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Original Research Article

Identifying transboundary conservation priorities in a biodiversity hotspot of China and Myanmar: Implications for data poor mountainous regions

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A B S T R A C T

Difficult to study species that inhabit inaccessible terrain, present significant challenges in obtaining accurate ecological, distributional, and conservation information. To address these challenges, we used an effective set of time- and cost-efficient methods including interview-based surveys assisted by Google earth 3D maps to document the distributional range of 32 native animal taxa in the biodiverse but difficult to access Gaoligong Mountains (GLGMS), located on the northern Sino-Myanmar Border. Five threatened flagship species, including the black snub-nosed monkey (*Rhinopithecus strykeri*), the Skywalker hoolock gibbon (*Hoolock tianxing*), Shortridge's langur (*Trachypithecus shortridgei*), Sclater's monal (*Lophophorus sclateri*) and the Mishmi takin (*Budorcas taxicolor*) were selected for intensive surveys and used as surrogate taxa to study community biodiversity. Field surveys of each species were conducted to determine their presence/absence and to confirm the reliability of species distribution data obtained from interview-based surveys. Multi-criteria Decision Analyses were used along with data on habitat suitability (MAXENT) to prioritize transboundary conservation areas. Our results indicate that approximately 83.4% (10,398.7 km^2) of the remaining habitat with high biodiversity conservation value in the GLGMs is unprotected. This includes six large zones located along the northern Sino-Myanmar border, separated by rivers and human settlements. These areas should be designated as a transboundary World Nature Heritage Site, national parks, or wildlife sanctuaries. This study presents a reliable, rapid and integrative method for developing informed policies for conservation prioritization in data poor areas, which can be applied successfully to assess conservation priorities in other mountainous regions where obtaining data on biodiversity is difficult.

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1. Introduction

Over the past 20 years, biodiversity conservation priorities have largely focused on species-based approaches at large spatial scales rather than on more targeted and smaller-scale analyses at the local level to determine the specific sites where species or habitat protection is required (Brooks et al., 2006; Hoffmann et al., 2008; Pimm et al., 2018). This may reflect the fact that many conservation assessments rely heavily on species occurrence data from open source databases (i.e. IUCN Red List of Threatened Species and Birdlife International) to inform the location of priority conservation areas (Beresford et al., 2011; Dorji et al., 2018; Pimm et al., 2018; Santarém et al., 2019). However, in many cases, these distributional databases contain geographic biases, are only updated every 5–10 years, and provide very general information on species distributions, limiting their value in developing fine-scale conservation priorities (Rondinini et al., 2006; Hoffmann et al., 2008; Di Minin and Moilanen., 2014; Brooks et al., 2019). For proper zoning and management planning at smaller scales, it is essential to have dimensionally accurate and high-resolution information of the geographical range of target species. This is especially challenging for species inhabiting mountainous or steeply sloped terrain, or for rare or cryptic species (Turvey et al., 2015; Ren et al., 2017).

An effective approach for obtaining cost-efficient and relatively accurate data in areas characterized by poor accessibility uses local ecological knowledge (LEK) to assess the distribution and conservation status of rare species (Ma et al., 2014, 2015; Turvey et al., 2015, 2017; Cui et al., 2016). These studies have shown that LEK can provide more accurate information than open source databases resulting in fact-based conservation policies at local levels (Groombridge et al., 2004).

1.1. The Gaoligong Mountains: conservation priority

The Gaoligong Mountains (GLGMs, 23°48-26°23′N, 97°38′-98°16′E) are located across the northern section of the China-Myanmar border at the convergence of three globally important biodiversity hotspots: the Himalaya, Indo-Burma, and the Mountains of Southwest China (Meyers et al., 2000). The GLGMs run north-south for more than five latitudes across an area of some 500 km. The main ridge of these mountains forms part of the China-Myanmar border. The GLGMs also represent the divide between two major river basins the Irrawaddy to the west and the Salween (Nu Jiang in Chinese) to the east.

With abundant rainfall, an elevational drop of 6,135 m, diverse microclimates, complex topography, and multiple latitudinal belts, the GLGMs are rich in vegetation types ranging from moist tropical forest to alpine meadows and contain a highly diverse set of flora and fauna (Li et al., 2000; Chaplin, 2005). According to incomplete accounts, the area is home to 486 avian and 117 mammalian taxa (Xue, 1995; Dumbacher et al., 2011), many of which have been recently described, including two flagship primate species: the black snub-nosed monkey (*Rhinopithecus strykeri*) and the Skywalker hoolock gibbon (*Hoolock tianxing*) (Geissmann et al., 2011; Fan et al., 2017). The area is of high priority for global conservation and has been listed by the Alliance for Zero Extinction (AZE) as an important site (Ricketts et al., 2005). The Chinese part of the GLGMs is recognized as a core component of the Three Parallel Rivers World Natural Heritage site (WNH) (UNESCO Ref: 1083bis, 2003). Given that the GLGMs are divided by the boundary of two nations, cooperative transboundary management and conservation are needed from both China and Myanmar.

To conserve the biodiversity of this region, the Chinese Government established the 4,055 km^2 Gaoligongshan National Nature Reserve (GLGMNNR) in 1983 (Fig. 1). On the Myanmar side, the area partially falls into the Northern Forest Complex (25,800 km^2 of intact mountain forest along the international border with China and India), which is one of 15 national Priority Corridors/Priority Sites for protected areas (PA) and conservation investment (*National Biodiversity Strategy and Action Plan* Myanmar, 2011). At present, only 22.8% of the Northern Forest Complex has been placed under conservation protection (Fig. 1). With the support of Fauna & Flora International (FFI), the Government of Myanmar (MoNREC) is working to establish a new national park in Imawbum, Sawlaw Township, Northeastern Kachin State to protect the habitats exploited by the black snub-nosed monkey (Meyer et al., 2017). Once established, this new national park will connect to the GLGMNNR (China) at the Pianma Township of Lushui County, Yunnan. Despite this initiative, a gap in conservation protection still exists, which extends from the east bank of N′ Mai Kha River to the main ridge of Gaoligongshan Mountains, on the Myanmar side of the border (Fig. 1). Forests and endangered species within this lacuna face the imminent threat of wildlife trade (Meyer et al., 2017; Zhang et al., 2017) and deforestation for slash-and-burn agriculture, timber, mining, and infrastructure development. Internal conflicts and insurgencies in the area also have contributed to illegal logging and the wildlife trade (Geissmann et al., 2011; EIA, 2015). Thus, both the Chinese and Myanmar governments, as well as international organizations are committed to strengthening the conservation protection of existing reserves in the GLGMs, and establishing new PAs along their northern border. However, to move these conservation management priorities forward, an accurate assessment of biodiversity distribution across the GLGMs is needed (Basnet et al., 2017).

In this study, we use community interview data along with 3D vision maps to obtain the LEK needed to develop a transboundary conservation priority plan for the GLGMs in the area of the Sino-Myanmar border. Our specific goals are (1) to

