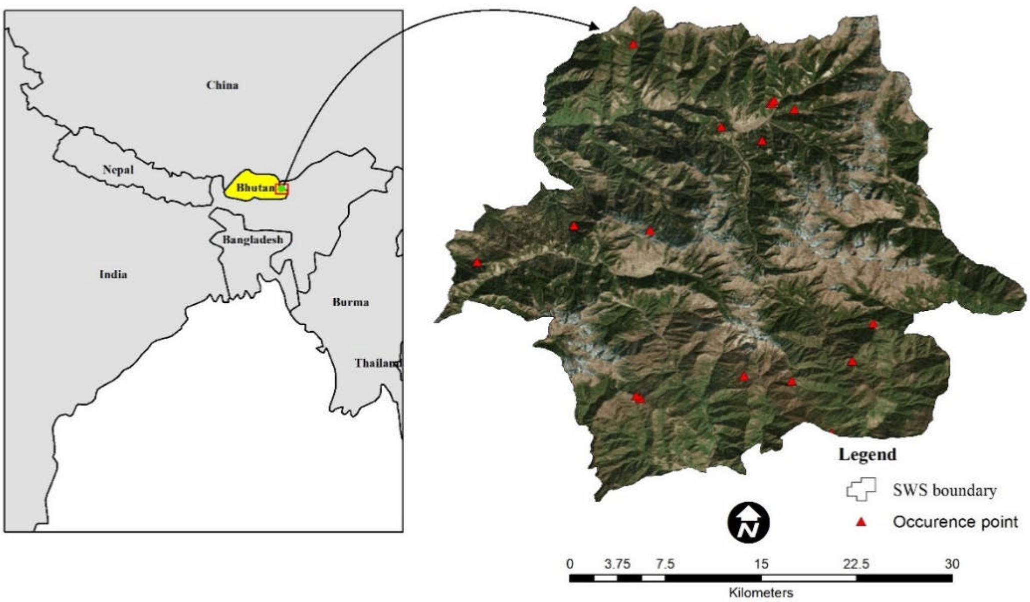

Figure 1 Location of Sakteng Wildlife Sanctuary (study site) and distribution of red panda occurrence points

livestock product and their immense dependence on forest and natural resources have further degraded the wild habitats, thus increasing the threat (Dorjee, 2009). Settlements in SWS have recently been connected with farm roads. Forest degradation, overuse of land for grazing, geological disturbances from excavation to construct roads and other climate factors have led to major landslides in and around the potential habitats of the red panda, leading to degradation and fragmentation. Timber requirements for construction and fuelwood for the settlement within and periphery of the SWS are also met from this forest. The existing trend of timber extraction and increasing demand will also result in habitat degradation (SWS, 2019).

Recent studies in Bhutan predicted increased in temperature and rainfall by up to more than 3.2^{0}C and 30% respectively at the end of the century (NCHM, 2019) which in turn increases the vulnerability of forests to climate change. Therefore, climate change, resources demand by huge livestock population and increasing timber needs by the inhabitant exerts intense pressure on forests in SWS which are important habitat for the endangered red panda.

Even though the red panda is identified as the priority species for conservation, information regarding the distribution of the potential habitat is sparse. Lack of reliable potential habitat distribution information for the red panda in SWS remains a challenge while implementing effective and holistic conservation initiatives. This study will identify potential habitat distribution of red panda within the landscape for current and future climate scenarios to ensure the long-term survival of the species.

2. METHODS

2.1. Occurrence points and predictor variables

The red panda occurrence data were acquired from the office of SWS collected during the national tiger survey (2014-2015), a biodiversity survey (2015), musk deer camera trapping exercise (2018), sustainable forest management plan survey (2018) and regular field patrolling by the field staff. Species are identified based on photographs captured by motion sensor camera traps, distinct scats and feeding characteristics of the Red panda. Red panda occurrence coordinates were collected using handheld GPS Garmin Etrex 30x. The systematic national tiger survey was conducted by the installation of a pair of camera traps in every 5km x 5km grid. Biodiversity surveys in 108 circular plots (12.62m radius) followed stratified random sampling and the musk deer survey used an opportunistic sampling method using motion sensor camera traps. The sustainable forest management plan survey adopted a systematic survey that was confined within potential resource extraction sites. Data collected during patrolling doesn't follow any defined survey method; however, extensive patrolling is regularly conducted across the landscape. After screening, 18 georeferenced occurrence points were selected for the study.

