The need for IUCN species distribution update - the case from a large threaten ungulate in Southwest China

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Abstract

Species distributions are one of the fundamental factors needed for understanding and conserving wildlife. While the IUCN Red List of Threatened Species is the primary applied reference for biodiversity conservation, limitations in data availability and analyses of the distributions of some species may limit accurate threat classification assessments and conservation recommendations. Improving the accuracy of species distributions in light of growing data and analytical methods is a key step to increasing the efficacy of the Red List. In this study, we reassessed the distribution of takin (Budorcas taxicolor tibetana), a large ungulate in Sichuan Province, southwest China , classified by the IUCN as vulnerable. Using species distribution models and reported habitat requirements, we updated the takin distribution map. Our updated distribution range in the study area (79,449km2) was 61.31% of current distribution range (CDR) on the IUCN red list. This reduction was in large part due to the inclusion in the CDR of substantial areas of lowland plains, high human disturbance, and non-forest habitat, which provide no suitable habitat for takin. According to our results, suitable takin habitat covered 18.97% of the CDR, suggesting a substantially over-estimated distribution. However, there are high proportions of habitat (40%) still covered by the nature reserve network, indicating the importance of protected areas (PAs) in conservation threaten species. We recommend that experts apply the basic approach presented herein to update the Red List distributions for more species to increase the accuracy of assessments and resulting conservation applications.

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Abstract: Species distributions are one of the fundamental factors needed for understanding and conserving wildlife. While the IUCN Red List of Threatened Species is the primary applied reference for biodiversity conservation, limitations in data availability and analyses of the distributions of some species may limit accurate threat classification assessments and conservation recommendations. Improving the accuracy of species distributions in light of growing data and analytical methods is a key step to increasing the efficacy of the Red List. In this study, we reassessed the distribution of takin (*Budorcas taxicolor tibetana*), a large ungulate in Sichuan Province, southwest China , classified by the IUCN as vulnerable. Using species distribution models and reported habitat requirements, we updated the takin distribution map. Our updated distribution range in the study area (79,449km^2) was 61.31% of current distribution range (CDR) on the IUCN red list. This reduction was in large part due to the inclusion in the CDR of substantial areas of lowland plains, high human disturbance, and non-forest habitat, which provide no suitable habitat for takin. According to our results, suitable takin habitat covered 18.97% of the CDR, suggesting a substantially over-estimated distribution. However, there are high proportions of habitat (40%) still covered by the nature reserve network, indicating the importance of protected areas (PAs) in conservation threaten species. We recommend that experts apply the basic approach presented herein to update the Red List distributions for more species to increase the accuracy of assessments and resulting conservation applications.

Key words: Red list, geographic distribution, Giant panda, Protected Area,

The distribution of a given species is the result of long-term interactions with natural processes (Morris 2003) and both short—and long-term anthropogenic impacts (Stabach et al., 2016). Numerous species are threatened due to habitat loss and population decline caused by anthropogenic changes across the global landscape and the over-exploitation of natural resources (Moyle & Williams, 2010; Sánchez-Bayo & Wyckhuys,2019). Therefore, spatial distributions are one of the very basic characteristics needed to understand the natural history and ecology of any given species (Grenyer et al., 2006). They are also dynamic, influenced by fluctuations in environmental conditions, including climate (Perry et al.,2005), population growth over time (Dou et al., 2013), and human disturbances (Moreno-Rueda & Pizarro, 2007; He et al., 2019). Thus, contemporary knowledge of the dynamics of a species' distribution is a key indicator of their conservation status, and critical to achieving desired outcomes (Liu et al.,2020) and guiding resource use for conservation actions regionally (Li et al., 2013; Myers et al., 2000). Unfortunately, species with limited data on their population and distributions are still common (IUCN 2020), reducing the accuracy and reliability of their respective conservation status assessments (Beresford et al., 2011, Syfert et al., 2014).