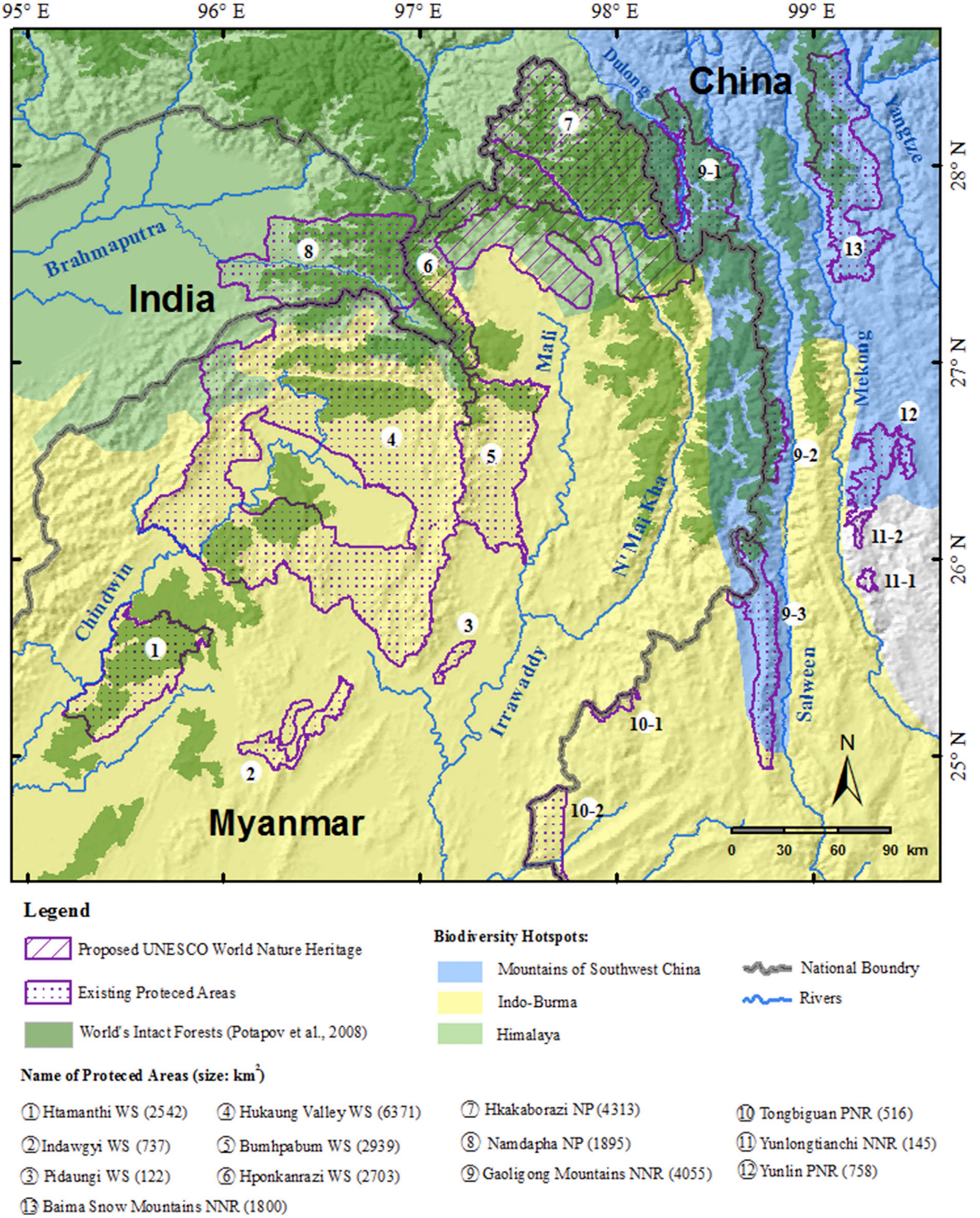

Fig. 1. Conservation areas in northern Myanmar and along the northern Sino-Myanmar border (NP = National Park; WS = Wildlife Sanctuary; NNR = National Nature Reserve; PNR = Provincial Nature Reserve).

select five charismatic and threatened flagship species as surrogates in order to model habitat distribution and use multi-criteria decision analysis (MCDA) of habitat suitability to prioritize transboundary conservation areas within this poorly-surveyed but highly biodiverse region; (2) to promote transboundary cooperation between China and Myanmar; and (3) to present a practical, rapid and integrative method to identify and prioritize effective small-scale conservation projects that can be used in mountainous regions.

2. Materials and methods

2.1. Vegetation types in the study area

Along the elevational gradients of the GLGMs, natural vegetation types include tropical monsoon rain forest (<1,000 m a.s.l.), monsoon evergreen broad-leaved forest (1,100–1,800 m a.s.l.), semi-moist evergreen broad-leaved forest (1,700–2,500 m a.s.l.), mid-montane moist evergreen broad-leaved forest (1,900–2,800 m a.s.l.), coniferous broadleaved mixed forest (2,700–3,500 m a.s.l.), and alpine bushes or meadows (>3,400 m a.s.l.) (Li et al., 2000).

2.2. Data collection

2.2.1. Community interviews

Interview-based surveys provide useful and low-cost information about both the distribution and abundance of animal taxa (Meijaard et al., 2011; Ma et al., 2015; Turvey et al. 2015, 2017). We initially selected 24 pheasant species, one bovid, the Mishmi takin (*Budorcas taxicolor*), and seven primate species as conservation targets for our surveys. These species were selected because they are relatively abundant and easily identified by local people (Ma et al., 1995). We interviewed local residents along the entire range of the GLGMs in Nujiang Autonomous Prefecture between July 2010 and July 2013 and made a specific effort to visit villages near areas of existing forests, and to interview older hunters or villagers who have made frequent visits into the forest (Table 1). Semi-structured interviews were carried out by trained investigators (Bunce et al., 2000) in which local residents were shown species' photographs from a photo pool and asked if any of the species existed in the area. If participants answered yes, then a prepared questionnaire was administered that asked about the animals' group size, the encounter time, date and year, forest types inhabited, as well as the animals' and the interviewees activities in the forests. Then the interviewee was asked to identify and draw the approximate location (polygon) of species' sightings using Google Earth 3D maps that were highlighted with recognizable locations and key environmental features (see also Ma et al., 2015).

2.2.2. Species selection

Following past protocols (Tulloch et al., 2011; Di Minin and Moilanen., 2014; Santarém et al., 2019), we selected our five target or flagships from our initial survey of 32 species using the following criteria: (1) the species' should be of relatively large body length (≥70 cm) and easily identifiable; (2) the species' should have medium or large home ranges (≥100 ha); (3) the species' should be relatively abundant in the study area; (4) the species' should be locally recognized as a flagship and or umbrella species and endemic to the Eastern Himalaya Region (Dorji et al., 2018); (5) the species' should inhabit more than one forest type and their distributional ranges should at least partially overlap with other flagship species; (6) the species is facing population decline and habitat destruction and thus requires a detailed population and habitat distribution assessment for protection; and (7) both legislation and public awareness require conservation funds must be available to protect these species (i.e. *Yunnan Provincial Conservation Program of Extremely Small Populations, 2010–2020*).

Based on the above criteria, we identified five flagship species, including: Sclater's monal (*Lophophorus sclateri*), the Mishmi takin (*B. taxicolor*), Shortridge's langur (*T. shortridgei*), the Skywalker hoolock gibbon (*Hoolock tianxing*) and the black snub-nosed monkey (*Rhinopithecus strykeri*) as surrogates for determining the location of critical habitat and conservation zones for species protection (Supporting Information: Fig. S1, Appendix S1).

We conducted field investigations of these five flagship species from 2013 to 2017 in areas of GLGMs that were relatively accessible and had a high probability of encounter with wild populations. A high probability of encounter was based on analyzing historical records of the distribution of each of the five species. Along with interview-based surveys, we collected the five species' presence data from recent published records. The field team of Fauna & Flora International (FFI) also investigated evidence of *H. tianxing* and *T. shortridgei* in the Imawbam Mountains in Myanmar. We combined the information from China and Myanmar into a single data set in our modeling analyses.

2.3. Environment data acquisition and vegetation mapping

As climatic conditions and vegetation types are two major factors limiting the distribution of wild animals (e.g. Kissling et al., 2010), we used both to predict the distribution of the selected species. For climate data we included 19 bioclimatic variables derived from 48 climate factors including maximum, minimum, and mean monthly temperature, and mean monthly precipitation (Table S1) obtained from WorldClim (30 arcsec spatial resolution, equal to 0.00833°, http://www.

Table 1
Five criteria used in prioritization criteria.