To model the potential habitats, 19 bioclimatic variables were downloaded from WorldClim (www.worldclim.org/bioclim) with 30 arc-second (~1km) spatial resolution (Hijmans, Cameron, Parra, Jones, & Jarvis, 2005). Bioclimatic variables consist of annual trends (mean annual precipitation and temperature) seasonality (annual range in precipitation and temperature) and extreme or limiting environmental factors (temperature of the coldest and warmest month, and precipitation of the wet and dry quarters) (Hijmans et al., 2005). However; for this study, ~1 km climate layer was resampled to 30 m resolution adopting a bilinear resampling technique in ArcGIS to represent the high climatic variability of the mountainous region. Downscaled IPPC5 (CMIP5) data of Community Climate System Model Version 4 were used to model the impact of climate change with RCP4.5 and RCP8.5 climate scenarios (Gent et al., 2011). The Representative Concentration Pathways (RCP) is a greenhouse gas (GHG) concentration trajectory used by the IPCC for its AR5 report. It provides a time-dependent projection of GHG concentration in the atmosphere or radiative forcing outcome such as stabilization level and trajectory that is taken over time to reach that outcome (Wayne, 2013). The emissions in RCP 4.5 will peak around 2040, then decline while in the case of RCP 8.5 emissions will continue to rise throughout the 21st century (Meinshausen et al., 2011). Global mean surface temperature for the year 2046-2065 is projected to change by 1.4ºC and 2ºC under the respective scenario of RCP 4.5 and RCP 8.5 (IPCC, 2014). The current scenario is represented by the average climate of the year 1950 to 2000 and the future climate for the year 2050 is the average of 2041 to 2060 (Hijmans et al., 2005). Slope and aspect layers were derived from 30m digital elevation model (DEM).

2.2. Predictor variable selection and modeling process

The Maxent (Maximum entropy algorithm) model is one of the robust species distribution modeling tool for presence only records (Elith et al., 2011). The performance of the model is not affected by collinearity (De Marco & Nóbrega, 2018; Elith et al., 2011; Phillips, Anderson, & Schapire, 2006). In the model, nineteen bioclimatic variables, slope and aspect were used as the predictor variables. However, elevation was excluded from the model since its inclusion in the model is known to result in a conservative prediction of species distribution range (Hof, Jansson, & Nilsson, 2012). The model was calibrated in the ENMeval package and a bias file was developed using Two-Dimensional Kernel Density Estimate (kde2d) function in R v3.4.4. The model was run with given settings; 5-fold cross-validation, regularization multiplier =2.5, features = linear, quadratic and hinge and output type = logistic. 70% of the occurrence data was used for training and the remaining 30% for testing the model. The model accuracy was evaluated based on the area under curve (AUC) of the receiver operating characteristic (ROC). AUC value ranges from 0 to 1; values > 0.5 suggest better performance with better discriminatory capability than the randomly generated model (Phillips et al., 2006).

Suitability value above 10 percentile training presence logistic threshold was selected as the suitable habitat for the species to generate the habitat map. The relative importance of each predictor variable was evaluated with the jackknife test. The model was executed in Maxent v3.4.1(Phillips, Dudík, & Schapire, internet). The mean center of 100 random sample points each from predicted habitat was used to determine the directional distribution of predicted habitats under the respective climate scenario. The directional distribution (standard deviational ellipse or SDE) tool summarizes the dispersion and direction of the features to understand the spatial distribution trend. The calibration of the SDE was done at 1standard deviation which will incorporate approximately 68% of all input feature centroids (Mitchell, 2005). The modeling involved different steps as mentioned in figure 2.