The International Union for Conservation of Nature (IUCN) Red List Categories are internationally recognized as the standard for assessing the extinction risk of species (Butchartet al. 2005; Mace et al. 2008). One of the five standard assessment criteria in the Red List, which determines the "Threatened Category" (e.g. critically endangered, endangered, vulnerable, etc.), is the geographic range of the species based on their extent of occurrence (EOO) and/or area of occupancy (AOO) (IUCN 2019). EOO are estimated by minimum convex polygons (MCP) with well sampled locations (Ramesh et al., 2017), providing the total area the species may be present, including unsuitable or disjunct (unoccupied) areas. AOO are a closer reflection of the actual habitat used by the species because they are based on suitability models or occupancy data within the EOO. Not all threaten species are well sampled throughout their potential range, and their geographic distribution delineated by MCP may differ significantly from reality, providing a clear opportunity to improve our conservation assessments and actions for those species (Pena et al., 2014). Therefore, potential improvements to these data limitations and species distributions should be a priority for species assessments, particularly in developing countries and species lacking sufficient research.

The takin (*Budorcase tibetanus*) is a rare species of ungulate found only in Asia, distribute along the south and east edge of Qinghai-Tibetan plateau, including India, Myanmar and Bhutan. Due to poaching, deforest and habitat isolation, takin are considered as vulnerable by IUCN and listed in appendix II of Red list(Guan et al.,2013), top level of national protected wildlife of China (Jiang et al.,2016). Due to its massive body size and group-living behavior, takin were once the most frequently poached mammal within its range, leading to drastic declines in their populations and distribution in the last century (Wu et al.,1990). There are currently four takin subspecies recognized, including the Sichuan takin (*B. t. tibetana*) the most widely distributed and abundant takin subspecies (Zeng et al., 2003) found in primarily in Sichuan Province, with minor portions of their range extending into Gansu Provinces (Guan et al., 2015). Data on their population size and distribution range is limited, restricting the accuracy of threat assessments and conservation actions, including effective habitat management.

Review of recent studies on takin and the diversity and distribution of large ungulates in Sichuan Province (Ge et al., 2011; Guan et al. 2013; Guan et al., 2015; Hu et al., 2018; Hu et al., 2019; Chen et al., 2019) indicated that the actual distribution of Sichuan takin should be much smaller than indicated on the IUCN Red List, due to basic known environmental limits for the species (e.g. elevation, distance to human disturbance, etc.). Thus, an update of their geographic distribution is essential. Furthermore, the Sichuan takin is sympatric with the giant panda (*Ailuropoda melanoleuca*), a flagship species of global wildlife conservation. Serving as an umbrella species, giant pandas benefit from numerous protected areas (PAs) across their range, within which extensive measures are taken to protect and restore habitat and connectivity (Wang et al.,2021). In addition to updating the distribution of Sichuan takin to be more accurate, conservation planning and recovery efforts would be bolstered by determining the ratio of takin habitat under protection by giant panda nature reserves or other PAs (Guan et al, 2015; Zhang et al., 2020).

In this study we had two primary objectives. First, we sought to update the distribution of Sichuan takin, from an EOO to AOO, providing new data necessary to more accurately assess their IUCN threat classification and plan conservation efforts. Second, we compared the results of our distribution, estimated via an ecological modeling method based on basic habitat requirement data, to the current distribution range (CDR) based on an MCP, to demonstrate the vast discrepancies between these assessments. Our goal is to both directly improve the conservation of Sichuan takin and encourage the broader conservation community to re-examine our standards for estimating species distributions.