Table 1. Five criteria used in prioritization criteria

Layer 1	Core habitat	Medium habitat		Edge habitat		None habitat
MAXENT	3	2		1		0
Layer 2	*T. shortridgei*	*H. tianxing*	*R. strykeri*	*L. sclateri*	*B. taxicolor*	Value Identification
IUCN Red List Category	3	4	4	2	2	4: CR, 3: EN, 2: VU, 1: NT
Endemism	3	3	4	2	2	4: endemic to study area, 3: endemic to GLGMs; 2: endemic to Eastern Himalaya Mountains
Layer 3	Intact (2016)	Degraded (2000-2016)	None	Value Identification		
Intact Forest Landscape (IFL);	4	2	0	IFL, which also contains naturally treeless areas such as grasslands, wetlands, and alpine areas, as defined by Potapov et al. (2008). The IFL map for the year 2016 was complicated by multiple joint research institutes (see http://www.intactforests.org/news.html). Value 4 was assigned to IFL, Value 2 to degraded IFL between 2000-2016, and a Value of 0 to areas with no intact forest.		
Layer 4	< 1 km	1-2 km	Value Identification			
Distance to resident zone (1:250000)	-4	-2	As forests surrounding human settlement are frequently impacted by human disturbance and degradation, maintenance and restoration of these habitats require large investments of time and funding to convert to a protected area. Therefore, for limiting conservation cost, if a patch was located within 1 km of a resident zone, it was assigned a value of -4; a patch within 1-2 km from the resident zone was assigned a value of -2.			

worldclim.org, see Hijmans et al., 2005). We downloaded 32 Landsat ETM+/OLI images from USGS Earth Explorer (http://earthexplorer.usgs.gov/) to map vegetation cover and vegetation type across the study area (Table S2). As with WorldClim, we transformed the Landsat images to a Universal Transverse Mercator coordinate system (UTM, WGS84 datum, Zone 47 N) and spatially interpolated to 30 m resolution via bilinear interpolation.

We obtained “Ground-truth data” by systematically sampling 510 sets of 30 × 30 m squares (9 squares per set) using visual interpretation of high-resolution images from Google Earth (Fig. S2). We used R Statistics software to generate square sample plots every 23.7 km along four angles from the first plot. Given the constraints of the software and the resolution of these images (based on Landsat TM/ETM+/OLI images (resolution = 30 m), we used a random forest algorithm with the “ground-truth data” (Breiman, 2001) to divide the study area into three habitat types: woodland (open forest and closed forest), shrub and alpine grassland, and non-vegetated areas (such as buildings and permanent glaciers). If the tree cover was higher than 40% in a square, it was considered woodland; otherwise, it was considered as non-woodland, such as, shrub or grassland, or built areas such as roads and villages (Table S3). We employed R Statistics software (http://www.r-project.org/) with the Random Forest package (Liaw and Wiener, 2002) and Raster package for this analysis (Hijmans, 2015b).

2.4. Species distribution modeling

In recent years, MAXENT ecological niche modeling has proven to be a robust predictor of species' distribution and effective in identifying priority conservation areas, especially for rare and cryptic species (Thorn et al., 2009; Ren et al., 2017). As data on species occurrence and environmental variables are required to set up a MAXENT model, we randomly selected 10,000 pixels (30 m resolution, based on the 67 climate variables) from the study area as background data. Among these pixels, we employed 2,000 samples as pseudo-absence data for the MAXENT model and used the remaining 8,000 samples for validation. Each of the distribution polygons for *T. shortridgei*, *H. tianxing* L. *sclateri*, and *B. taxicolor* were aggregated and rasterized at a resolution of 30 m. We randomly and separately selected 2,000 pixels from the distribution polygons for the four species. Seventy percent of the 2,000 pixels of each species were systematically sampled as presence data and the remainder were used as test data. The MAXENT model for each species was built using the 1,400 presence samples and the 2,000 background samples based on 67 climate variables assessed by the Jackknife variable contribution test (see Table S1 for a list of these 67 climate variables, Pearson, 2007), with the default parameters setting in the R package, dismo (Hijmans et al., 2015b). As a result, climatic suitability layers for each of the four species in the study area were obtained.

For appraising core, medium, low quality and unsuitable habitat for each species, four levels of climate suitability data were quantified according to corresponding parameters of the MAXENT model (Table S4). We found that the habitats occupied by the four species differed in terms of vegetation types. Therefore, according to the different habitat requirements of each species, we masked out non-habitat areas from the climatic suitability layer by using the data collected on vegetation cover in 2015. For example, *H. tianxing* inhabit principally intact subtropical broad-leafed forests, therefore, areas such as open forests, shrub and grass lands, farmland, and buildings were regarded as non-habitat for this species and omitted.

For ***R. strykeri***, we used data and results from recent studies by Ma et al. (2014) and Ren et al. (2017), based on LEK and MAXENT modeling, to predict their current range and habitat preferences.

We evaluated the models' predictive accuracy for each species using the area under the curve (AUC) of the receiver operating characteristics (ROC) plot. The ROC curve adopted the sensitivity and specificity as a reference for judging the predictive accuracy of the model. The AUC area of the ROC curve varies from 0 to 1, with values > 0.9 signifying strong predictive value (Araújo et al., 2005). A map of habitat suitability for all of the species was then plotted in ArcGIS 10.0.

2.5. *Multi-criteria decision analysis*

Prioritization using Multi-Criteria Decision Analysis (MCDA) has been widely used in natural resource management and conservation planning (Adem Esmail and Geneletti, 2018). The MCDA makes decisions by considering conservation goals and economic costs, as well as by exploring the trade-offs between different alternative decisions across multi criteria to achieve a particular goal (Adem Esmail and Geneletti, 2018). By weighing different considerations, five criteria including habitat suitability, species' conservation status, endemism, landscape levels (the presence of intact forests), and costs (distance to settlements) were used to map the suitability of local habitats to prioritize protected conservation areas. The evaluation column in Table 2 presents the reasons used to evaluate each criterion. The aggregate score for each pixel (30 m × 30 m) in the study areas was calculated using the equation:

$$CA = \sum H \times (I + E) + IF\text{-}R$$

Table 2
Data from interview-based surveys and field surveys.

Species	Data type	Date of investigation	Number of people & villages visited	Investigated Areas	Independent distributed ranges (polygons)	Published Reference
T. shortridgei	Interview survey	Jul. 2010 - Aug. 2012	715 residents from 118 villages	Lushui, Fugong, Gongshan & Dulong County	36	Cui et al., 2016
	Field survey	2010 - 2017	—	Mt.Imawbom in Myanmar	7	
R. strykeri	Interview survey	Apr. 2011 - Dec. 2012	358 residents from 68 villages	Lushui, Fugong, & Gongshan County	46	Ren et al., 2017
	Interview survey	Feb. - Mar., 2010	65 residents from 33 villages	Maw River areas of Myanmar	3	Geissmann et al, 2011
H. tianxing	Interview survey	Apr. 2011 - Dec. 2012	358 residents from 68 villages	Lushui, Fugong, & Gongshan County	13	
	Field survey	Mar.- Aug. 2009	—	Baoshan, Tengchong & Yinjiang Countys	45	Fan et al., 2011
		Apr. - Nov. 2016	—	Tengchong		Chan et al., 2017
		2004 -2017	—	Mt. Imawbom in Myanmar	15	
L. sclateri	Interview survey	May. 2012 - Aug. 2012	370 residents in 78 residential areas of 68 villages	Lushui, Fugong, & Gongshan County	49	
	Field survey	Oct. 1999 - Aug. 2003	—	Baoshan, Tengchong, Lushui, Fugong, & Gongshan County	15	Han et al., 2004
B. taxicolor	Interview survey	May. 2012 - Aug. 2012	370 residents in 78 residential areas of 68 villages	Lushui, Fugong, & Gongshan county	153	
	Interview survey	Dec. 2012 - Jul. 2013	25 villages	Dulong County	30	Zhang et al., 2014

Notes: The green highlight shows the interview survey completed by authors in this study.