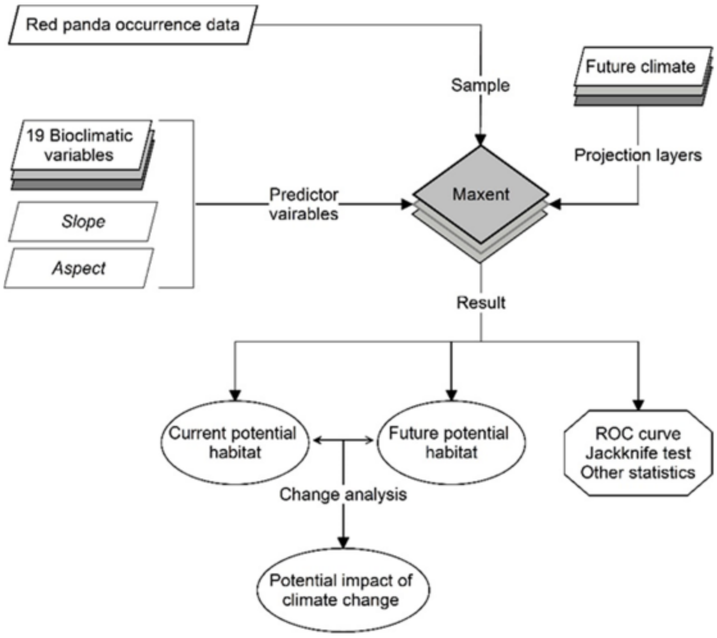

Figure 2 The workflow of the modeling process

3. RESULTS

3.1. Potential habitat distribution and influencing predictor variables

In Sakteng Wildlife Sanctuary (SWS), the Maxent model (mean AUC =0.772, SD = 0.041) predicted the availability of 226 km² of suitable habitat for red panda under current climate scenario. This accounts for 24.1% of the total area in SWS. Out of 226 km^2 predicted habitats, 54.63% falls within the jurisdiction of the Merak range followed by Sakteng (35.11%) and least in Joenkhar (10.34%). Although; Joenkhar has a small patch of suitable habitat, it acts as an important connecting link between larger habitats of Merak and Sakteng (Figure 4). The mean AUC = 0.772 suggests that model performance is relatively better than random prediction (Figure 3).

Amongst the 21 predictors (19 bioclimatic variables, slope and aspect), mean temperature of coldest quarter (Bio11) has contribute 86.4%, mean temperature of coldest month (Bio06) 7.5%, precipitation of warmest quarter (Bio18) 3.9% and combination of mean diurnal range (mean of monthly (max temp. – min temp.)) (Bio02), mean temperature of warmest quarter (Bio08) and mean temperature of driest quarter (Bio19) 2.3% to the current and future potential habitat distribution. The remaining 15 predictor variables do not contribute to the model and amongst the contributing variables, Bio19 has the least contribution (0.1%). Overall, variables related to temperature have a significant influence on the prediction of potential habitat for a red panda in SWS (Figure 5).