Study area

Assessment of the distribution of Sichuan takin in this study was limited to the core takin population, located in Sichuan Province(Figure 1), as environmental data availability in the provinces of Gansu was restricted. Sichuan Province is located in southwest China, and is characterized by a varied topography, including a large flat basin, swaths of hilly landscapes, and high mountains and plateaus, stretching from less than 400m asl to higher than 4000m asl. The heterogeneous terrain has resulted in a landscape with numerous distinct environments and high species diversity and richness (Zhang et al., 2009). Several species are endemic or particularly abundant in this region, including Sichuan takin, giant panda, golden snub-nosed monkey (*Rhinopithecus roxellana*), Tibetan macaque (*Macaca thibetana*), and Chinese monal (*Lophophorus lhuysii*). To date, 46 giant panda nature reserves have been designated in Sichuan, covered 5.24% of the total area of the province (Forestry Department of Sichuan Province, 2015). Due to its high richness of biodiversity, and as the main component of the mountains of southwest China, large areas of Sichuan are considered a global biodiversity hotspot (Myers et al., 2000; Noroozi et al., 2018).

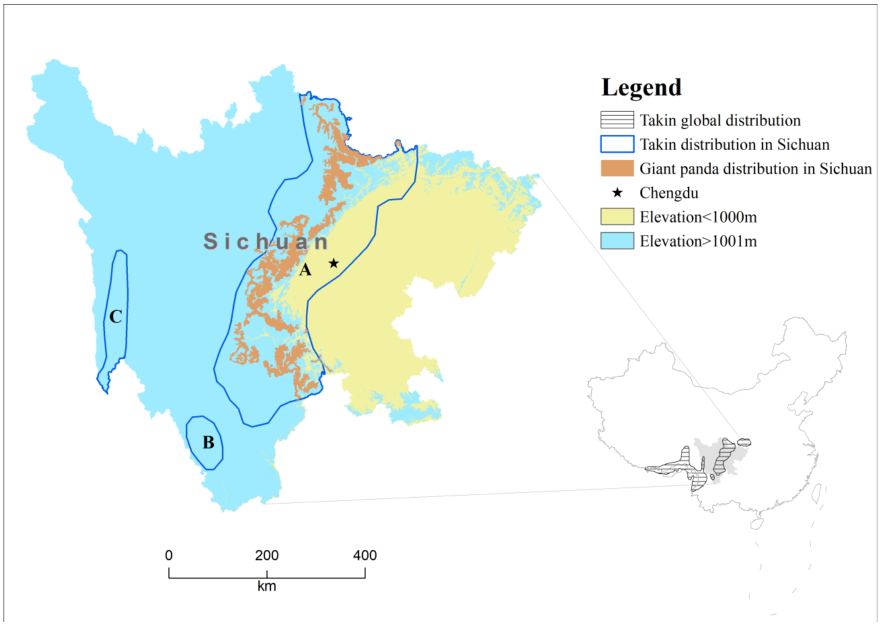


Figure 1: Current published Takin distribution in Sichuan province with reference to giant panda distribution range (IUCN data)

Data source and Analyses

Data source

The spatial distribution data for evaluation were downloaded via the IUCN website (https://www.iucnredlist.org/). To produce a suitable habitat distribution map (SDM), we utilized MaxENT (v.2.0). All takin occurrence data were collected from two sources: data prior to 2015 were from the National Giant Panda Survey (Forestry Department of Sichuan Province, 2015), and data from 2015 to 2020 were provided from Forestry department of Sichuan and collected during ongoing biodiversity monitoring surveys in each giant panda nature reserve in Sichuan. Monitoring of the giant panda nature reserves was routine work performed by local authorities and under the oversight of provincial and national management plans. The surveys focus on giant pandas and their sympatric species, and are typically conducted seasonally or every six months, using an existing network of transects (Gu et al. 2003; Zheng et al.,2012). More details about the giant panda surveys are found in the related reports (Forestry Department of Sichuan Province,2015).