Where H is the value of habitat suitability, I is the IUCN Red List Category level, E is the level of a species' endemism, IF is the score of Intact Forest Landscape area (see Table 2 and Potapov et al., 2008), R represents the distance to human settlement areas or residential areas, and CA is the aggregate score of a pixel (30×30 m). We then used the Quantile Classification Scheme to order the values into 3 categories (priority 40%, 60% and 100%) according to each score's accumulated contribution rates and input the score into ArcGIS 10.0 to map prioritization areas for conservation. A pixel with a CA value > 0 was designated as a conservation priority area. In addition, any pixel with a CA value ≥ 8, indicated that the area within the pixel contained edge habitat suitable for at least two flagship species' and was considered as high priority conservation area. Each of the above procedures was conducted in R Statistics software (version 3.0.3, R Core Team, 2016) along with additional packages such as raster (Hijmans et al., 2015a) and dismo (Hijmans et al., 2015b).

3. Results

3.1. Distribution data of selected flagship species

We identified 38 localities with the possible presence of ***T. shortridgei***. We estimated that there were 250–370 Shortridge langurs residing in 19 groups located in the Dulong River Valley and possibly one group in the lower forests in Pianma Township. Subsequent field surveys confirmed two groups in the Dulong River Valley. In addition, data on eight distribution areas of *T. shortridgei* in the Imawbum Mountains in Myanmar were obtained by camera traps from 2010 to 2017. After merging all overlapping records, we obtained a distribution for *T. shortridgei* of 43 non-overlapped polygons ranging from 0.2 to 96 ha (Table 2, Fig. 2).

We obtained 15 distribution records for ***H. tianxing***, (11 of which were pre-1985 and the others from 1985 to 2000) from interviews with local villagers. This information suggested the existence of gibbons in Shangjiang and Pianma townships of Lushui county in the southern part of Nujiang Prefecture. Data for this species' southernmost distribution in the GLGMs were obtained from Fan et al. (2011) and Chan et al. (2017). We identified 17 separate forests in nine townships over three counties. For Myanmar, using data obtained by Fauna & Flora International (FFI) (covering an area of 3,000 km^2 to the east of the N'mai Kha River) we identified 12 records of gibbon sightings or calls along with three historical records of gibbons located in the Myitkyina and Imawbum Mountains east of N'mai Kha River from an altitude of 380 m to 2,620 m above sea level. Overall, the Skywalker hoolock gibbon was found in 73 independent polygons ranging in area from 3.6 to 64.6 ha (Fig. 2).

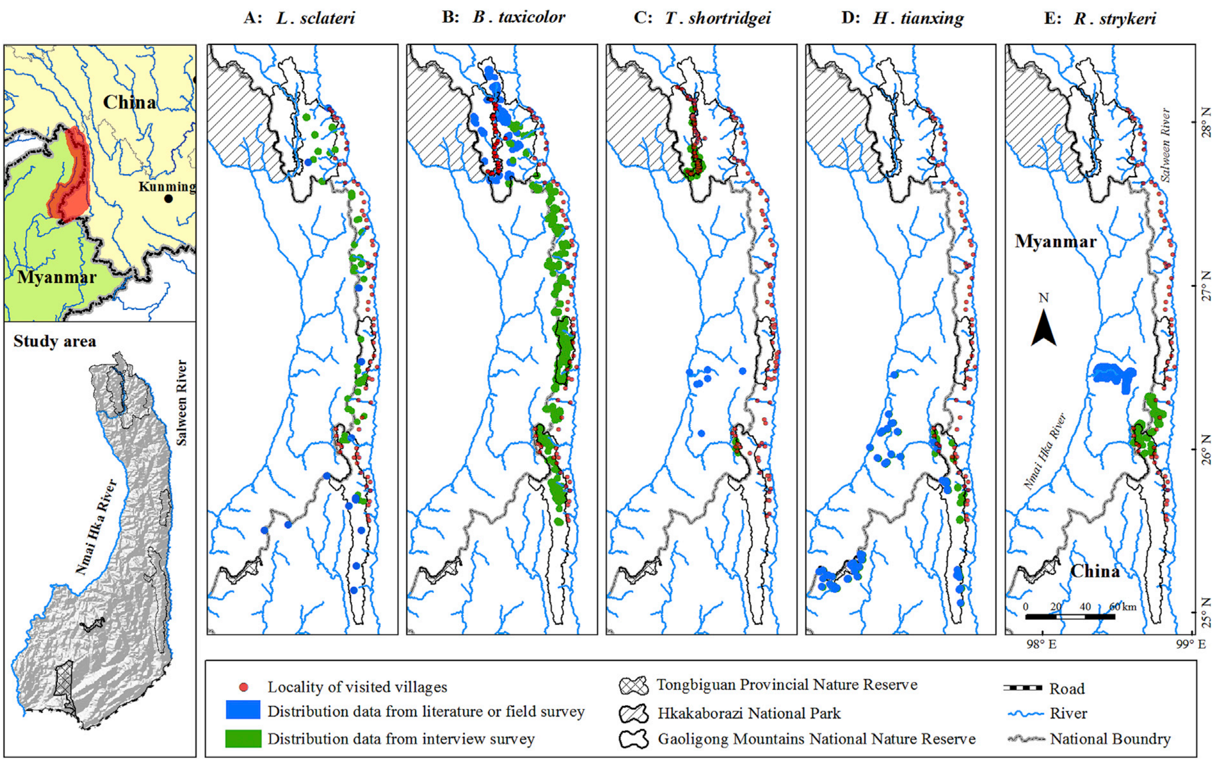

Fig. 2. Map of the study area and distribution of five selected flagship species based on interviews and field surveys in the Sino-Myanmar border region.

Based on interviews, we obtained 129 encounter records for ***L. sclateri*** (Table 2). We observed *L. sclateri* at four localities. Using data from Han et al. (2004), who documented *L. sclateri* at 15 sites located in the area from 25°50′-28°50′N to 98°33′-98°33′E. This species was found to be present in 64 non-overlapped polygons ranging in size from 2.6 to 109 ha (Fig. 2).

Our results indicate 254 distribution records for ***B. taxicolor*** covering an area of 4,200 km^2 within the Nujiang Prefecture of the GLGMs. Adding Zhang et al.'s (2014) results of 30 takin distribution ranges obtained during 2012–2013 in 25 villages in the Dulong River Basin (Table 2) to our 30 living traces (feces and footprints), three encounters with wild groups (group size ranged from 10 to 58 individuals), and camera trap records of takin groups or individuals at six interviewee-reported sites (including one group estimated to contain 65 individuals), we identified 183 polygons ranging in area from 0.7 to 3,181 ha inhabitated by this species (Fig. 2).

3.2. Habitat distribution of selected flagship species

The AUC values for the *T. shortridgei*, *H. tianxing*, *R. strykeri*, *L. sclateri* and *B. taxicolor* were 0.914, 0.969, 0.957 (Ren et al., 2017), 0.975 and 0.978, respectively, demonstrating that our habitat evaluation models had high efficiency in predicating the distributions of these five species' in the study area.

The predicted habitat distributional range and habitat suitability of each of the five flagship species within the study area differed markedly (Table 3). The habitat predicted for *T. shortridgei* covered 8,691 km^2 at an elevation of 1,100–2,900 m. Most of the highly suitable habitat for this species (85.3%) was found on the western slope of the GLGMs in Myanmar, and only about 16.9% of the highly suitable habitat (core + medium) was located in Hkakaborazi National Park in Myanmar and the GLGMNNR in China. *R. strykeri* and *H. tianxing* were distributed in the mid and southern most segments of the GLGMs, covering an area of 3,575 km^2 (see Ren et al., 2017 and Fig. 3) and 6,424 km^2 respectively. Currently, only about 13.9% of *R. strykeri*'s highly suitable habitat is present in the GLGMNNR. In the case of *H. tianxing*, China and Myanmar each shared almost half of the remaining highly suitable habitat at an elevation between 1,000 and 2,700 m. Only 25.1% of the remaining highly suitable habitat for *H. tianxing's* is located in protected reserves. These are the Tongbiguan Provincial Nature Reserve and the GLGMNNR, in China.