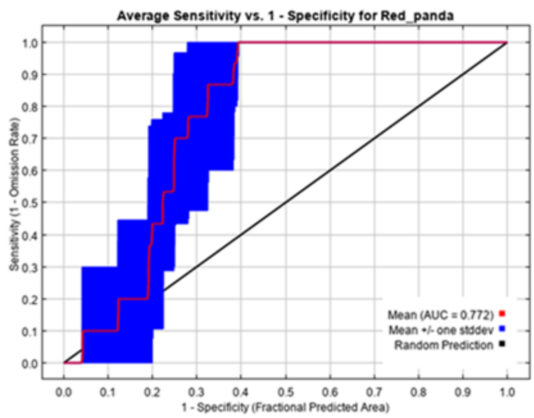

Figure 3 The ROC curve with AUC=0.772

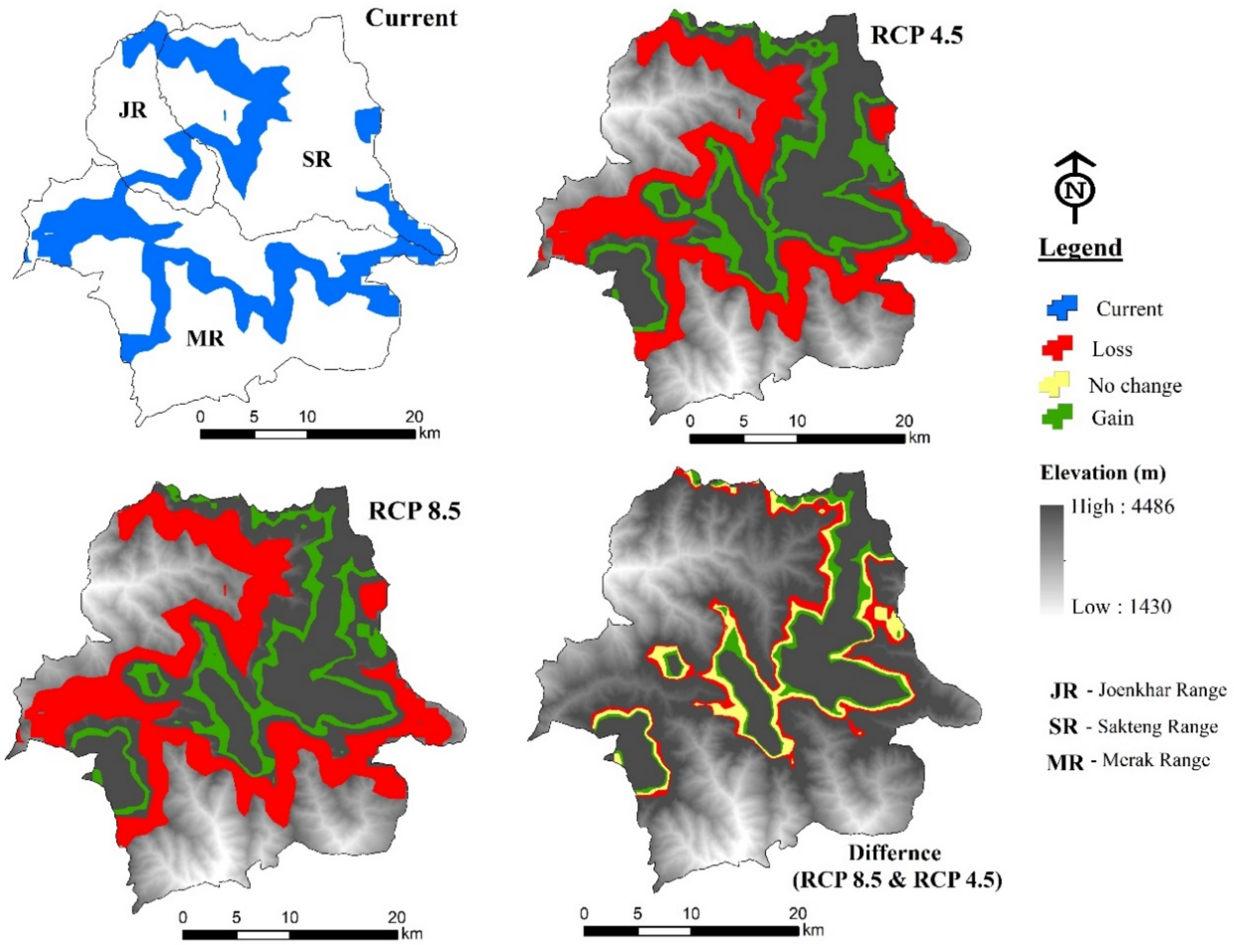

Figure 4 Model-based predicted potential habitat for the red panda in SWS. With future climate scenarios model predicted reduce in habitat suitability by up to 57.52% and 61.50% with RCP 4.5 and RCP 8.5 respectively