Table 1 Data and source applied during evaluation and analysis

Data type	Source
Distribution range	IUCN Red List website(https://www.iucnredlist.org/)
Species occurrence	Giant panda survey and monitoring records in nature reserves, data copied holder with permission
Vegetation	Finer Resolution Observation and Monitoring of Global Land Cover (http://data.ess.tsinghua.edu.cn/f
Terrain	Extracted from DEM, and DEM was downloaded via Geographic Data Cloud (http://www.gscloud.cn
Disturbance data	Download from national geomatics center of China with permission (http://www.ngcc.cn/ngcc/)
Climate data	Download from worldclim website(https://www.worldclim.org/)

Modelling Procedure

To build the model, the authors referred to the protocols suggested by various studies (Bradie & Leung,2017;

Halvorsen 2013; Kaky et al.,2020; Zhang et al., 2019), and selected several basic environmental factors, including terrain, vegetation, human disturbance variables, and climate data (Table 1), which are widely available for many locations around the world. MaxENT was adopted to develop the models (Elith et al., 2011; Phillips & Dudík, 2008), as it is a widely applied method to predict species distributions and proven to be reliable for numerous taxa (Kumar & Stohlgren, 2009; Onojeghuo et al., 2015; Khadka et al., 2017; Thapa et al., 2018). Before running MaxENT, all relevant accessible factors in the dataset were given full consideration and transformed into raster format (90m × 90m), using UTM coordination system. A total 19 climate variables, 2 terrain variables (elevation, slope), vegetation (forest), 2 disturbance variables (distance to towns, density of main roads) were included in the analysis. A jack-knife method based on 10 repetitions was used to evaluate model performance, using the AUC value to evaluate the performance of the models. Finally, we adopted the average results of the 10 repetitions. The threshold value to divide the suitability into suitable habitat or unsuitable habitat was based on the Maximum Youden index (Fluss et al., 2005).

To improve the accuracy of takin distribution map, a suitable habitat distribution map based on the final model was created. The raw takin habitat map was created after converting the resulting raster file into a shape file, which was overlayed with 5 kmx5km polygons with the resulting habitat suitability value. All known takin occurrence locations were used to generate a raster map based the euclidean distances to the locations and divided the raster value into 5 classes using 10km intervals. Based on the takin distribution map and euclidean distance map, polygons at the edge of suitable habitat were identified. The edge was selected where habitat present or distance to nearest location less than 20km, producing a species distribution polygon with jagged edges. To smooth the shape and cover as much potential habitat in the distribution range, the edge angles were modified to those less than 90 degrees or equal to 90 degrees by connecting consecutive corners with a straight line, making all angles larger than 90 degrees. After smoothing, this map was overlapped with CDR of takin from the IUCN and considered the overlapped area as the updated distribution range (UDR).

Conservation status evaluation

To evaluate the relationship between takin habitat distribution and protected area contribution in Sichuan province, the size of distribution range and suitable habitat within nature reserves was calculated. The number and size of PAs in five major mountains were also calculated, to quantify the relative contribution of takin habitat under some level of conservation protection.

Results

Current distribution and suitable habitat distribution predictions

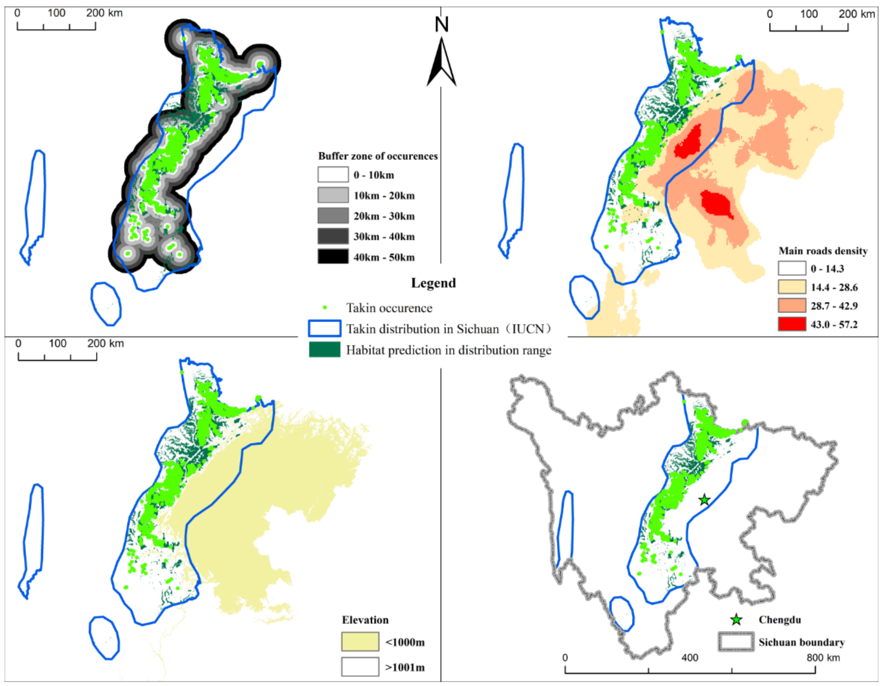
According the distribution map from IUCN (Fig1), takin range in Sichuan Province comprised 129,582 km^2 within three distinct patches. The largest patch was located in middle of Sichuan (Patch A), covering 114,038km^2, or 88% of takin distribution in Sichuan. Patch B and patch C covered 5,857km^2 and 9,709km^2 respectively.