L. sclateri was distributed principally along the main ridge of the GLGMs [55.4% highly suitable habitat (Table 3) in China and 44.6% in Myanmar], covering 9,277 km^2 of the study area, principally at the elevational range of 2,700–3,900 m. Only 35.5% of the highly suitable habitat of this species was located in currently PAs. *B. taxicolor* had the broadest distribution of all five species, covering 9,932 km^2. This species' main habitat was predicted to be between 2,700 and 4,600 m, with 46.9% of the highly suitable habitat located in PAs. For *B. taxicolor*, 63.8% of highly suitable habitat was located in China and 36.2% in Myanmar.

3.3. High priority areas

Fig. 4A shows the results of the prioritization areas produced by the MCDA. The CA value ranged from 2 to 61. The area of pixels with a CA value $\geq$ 16 accounted for 40% (8,299.5 km^2, Fig. 4B, dark green parts) of the priority area indicating that these areas are the most valuable for conservation as they include medium suitable habitat for at least two species or the core habitat of at least one species within the intact forests. Pixels with a CA value $\geq$ 12 accounted for 60% (12,464 km^2, dark green parts + light green parts) of the priority area and include the most critical habitats of each of the five flagship species along with other fauna in the GLGMs. In total, thus 60% priority area (CA > 12) accounted for only 28.7% of the total study area. This likely reflects that fact that the high biodiversity areas in the GLGMs are distributed in relatively small and fragmented locations and that approximately 10,398.7 km^2 (83.4%) of the high priority area occurred outside of the existing system of PAs.

4. Discussion

The availability of sufficient and robust data are key to fine-scale conservation planning and evidence-based conservation management. However, difficult terrain, dense forests, low species encounter rates, and logistical challenges in remote mountainous areas make traditional animal survey methods such as linear transects time-consuming, labor-intensive and

Table 3
Summary of different categories of suitable habitats and elevational range predicted for each of the selected flagship species.

Species	Core habitat (km^2)	Medium habitat (km^2)	Edge habitat (km^2)	Elevation (m)	China (core + medium, %)	Myanmar (core + medium, %)	Highly suitable habitat in reserves (core + medium, %)	Note:
T. shortridgei	1525.6	3426.2	3739.2	1105–2986	14.7	85.3	16.9	
H. tianxing	1128.8	1916	3379.5	1091–2695	48.3	51.7	25.1	
R. strykeri	1420	750	1405	2330–3240	29.3	70.7	13.9	Ren et al. (2017)
L. sclateri	1477	3299	4451	2710–3824	55.4	44.6	35.5	
B. taxicolor	2052.5	2742.7	4536.6	2307–3770	63.8	36.2	46.9	

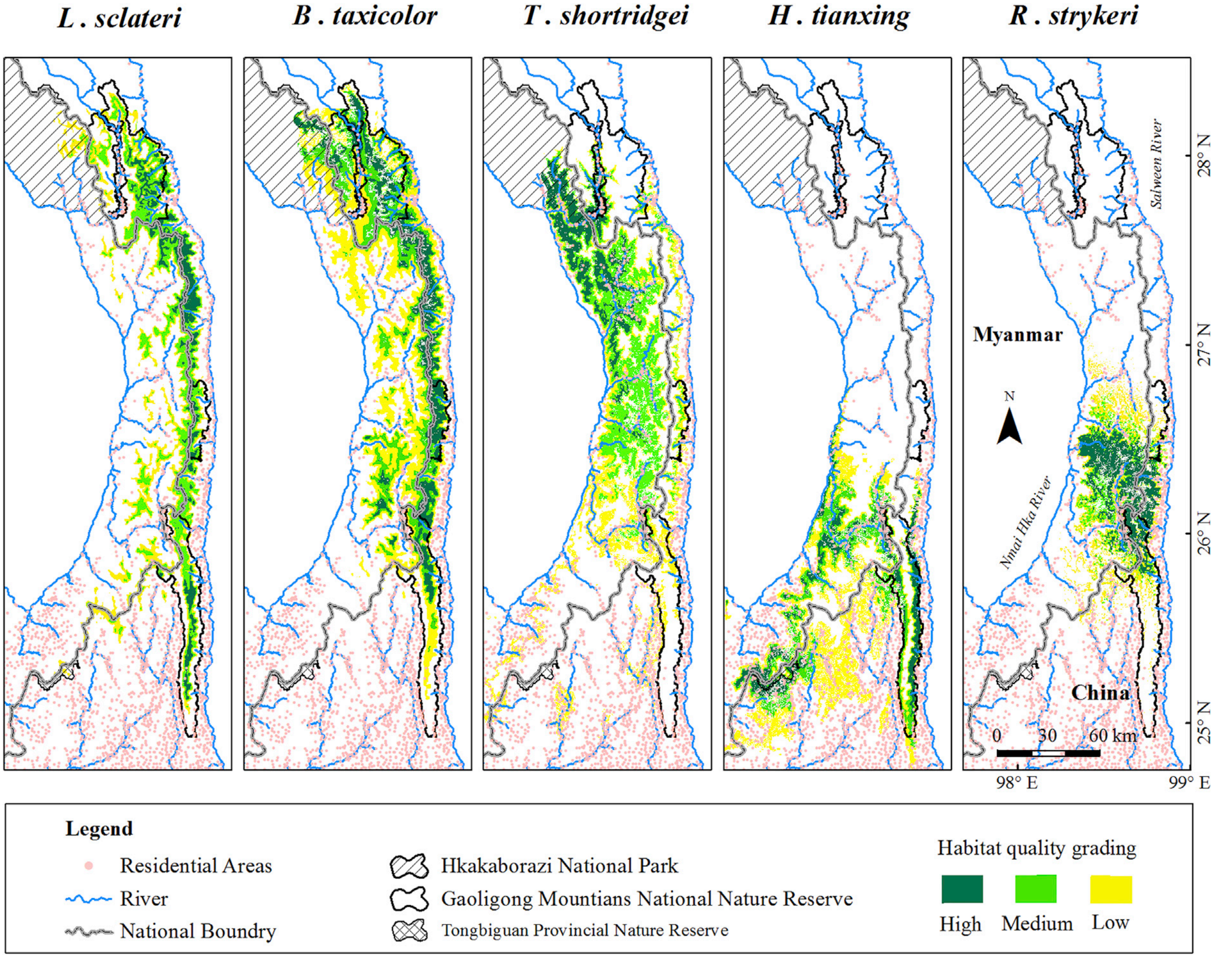

Fig. 3. Predictive habitat distribution and habitat suitability of five selected flagship species based on MAXENT modeling in the Sino-Myanmar border region.

impractical. This is the situation in the GLGMs (e.g. Yang et al., 2018; Yang et al., 2019). Moreover, data on species occurrences and distributions obtained from out-of-date or incomplete open source materials can generate large inaccuracies or omission errors (Figs. S3 and S4). Our results show that when used together, large-scale community interviews assisted by 3D visual maps, selective field surveys, and species distribution modeling can represent an effective set of research tools providing reliable data from which to predict population size, distribution, and availability of suitable habitat, as well as the conservation status of difficult to study species (cf. Ma et al., 2014; Turvey et al., 2015; Turvey et al., 2017; Ren et al., 2017). In combining data on species-specific habitat distribution patterns with the location and distance to roads, residential areas, agricultural fields and mining sites, and conservation prioritization methods (e.g. MCDA in this study) or software (e.g. Zonation, Marxan and C-Plan), researchers can effectively identify the location of critical conservation areas, travel or dispersal corridors, and target new areas for habitat restoration as part of a finer scale - lower cost conservation strategy than based on traditional methods (see also Fig. 5).