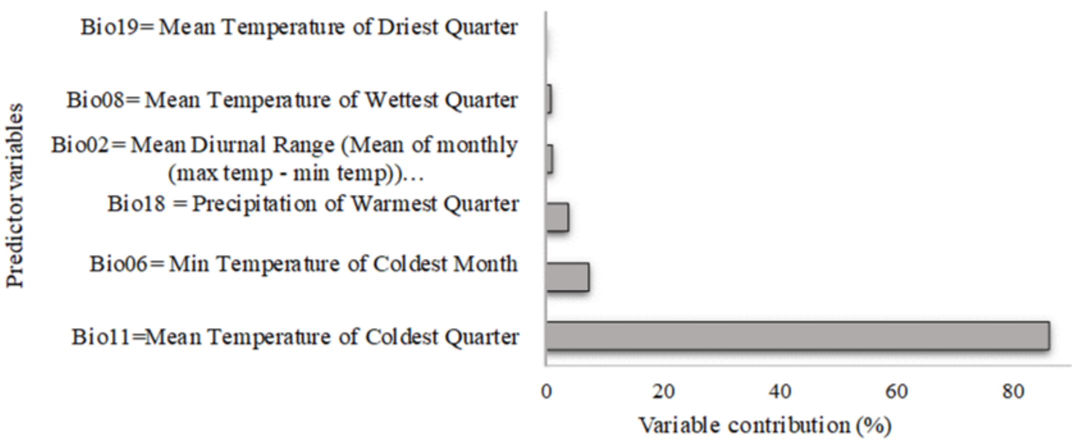

Figure 5 Contribution of the predictor variables to the model

3.2. The potential impact of climate change on habitat distribution

According to the model prediction under climate change scenarios; potential habitat for the red panda in SWS is likely to experience a loss and shift towards the higher elevation by the year 2050. The model predicted a loss in potential habitat up to 57.52% and 61.50% under RCP 4.5 and RCP 8.5 respectively. Habitat loss will likely be approximately 4% higher with RCP 8.5 in comparison RCP4.5. Based on the mean center and standard deviational ellipse, it is likely that places in the central parts of the SWS with relatively higher elevation will become suitable for red panda habitat by the year 2050 (Figure 6).

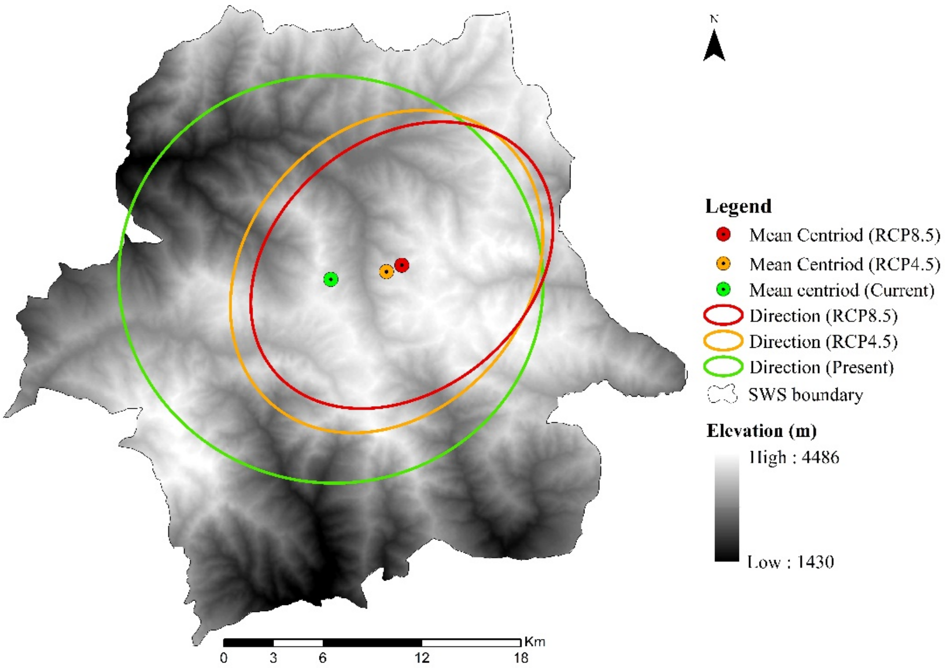

Figure 6 The predicted directional distribution of potential red panda habitats with climate change

According to the jurisdiction of the range, potential habitats in the Merak range are likely to experience significant loss (> 69%) followed by Joenkhar (< 64%) and least in Sakteng (< 41%) irrespective of the RCP. Besides habitat loss, the model also predicted the shift of habitat toward higher elevation concerning to the potential habitat predicted under the current climate scenario (Table 1).