Table 1 Analysis of variable contributions in models

Variable	Explanation	Percent contribution (%)	**Permutation importa**
bio12	Annual Precipitation	10.6	**26.6**
Dem	Digital elevation model	18.2	**24**
bio04	Temperature Seasonality	4.3	**7.1**
Distown	Distance to towns	8.6	**6.9**
bio14	Precipitation of Driest Month	0.2	**6.7**
bio10	Mean Temperature of Warmest Quarter	7.3	**6.1**
bio06	Min Temperature of Coldest Month	12.3	**3.5**
bio15	Precipitation Seasonality	25.6	**3.1**
bio09	Mean Temperature of Driest Quarter	3.9	**2.3**
bio02	Mean Diurnal Range	1.3	**2**

bio01	Annual Mean Temperature	0.3	**2**
Accumulated contributions		92.6	**90.3**

With 10 repeats, the AUC was 0.951, indicating a reliable performance of the model. Among the candidate environmental variables, annual precipitation and elevation were most important indicators of takin distribution, based on the resulting permutation importance estimations (Table1). Temperature, seasonality, distance to towns, precipitation of driest month, and mean temperature of warmest month also impacted takin distributions.



The model predicted there were 24,583km^2 classified as takin suitable habitat(Figure 2), equaling 18.97% of CDR. The number of patches larger than seasonal home-range of takin (5km^2; Guan et al.,2015) was 122, covering 23,710km^2 or 96.45% of the UDR. The total habitat size in patch B was less than 7km^2, and the largest contiguous habitat within patch B (2.8km^2) is much less than takin annual home range (15km^2, Guan et al.,2015). There was no suitable habitat in patch C.

Figure 2 Takin habitat prediction in Sichuan with reference to current distribution range and environment limits.

Takin distribution update By delineating the grids corners on the edges (Figure 3), we created a range based on conservative predictions and known environment limits. Then, after overlapping the range with polygon published in the IUCN Red List, we derived the updated map of takin distribution (Figure 4). The size of UDR of takin in Sichuan was 79,449km^2, 61.31% of the total area of the CDR.