The results indicate that over 80% of the priority conservation areas for the five flagship and threatened species examined in this study currently occur outside of the existing protected area system. Thus, urgent rethinking of the existing conservation policies and planning and management of the protected area network in the GLGMs are required. We propose the following three primary recommendations:

4.1. Upscaling the methodology for regional information collection and monitoring

The vast biologically-rich region from the GLGMs to northeastern India and northern Myanmar (the Northern Myanmar Forest Complex) represents a mountainous geographical zone that presents significant challenges regarding the acquisition of conservation information. These challenges include extremely poor accessibility, highly rugged topography, dense forests, low human population density, a severe shortage of information on the behavior and ecology of threatened species, prohibitively high costs of data acquisition, and limited government budgets for intensive field surveys. Adopting the approaches

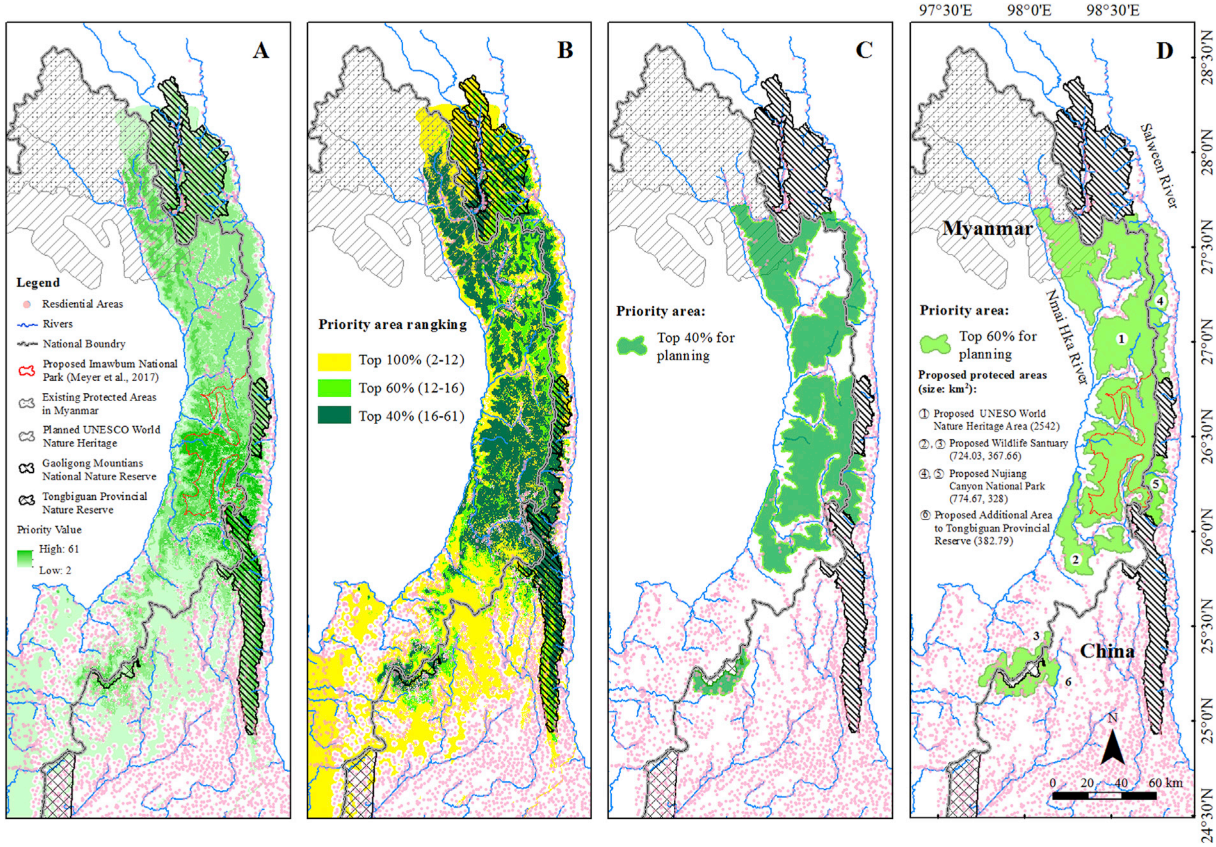

Fig. 4. Priority areas for transboundary conservation along the north Sino-Myanmar border based on the remaining habitat distribution area for the five selected flagship species and multi-criteria decision analysis. C: Top 40% priority area; D; 60% priority area.

and methodologies introduced in this paper can provide park rangers and conservation managers with the data required to make critical conservation policies at an affordable cost. Moreover, using a similar region-wide methodology serves to generate quality and comparable landscape level information and promote meaningful regional collaboration for conservation. Many international organizations that work on landscape conservation such as the International Centre for Integrated Mountain Development (ICIMOD), FFI, and Wildlife Conservation Society (WCS) advocate the use of standardized approaches for collecting conservation data.

4.2. Coordinating conservation policies and planning between Myanmar and China for the GLGMs

It is essential that China and Myanmar strengthen transboundary collaboration in their conservation planning and implementation in the GLGMs in order to effectively protect vulnerable and endangered animal and plant species, whose populations or habitats are distributed on both sides of these national borders.

In the current study, we identified five flagship species that are geographically restricted to the GLGMs or eastern-Himalaya region, and are facing a high risk of extinction (Appendix S1). Landscape integrity and connectivity (see Fig. 4C and D) are thought to be essential for maintaining animal populations, thus we recommend that the top 60% of priority areas identified in our MCDA model (Fig. 4D) be set aside and protected for conservation. This would require Myanmar to add approximately 7,055 km^2 into their current PA system, including three large patches (Fig. 4D, No. 1: 5,693 km^2, No. 2: 724.03 km^2, and No. 3: 367.66 km^2) that are fragmented by rivers and human inhabitation. In China, the priority areas are mainly located on the eastern slopes of the GLGMs, comprising two unprotected areas along the main ridge (Fig. 4D, No. 4: 774.63 km^2 and No. 5: 328 km^2) and an additional area adjacent to the Tongbiguan Provincial Nature Reserve (Fig. 4D, No. 6: 382.79 km^2, bordering with No.3). Given that most of the southern part of the study area is densely settled by humans, its value as a conservation area is limited.

While the Government of Myanmar (MoNREC) is planning to create the Imawbum National Park in Sawlaw Township to protect its remaining population of some 200 *R. strykeri* (Fig. 4A, Meyer et al., 2017), the proposed area may be too small to protect other threatened species such as the *H. tianxing* and *T. shortridgei*. In both China and Myanmar, less than 300 individuals of each species exist in PAs. Additionally, MoNREC proposed the Hkakabo Razi Landscape as Myanmar's first

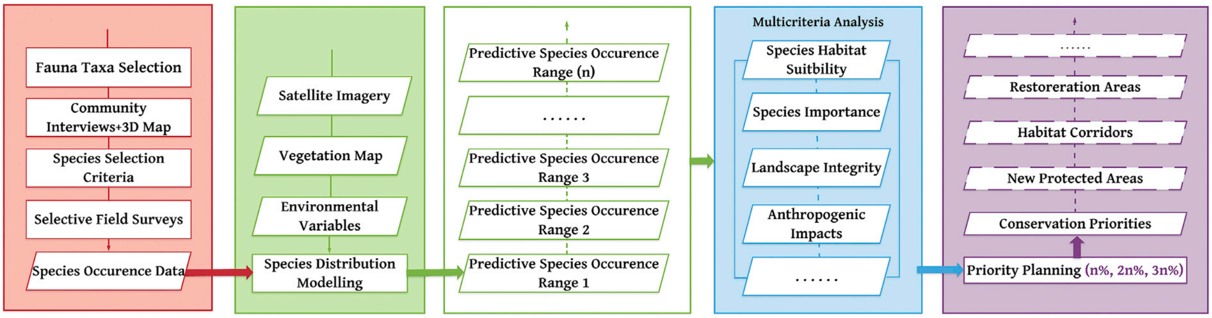

Fig. 5. A recommended conservation prioritization framework for relatively quick and reliable conservation planning in poorly-studied areas.