Name of the Range	Range area (km^2)	Predicted potential habitat (km^2)			% Change in habitat in relation to current status	
		Current	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Sakteng	333.93	79.36	49.66	47.40	-37.42	-40.27
Joenkhar	121.50	23.37	8.86	8.45	-62.10	-63.86
Merak	482.60	123.45	37.60	31.30	-69.55	-74.65

Table 1 Potential impact of climate change to the potential habitats of red panda in respective range

3.3. Conservation status of predicted habitat

Areas within the SWS are divided into different management zones according to their usage. The core zones are designated for strict conservation where activities other than conservation works and research are prohibited while buffer zones are a transition zone between the SWS and areas outside the sanctuary. In between the two zones lies a multiple-use zone designated with few restrictions (WWF & SWS, 2011).

The timber extraction sites are the area designated for extraction of timber resource from the SWS to meet the growing demand for timber for local use (SWS, 2019). It is a part of the multiple-use zone. The area under timber extraction sites, buffer and multiple-use zones are likely to experience a relatively higher frequency of disturbances from human-related activities.

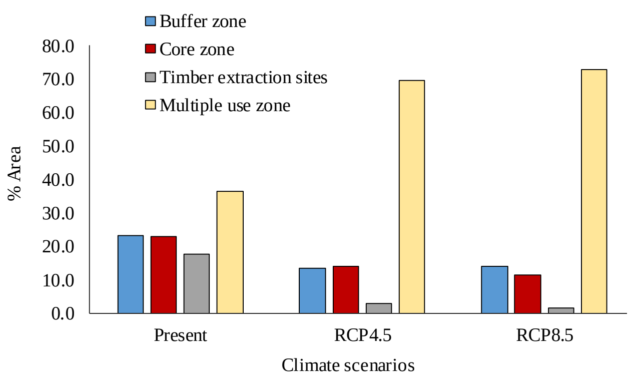

Figure 7 Distribution of predicted habitats under the respective management regime

Out of 226 km^2 of potential habitat predicted under the current climate scenario; 23.2% falls within the buffer zone, 22.9% in the core zone, 36.3 % in multiple-use and 17.6% in timber extraction sites. In the case of RCP4.5 scenarios, 69.5% occurs within the multiple-use zone followed by core (14.2%) buffer (13.4%) and timber extraction site (2.9%). Similarly, with RCP8.5, the distribution of potential habitat occurs more in the multiple-use zone (72.8%) followed by a buffer zone (14.1%) then core zone (11.5%) and 1.5% in timber extraction sites (Figure 7).

4. DISCUSSION

The IUCN conservation status of the red panda has changed from vulnerable to endangered (Glatston, 2015), which indicates that the species has and is experiencing significant threats. Understanding the spatial distribution of the potential habitat of species with the help of a model can enable conservationists to assess the existing threat and plan for future uncertainties.

The model predicted that in SWS, the changing climate will have a major impact on the distribution of the red panda habitat with a predicted decrease in the suitable habitat of up to approximately 62%. Though the model predicted 226 km^2 of potential habitat (fundamental niche) for red panda under the current climate scenario, actual habitat (realized niche) is likely to be less since the correlative species distribution model predicts fundamental niche which is larger than the realize niche (Polechová & Storch, 2008). Further, the distribution of species can be limited by other environmental factors like land use, edaphic and anthropogenic disturbances that are not incorporated in the model (Ranjitkar et al., 2014; F. Wang et al., 2018). Resampled bioclimatic variables may not represent the immense variability of climate in the high mountainous region, further increasing the uncertainty of the model. However, the predicted red panda distribution matches the anecdotally known and methodically confirmed distribution of the species in SWS (Dorjee, 2009). Taking into account the average density of 1/4.4 km^2 (Yonzon & Hunter, 1991) and 226 km^2 of predicted fundamental niche under ideal conditions, SWS is likely to support approximately 51 individuals of the red panda. However, the actual population might be lower with the realized niche.