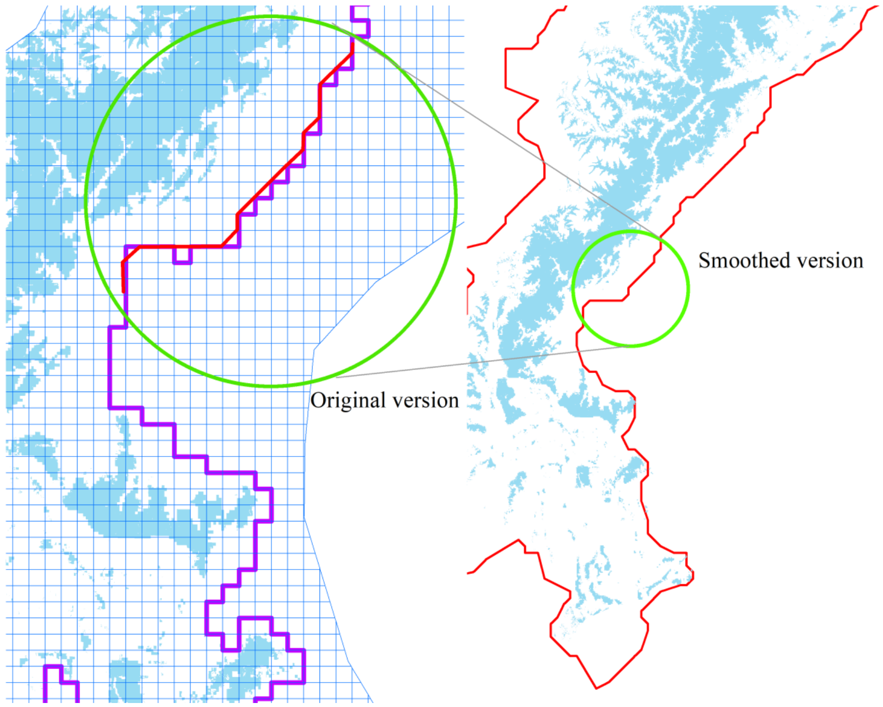


Figure 3 Example of the method used to smooth the distribution edge by delineating consecutive corners of rectangles.

Conservation status

Within the UDR, there were 44 giant panda related nature reserves in five mountains, totaling 24,290km^2. Relative to these PAs, 20,834km^2 (26.22%) of the area they comprise was located in the UDR. Thus, 86.95% of the PAs protected 40.3% of takin suitable habitat in Sichuan (Table 2), with an average patch size of 240.4

±36.2 km^2. Among these five mountains, Minshan and Qionglai covered 35.8% suitable habitat and 88.83% of all the area contributed by PAs. By contrast, Daxiangling, Xiaoxiangling and Liangshan contributed less than 1% suitable takin habitat. The nature reserve that comprised the largest suitable habitat area was Wolong in Qionglai Province (4.86%, 1,195km^2), following by Baodinggou (3.2%, 788 km^2), Baiyang (2.36%, 581km^2) and Xuebaoding (2.34%, 573km^2).

Figure4. Suggested updated takin distribution range (UDR) in Sichuan, China

Table 2 The contributions of protected areas to takin distribution and suitable habitat in the five mountain ranges occupied by takin in Sichuan Province. Percentages indicate the proportion in each mountain relative to the total in Sichuan.

Mountains	Distribution range (km^2)/Percentage	Suitable habitat (km^2)/Percentage	Size of PAs	Number of NPA
Minshan	9481/11.93%	5867/23.86%	10705	9
Qionglai	5390/6.78%	2936/11.94%	5766	3
Daxiangling	671/0.84%	480/1.95%	674	0
Xiaoxiangling	3037/0.38%	508/2.06%	4933	2
Liangshan	2244/0.28%	116/0.47%	2212	3
Total	20834/26.22%	9908/40.3%	24290	17

* NPA=national protected area, #PPA=provincial protected area

Discussion

The takin is a large montane species with a seasonal migration (Guan et al.,2013), and preference for habitat with forest cover and low human disturbance (Guan et al., 2015). The previously published species distribution map used in the threat classification in the IUCN Red List includes large areas of distribution in the Sichuan Basin plain, characterized by relatively low elevation and a high density of human disturbances, where no suitable takin habitat exists. Our analysis, based on readily available environmental data and a standard habitat suitability modeling approach, indicate that the CDR in Sichuan is substantially larger than its likely realized distribution(Figure 2). Our informed prediction of the total area of habitat available was only 19% of the area used to determine its threat classification, potentially vastly underestimating their extinction risk. Therefore, we suggest two steps to adjust Sichuan takin CDR and improve the accuracy of the IUCN Red List assessment. First, eliminate patch B and C where there is no effective habitat for takin. Second, shrink the east range of area A based on the boundary of these results and the known elevation lower limits (1,000m).