candidate for a UNESCO WNH site in 2014. The proposal recommended that the heritage area extend to the east side of the N'Mai Kha River and be connected with the GLGMNNR of China in order to strengthen its natural and conservation values (UNESCO Ref.: 5871, 2014). We, therefore, propose that that priority area No.1 (Fig. 4D) be added to the Hkakabo Razi Landscape as a WNH area (Appendix S2) and that priority areas No. 2 and No. 3 be designated as wildlife sanctuaries to protect the remaining populations and habitats of *H. tianxing* and *T. shortridgei*, as well as other threatened and endangered primates such as Phayre's langur (*T. phayrei*) and the northern slow loris (*Nycticebus bengalensis*) (Momberg et al., 2010). Habitat No. 3 (Fig. 4D) has undergone extensive banana cultivation (Zhang Lixiang, pers. comm.) and thus requires conservation measures such as “enclosing the mountain for natural afforestation” and an active program of reforestation to ensure wildlife protection. Moreover, area No. 6 should be added to the Tongbiguan Provincial Nature Reserve in order to link the No. 3 wildlife sanctuary with the transboundary conservation area for protecting *H. tianxing*. Furthermore, the mid- and southern parts of the Nujiang Grand Canyon National Park, Area No. 5 (Fig. 4D), which contains the remaining major population of *R. strykeri* should be added to the Chinese National Park system (see *The Program for National Park Development in Yunnan Province, 2009—2020*). Finally, the proposed Nujiang Grand Canyon National Park (Fig. 4D, Areas No. 4, and 5) in China and the WNH area in Myanmar are expected to cover all or most of the remaining habitat of *B. taxicolor* and *L. sclateri* (an area of 7,443 km^2), along with other endangered fauna such as the grey-bellied tragopan (*Tragopan blythii*), the red panda (*Ailurus fulgens*), and the dhole (*Cuon alpinus*).

These measures would result in the creation of a large and continuous belt of protected conservation areas extending from China to India through Myanmar, resulting in one of the world's largest transboundary conservation networks, covering 13 PAs over 30,067 km^2, four Alliance for Zero Extinction sites, four globally important ecoregions, and eleven key biodiversity areas. In addition the successful inclusion of the Hkakaborazi Landscape (including the proposed addition of area No 1) into the WNH list will provide a framework of opportunity for China (the Three Parallel Rivers WNH area) and Myanmar to develop and promote the transboundary management of a joint WNH site. The two countries also could work jointly to create an international peace park for biodiversity conservation, and ecotourism along the northern Sino-Myanmar border (see Vasilijević et al., 2015).

Increasing coordination between China and Myanmar in conservation policy-making and planning can help to identify conservation gaps, the locations of critical biological corridors, and common conservation priorities.

4.3. Exploring possibilities for joint or transboundary protected areas along the northern China-Myanmar border

Considering the transboundary nature of the socio-ecological systems, in particular, the cross-border distribution of many small ethnically diverse human populations and highly endangered flagship wildlife species and their habitats in the GLGMs, effective conservation policies require that decision-makers, managers and scientists of China and Myanmar work together to study the possibilities of joint or transboundary protected area management, especially in the northern sector. This is especially relevant given that some of the currently protected areas created by China and Myanmar are geographically connected.

Transboundary PAs are needed to secure and promote the ecological integrity and long-term survival of resident and migratory species, while transboundary conservation can generate socio-cultural and economic benefits to local human communities (Vasilijević et al., 2015). In the past decade, transboundary collaboration for conservation and development in the Hindu Kush-Karakoram-Himalaya region has made considerable headway in protecting transboundary landscapes of high biodiversity value through initiatives such as the Kangchenjunga Landscape Initiative (Gurung et al., 2019) and the Landscape Initiative for Far-Eastern Himalayas (HI-LIFE) (Basnet et al., 2018). This collaboration has been facilitated by the ICIMOD. HI-LIFE, which aims to foster long-term conservation partnerships between China, India and Myanmar. The initiative has facilitated much dialogue among the key stakeholders including policy makers from both sides (Basnet et al. 2017, 2018). The on-going efforts by the Government of Myanmar to inscribe the Hkakaborazi Landscape (including the proposed addition of area No 1) into the WNH list, if successful, will provide additional opportunities for China (the Three Parallel Rivers WNH area) and Myanmar to develop and promote transboundary management of this WNH site. We therefore recommend that further steps be taken to explore the possibilities for joint or transboundary protected area management between China and Myanmar in the GLGMs. To achieve this goal, the following initial steps can be taken:

- Establish regular mechanisms for policy makers, PA managers, conservation scientists and members of concerned local communities to share biodiversity data and management information, jointly identify common conservation priorities and gaps in the existing PA network, and exchange experiences, best practices, and management programs and policies;
- Develop joint research projects to investigate and monitor key threatened species and their habitats and study landscape level changes in deforestation and the affects of climate change species survivorship using common methodologies;
- Jointly monitor and control cross-border poaching, wildlife trade, logging, forest fires, non-timber forest product harvesting and trading, and respond to natural disasters; and
- Promote the transparent, equitable and sustainable cross-border trading of biological resources.

5. Authors' contributions

WX, YY, GPR, AB conceived the ideas and methodology. ZPH, AKL, CM, YY, FM, XWW, GSL collected the data. RGP, YY, WJL analyzed the data. YY drafted the manuscript. PAG, AB, SLY, YY, WX, GPR revised the manuscript and contributed to the development of ideas. YY, GY illustrated the maps.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2019.e00732.

References

Adem Esmail, B., Geneletti, D., 2018. Multi-criteria decision analysis for nature conservation: a review of 20 years of applications. Methods. Ecol. Evol. 9, 42–53.
Araújo, M.B., Pearson, R.G., Thuiller, W., Erhard, M., 2005. Validation of species–climate impact models under climate change. Glob. Chang. Biol. 11, 1504–1513.
Basnet, D., Pradhan, N., Yi, S.L., Shakya, B., Moe, A.T., 2018. Regional Workshop on Planning Transboundary Technical Collaboration for Landscape Management. ICIMOD Workshop Report 2018. ICIMOD, Kathmandu.
Basnet, D., Yi, S.L., Shakya, B., Dorji, T., 2017. Workshop on 'opportunities for trans-boundary collaboration for conservation and development along the northern section of the China-Myanmar border'. In: ICIMOD Proceedings 2017/5. ICIMOD, Kathmandu.
Beresford, A.E., Buchanan, G.M., Donald, P.F., Butchart, S.H.M., Fishpool, L.D.C., Rondinini, C., 2011. Poor overlap between the distribution of protected areas and globally threatened birds in Africa. Anim. Conserv. 14, 99–107.
Breiman, L., 2001. Random forests. Mach. Learn. 45, 5–32.
Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A., et al., 2006. Global biodiversity conservation priorities. Science 313, 58–61.
Brooks, T.M., Pimm, S.L., Akçakaya, H.R., Buchanan, G.M., Butchart, S.H., Foden, W.,, et al., 2019. Measuring terrestrial area of habitat (AOH) and its utility for the IUCN red list. Trends Ecol. Evol. https://doi.org/10.1016/j.tree.2019.06.009.
Bunce, L., Townsley, P., Pomeroy, R., Pollnac, R., 2000. Socioeconomic Manual for Coral Reef Management. IUCN, the World Conservation Union. Australian Institute of Marine Science, Townsville, Australia, pp. 96–100.
Chan, B.P.L., Mak, C.F., Yang, J.H., Huang, X.Y., 2017. Population, distribution, vocalization and conservation of the Gaoligong hoolock gibbon (*Hoolock tianxing*) in the tengchong section of the gaoligongshan national nature reserve, China. Primate Conserv. 31, 107–113.
Chaplin, G., 2005. Physical geography of the Gaoligong Shan area of Southwest China in relation to biodiversity. Proc. Calif. Acad. Sci. 56, 527–556.
Cui, L.W., Li, Y.C., Ma, C., et al., 2016. Distribution and conservation status of Shortridge's capped langurs *Trachypithecus shortridgei* in China. Oryx 6, 732–741.
Di Minin, E., Moilanen, A., 2014. Improving the surrogacy effectiveness of charismatic megafauna with well-surveyed taxonomic groups and habitat types. J. Appl. Ecol. 51, 281–288.
Dorji, S., Rajaratnam, R., Falconi, L., Williams, S.E., Sinha, P., Vernes, K., 2018. Identifying conservation priorities for threatened Eastern Himalayan mammals. Conserv. Biol. 32, 1162–1173.
Dumbacher, J.P., Miller, J., Flannery, M.E., Xiaojun, Y., 2011. Avifauna of the Gaoligong Shan Mountains of western China: a hotspot of avian species diversity. Ornithol. Monogr. 70, 30–63.
EIA (Environmental Investigation Agency), 2015. Organized Chaos: the Illicit Overland Timber Trade between Myanmar and China. EIA, London, UK.
Fan, P.F., He, K., Chen, X., et al., 2017. Description of a new species of Hoolock gibbon (Primates: hylobatidae) based on integrative taxonomy. Am. J. Primatol. 79, e22631.
Fan, P.F., Xiao, W., Huo, S., Ai, H.S., Wang, T.C., Lin, R.T., 2011. Distribution and conservation status of the vulnerable eastern hoolock gibbon *Hoolock leuconedys* in China. Oryx 45, 129–134.
Geissmann, T., Lwin, N., Aung, S.S., et al., 2011. A new species of snub-nosed monkey, genus *Rhinopithecus* Milne-Edwards, 1872 (Primates, Colobinae), from northern Kachin state, northeastern Myanmar. Am. J. Primatol. 73, 96–107.
Groombridge, J.J., Massey, J.G., Bruch, J.C., et al., 2004. An attempt to recover the po'ouli by translocation and an appraisal of recovery strategy for bird species of extreme rarity. Biol. Conserv. 118, 365–375.