The Himalayan ecosystem is rapidly changing under the influence of current global and regional warming and expected to exacerbate with the predicted increase in mean temperature by 0.3-4.8^{o}C for 2100 (Stocker, 2014). In particular, Bhutan is predicted to experience an increase in temperature (> 3.2^{0}C) and rainfall (>30%) by the end of the century (NCHM, 2019). Changing climate is expected to affect vegetation patterns and will significantly influence the distribution, structure, and ecology of forests (Sharma et al., 2009) and upward range expansion is widely documented as a response of vegetation to a warming climate (Kullman, 2002; Parmesan & Yohe, 2003). The phenomenon of such range expansion will alter the availability of food and shelter in the current habitat, influencing the future upward distribution of the red panda as predicted in the model. A similar upward shift in elevation in response to climate change has been observed in birds (Peh, 2006), mammals (Payette, 2011), plants (Kullman, 2002) and various other taxa (Parmesan & Yohe, 2003).

Livestock rearing is the main economy for the semi-nomadic inhabitants of SWS. They practice open grazing in higher elevation meadows on an extensive scale. The predicted upward shift of the red panda habitats to a relatively higher elevation will result in distribution of red panda closer to grazing grounds, ultimately increasing the rate of an anthropogenic disturbance despite suitable climate space. The abundance of red panda reduces in the areas accessible to livestock grazing due to disturbances (Dendup et al., 2016; Sharma, Belant, & Swenson, 2014) and reduced bamboo growth to an optimum height to be fed by a red panda (Yonzon & Hunter, 1991). Increasing demand for livestock products has resulted in increased livestock population (SWS, 2019). Approximately, 39% of the SWS is an open pasture where extensive grazing is in practice and another 36 % are accessible to livestock with varying grazing intensity (SWS, 2019). Widespread herders and livestock are always accompanied by dogs which are known to carry canine distemper that is contagious to red pandas through contact with faeces and urine or a bite from infected dogs (Deem, Spelman, Yates, & Montali, 2000). However, our model is based on the assumption that the forest of SWS will shift to a relatively higher elevation in response to climate change (Wangdi et al., 2019) and livelihood option of Brokpas will remain as usual. This assumption may not hold if forest fails to migrate to higher elevation and occupation of Brokpa changes from nomads to the agriculturist. Hence, findings in this study may be a conservative estimate of the impact of climate change on a red panda. The free-roaming dog population is increasing in SWS due to the abandonment of old dogs by herder communities and the high birthrate of stray dogs. Incidences of dog hunting the red panda were reported (Dorji et al., 2012; Yonzon & Hunter, 1991), which could be a severe threat to the red panda in SWS with the observed increasing free-roaming dog population.

In all the climate scenarios, as shown in Figure 7 more than 75% of the potential habitats for red panda in SWS were predicted outside the core zone where the frequency of anthropogenic disturbances is relatively high. Though the network of the protected area is known for successful conservation and protection of species against various threats from outside the protected areas, within protected area management options might have to be reconsidered for the long-term persistence of the species.

5. CONCLUSIONS

The information generated through a species habitat distribution model can help conservation planners to be informed and decisive. This study used presence-only species distribution modeling tool (Maxent) to model potential habitat distribution under different climate scenario for the endangered red panda in SWS. The finding of this study suggests that climate change will reduce the potential habitat along with the shift of the habitat to a relatively higher elevation. Irrespective of any present or future emission mitigation initiatives, the natural system will probably experience the change as a consequence of already happening climate change. Hence, the conservation management of SWS should set priorities on the identification and accomplishment of realistic goals that would help the red panda to adapt to predicted change or new habitats in the landscape.

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