Our approach in this study was conservative. In reality, takin populations are sensitive to intense human disturbances (Zeng et al, 2008, Guan et al.,2015) and their populations are strongest within the nature reserve network and nearby forests that are protected by rangers from extensive human activities. This is supported by both the species distribution model results of this study, which indicated that more than 40% suitable habitat was located within PAs, and our previously published distribution, in which we found 77% of suitable takin habitat was located within 3km from the border of PAs in northern Minshan (Guan et al.,2015). It is likely that further species distribution models, with additional habitat disturbance variables, would indicate that the real world distribution of takins would be much smaller than current maps.

The IUCN Red List assessment is the most widely applied standard and reference for wildlife conservation used to determine priorities for conservation and ecological studies (Pimm et al., 2014). Thus, the accuracy of Red List assessments has global impact. The distribution of takin in our reassessment makes a clear case for the use of basic occurrence data to reduce inaccuracy, as about 40% of the CDR was outside of their possible distribution area. By contrast, giant panda distribution range in the same region is much more elaborate in shape and closer to their real world distribution (Tang et al., 2020), as the result of enormous monitoring and focal surveys (Zheng et al.,2012;Foretry Department of Sichuan Province,2015).

Such condition demonstrate that the accuracy of estimats are highly varied among species, even those that are sympatric.

Species distributions are extremely important topics in both biology and ecology (Jetz & Guralnick, 2012; Pimm et al., 2014; Schluter& Pennell, 2017), since they evolve through both long-term evolutionary pressures and interactions with contemporary environmental and anthropogenic impacts. Thus, they are also a primary concern in wildlife conservation. For many common species on Red List, the occurrence data for distribution assessments and population estimates are still lacking (Roberts et al., 2016; Ocampo-Peñuela et al., 2016; Popov et al.,2017). To date, there are 17,878 species assessed by IUCN classified as "Data Deficient", though comprising only 17.8% of all assessed species (IUCN 2020). As more research is done this percentage decreases, supporting more reliability in conservation assessments and more effective planning. We recognize that the data for species assessments often originate from widespread and long-term surveys, which are dependent on numerous factors, including the number of individuals participating in the research, support from pertinent stakeholders, and funding availability. However, as even the most conservative estimates indicate that the rate of extinction is 100 times higher than the normal background rate between the Earth's six mass extinction events (Ceballos, et al., 2015). It is imperative that more targeted studies and surveys are completed to rapidly produce the critical data for conservation. Our results are likely true for numerous species, and there are significant opportunities for IUCN Red List species distribution estimates to be improved by including even basic biological limits and conservation dependencies (e.g. takin are not found within cities or other densely populated areas or below 1000m asl) into distribution maps (Sillero et al.,2014; Syfert et al.,2014; Ramesh et al.,2017;Gomes et al.,2018).

Biodiversity conservation has often been seen to conflict with economic development, lead to relatively limited conservation-related investment from governments, particularly those of developing countries. With the global economy growth and poverty reductions, long term monitoring and survey work in large areas become more affordable and feasible (Cordero et al., 2020); the body of related data is growing. For example, a recently deployed widespread infrared camera monitoring network in China has contributed national species distribution data (Li, 2020). However, the practical use of these data into species assessments and conservation actions remain to be seen. As data becomes increasingly available, it is absolutely essential that ecologists, biologist, conservation scientists and other organizations share data through transparent collaborations to improve our capacity to assess and protect wildlife.

Conclusion

By using the takin as a case study, we found significant disparities between their current published range in the IUCN Red List based on basic habitat requirements of the species. These differences can have substantial implications on the conservation of the species, including its threat classification, prioritization for funding and research, political and public attention, and more. Our findings related to the takin are likely exemplary of numerous species, even those not classified as "Data Deficient." We strongly encourage an increased emphasis on widespread assessment of species ranges, even with only the most basic and intuitive data, to increase their accuracy and efficacy in conservation planning.

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Data Accessibility

Shape files for the MaxENT and final maps are uploaded at Dryad, Dataset, https://doi.org/10.5061/dryad.n8pk0p2xd

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