Gurung, J., Chettri, N., Sharma, E., et al., 2019. Evolution of a transboundary landscape approach in the Hindu Kush Himalaya: key learnings from the Kangchenjunga landscape. Glob. Ecol. Conserv. 17, e00599.
Han, L., Huang, S., Luo, X., Yang, H., 2004. The distribution and conservation of Sclater's monal in Yunnan, China. Chin. Biodivers. 12, 523–527 (In Chinese).
Hijmans, R., van Etten, J., Mattiuzzi, M., et al., 2015a. Raster: geographic data analysis and modeling. R package ver 2, 3–40.
Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. Int. J. Climatol. 25, 1965–1978.
Hijmans, R.J., Phillips, S., Leathwick, J., Elith, J., 2015b. *Species Distribution Modelling with R. R Package "Dismo."* Version 1.0, p. 12.
Hoffmann, M., Brooks, T.M., Da Fonseca, G.A.B., et al., 2008. Conservation planning and the IUCN red list. Endanger. Species Res. 6, 113–125.
Kissling, W.D., Field, R., Korntheuer, H., Heyder, U., Böhning-Gaese, K., 2010. Woody plants and the prediction of climate-change impacts on bird diversity. Philos. Trans. Royal Soc. 365, 2035–2045.
Li, H., Guo, H.J., Dao, Z.L., 2000. Flora of Gaoligong Mountains. Science Press, Beijing (In Chinese).
Liaw, A., Wiener, M., 2002. Classification and regression by random forest. R. News 2, 18–22.
Ma, C., Huang, Z.P., Zhao, X.F., et al., 2014. Distribution and conservation status of *Rhinopithecus strykeri* in China. Primates 55, 1–6.
Ma, C., Luo, Z., Liu, C., Orkin, J.D., Xiao, W., Fan, P., 2015. Population and conservation status of indochinese gray langurs (*Trachypithecus crepusculus*) in the wuliang mountains, jingdong, yunnan, China. Int. J. Primatol. 36, 749–763.
Ma, S.L., Han, L.X., Lan, D.Y., Ji, W.Z., Harris, R.B., 1995. Faunal resources of the gaoligongshan region of yunnan, China: diverse and threatened. Environ. Conserv. 22, 250–258.
Meijaard, E., Mengersen, K., Buchori, D., et al., 2011. Why don't we ask? A complementary method for assessing the status of great apes. PLoS One 6, e18008.
Meyer, D., Momberg, F., Matauschek, C., et al., 2017. Conservation Status of the Myanmar or Black Snub-Nosed Monkey Rhinopithecus Strykeri. Fauna & Flora International, Yangon, Myanmar and German Primate Center, Göttingen, Germany.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853.
Momberg, F., Lwin, N., Geissmann, T., 2010. Report on a Snub-Nosed Monkey and Biodiversity Field Survey, April 24–May 8, 2010. Y. Myanmar Primate Conservation Program, angon, p. 16p.
Pearson, R.G., 2007. Species' Distribution Modeling for Conservation Educators and Practitioners, Native Plants. Center for Biodiversity and Conservation, American Museum of Natural History, New York, New York, USA.
Pimm, S.L., Jenkins, C.N., Li, B.V., 2018. How to protect half of Earth to ensure it protects sufficient biodiversity. Sci. Adv. 4, eaat2616.
Potapov, P., Yaroshenko, A., Turubanova, S., et al., 2008. Mapping the world's intact forest landscapes by remote sensing. Econ. Soc. 13, 51.
R Core Team, 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL. https://www.R-project.org/.
Ren, G.P., Yang, Y., He, X.D., et al., 2017. Habitat evaluation and conservation framework of the newly discovered and critically endangered black snub-nosed monkey. Biol. Conserv. 209, 273–279.
Ricketts, T.H., Dinerstein, E., Boucher, T., et al., 2005. Pinpointing and preventing imminent extinctions. Proc. Natl. Acad. Sci. U.S.A. 102, 18497–18501.
Rondinini, C., Wilson, K.A., Boitani, L., Grantham, H., Possingham, H.P., 2006. Tradeoffs of different types of species occurrence data for use in systematic conservation planning. Ecol. Lett. 9, 1136–1145.
Santarém, F., Pereira, P., Saarinen, J., Brito, J.C., 2019. New method to identify and map flagship fleets for promoting conservation and ecotourism. Biol. Conserv. 229, 113–124.
Thorn, J.S., Nijman, V., Smith, D., Nekaris, K.A.I., 2009. Ecological niche modelling as a technique for assessing threats and setting conservation priorities for Asian slow lorises (Primates: *Nycticebus*). Divers. Distrib. 15, 289–298.
Tulloch, A., Possingham, H.P., Wilson, K.A., 2011. Wise selection of an indicator for monitoring the success of management actions. Biol. Conserv. 144 (1), 141–154.
Turvey, S.T., Bryant, J.V., Duncan, C., et al., 2017. How many remnant gibbon populations are left on Hainan? Testing the use of local ecological knowledge to detect cryptic threatened primates. Am. J. Primatol. 79, e22593.
Turvey, S.T., Trung, C.T., Quyet, V.D., et al., 2015. Interview-based sighting histories can inform regional conservation prioritization for highly threatened cryptic species. J. Appl. Ecol. 52, 422–433.
Vasilijević, M., Zunckel, K., McKinney, M., Erg, B., Schoon, M., Rosen Michel, T., 2015. Transboundary conservation: a systematic and integrated approach. In: Best Practice Protected Area Guidelines Series, No. 23. IUCN, Gland, Switzerland xii + 107 pp.
Xue, J.R., 1995. Gaoligong Mountain National Nature Reserve. China Forestry Publishing House, Beijing (In Chinese).
Yang, Y., Groves, C., Garber, P., et al., 2019. First insights into the feeding habits of the Critically Endangered black snub-nosed monkey, Rhinopithecus strykeri (Colobinae, Primates). Primates 60, 143–153.
Yang, Y., Tian, Y., He, C., et al., 2018. *Rhinopithecus strykeri* found in salween river basin. Oryx 52, 134–136.
Zhang, L., Bai, H., Feng, Z., et al., 2014. Distribution, population and conservation status of *Budorcas taxicolor taxicolor* in Dulong Jiang township. Sichuan J. Zool. 493–497 (In Chinese).
Zhang, M., Gouveia, A., Qin, T., Quan, R., Nijman, V., 2017. Illegal pangolin trade in northernmost Myanmar and its links to India and China. Glob. Ecol. Conserv. 10, 23–31.