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PLATINUM OPEN ACCESS

Mammals of Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China

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Abstract: We conducted field surveys on the mammalian diversity in the Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China, using camera trap and transect method between April 2014 and May 2018. A total of 46 identifiable mammal species were recorded, including one new record for China and nine new species for the Tengchong County. Of the 46 species, nine are globally threatened (three Endangered and six Vulnerable) and six are Near Threatened on the IUCN Red List of Threatened Species. Species richness of most mammal groups in Tengchong remains high compared to similar sites in neighbouring countries; however, encounter rates for species vulnerable to high hunting pressures were quite low and large carnivores, except the Asiatic Black Bear, were either extirpated or at critically low numbers. Future surveys should cover a wider elevation range and a variety of microhabitats to increase the probability of detecting the species not yet recorded. To enhance the conservation value of the reserve for the diverse mammalian community, poaching and livestock grazing should be further controlled; in addition, protection and restoration of low-altitude forests should be encouraged. Monitoring and research on selected flagship species should also be conducted.

Keywords: Camera trap, new records, spotlighting, threatened species, transect survey.

Chinese 摘要： 2014 年 4 月至 2018 年 5 月，笔者利用红外线相机以及样线调查对高黎贡山国家级自然保护区腾冲片区开展了兽类考察工作。考察共记录兽类 46 种，包括 1 种中国新纪录及 9 种腾冲新纪录。其中 9 种被 IUCN 红色名录列为全球受胁物种（3 种濒危；6 种易危），6 种为近危。与临近国家的相似保护地比较，腾冲大部分类群的兽类物种丰富度较高，但容易受盗猎影响的物种的遇见率相对较低，大型食肉类动物除去黑熊外已经区域性灭绝或只残留极小的种群。建议未来调查应涵盖更广的海拔跨度以及更多的生境类型，以增加对缺失物种的发现几率。为了更好的保护研究区域的兽类多样性，笔者建议对盗猎及保护区中的放牧现象加大管理打击，加强低海拔森林的保护和恢复，并对个别旗舰物种开展进一步的研究与监测。

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Author contribution: Fei Li and Bosco Chan performed the analysis and wrote the paper. All authors collected and contributed data.

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INTRODUCTION

Gaoligongshan Mountains (hereafter GLGS) is well-known for its rich biodiversity and unique geomorphological features (Chan et al. 2019). It attracted visiting naturalists as early as the 19th Century; the most notable among them were John Anderson, George Forrest, Frank Kingdon-Ward, and Roy Chapman Andrews, who made a series of significant mammal collections from GLGS. Anderson collected the type series of Yunnan Giant Flying Squirrel *Petaurista yunnanensis* from the surroundings of Tengchong Town in 1868 (Anderson 1878) and the type specimen of Yunnan Hare *Lepus comus* from Tengchong in 1917 (Allen 1938). The collection of insectivores and rodents from GLGS by Forrest and Kingdon-Ward greatly improved our understanding of these little-studied groups in the eastern Himalaya (Thomas 1912, 1914, 1922; Hinton 1923). From the mid-20th Century, research on the area's mammals was carried out by Chinese zoologists, further enhancing understanding of the mammalian fauna of the region, especially on the species composition of communities and their geographic distribution across the vast mountain range (Pen et al. 1962; Peng & Wang 1981). A baseline survey of Gaoligongshan National Nature Reserve listed 89 mammal species for Tengchong County, including five species of Chiroptera and 16 species of Muridae (Xue et al. 1995).

In April 2014, we launched a systematic mammal survey in the Tengchong Section of Gaoligongshan National Nature Reserve (hereafter TC-GLGS). We provide a report on the current mammal diversity and conservation status in TC-GLGS based on camera trap and transect surveys conducted between April 2014 and May 2018.

MATERIALS AND METHODS

Camera trap survey

The camera trap survey was conducted between September 2014 and May 2018. The total number of camera trap stations was 147, and they covered elevations from 1,515m to 3,350m. Three models of infrared camera traps (Loreda L510, Loreda; SG-990V, Shenzhen Siyuan Digital Technology Company; Reconyx PC900, Reconyx) were used. Camera traps were deployed in microhabitats thought to likely maximize the probability of detecting medium- to large-sized ground-dwelling mammals, such as animal trails, salt licks, ridgelines, water sources, and underneath fruiting trees. A group of knowledgeable reserve wardens assisted in identifying suitable locations for deploying camera traps, and about 60% of our camera trap stations were selected based on their advice. Most of the cameras were mounted on trees at a height of c. 30–40 cm from the ground at a distance of 2–4 m to the target area. Time and date were automatically recorded on each exposure. Commercial lures (Hawbaker's Weasel and Marten Lure) were used at five camera trap stations as a trial to test the effectiveness for future camera trapping study.

Non-random transects

Both diurnal and spotlighting transects were conducted in addition to the camera trapping. Forest trails, watercourses, and quiet forest roads were walked on to complement the inefficiency of camera trapping for strictly arboreal species and to maximize encounter rate of mammal species. Fifteen transects were surveyed, amounting to a total of 180.76km and 172 man-days, covering elevations between 1,300m and 3,430m, during both the cold-dry and wet-warm seasons. During these walks, all observed animals were recorded. Tracks, feeding signs, and droppings which could be confidently identified were also recorded (see Table 2 for field signs recorded for each species). Spotlighting surveys were conducted in 11 of these transects, amounting to 37.27km; we walked along quiet roads, trails, and streams at a slow pace (under 1km/h) with two or three observers (Table 1). Locations of our camera trap and transect surveys can be found in Fig. 1.

Data analysis

We included all mammals detected except Chiroptera, Muridae, and Cricetidae, due to the difficulties in identifying species in these groups, often because of taxonomic uncertainties (e.g., Zhang et al. 2016). We included distinctive species of Insectivora in which field identification is unequivocal; these included Gaoligong Forest Hedgehog *Mesechinus wangi*, Elegant Water Shrew *Nectogale elegan*, and Northern Treeshrew *Tupaia belangeri*. Nomenclature followed Wilson & Reeder (2005), Wilson et al. (2009, 2011, 2016), and Mittermeier et al. (2013). Some species incorporated the latest taxonomic updates, and the reasons for these deviations from Wilson et al. (2009) and Wilson & Reeder (2005) are explained in the respective species account.

We defined a camera trap record as a notionally independent record if it occurred 30 minutes or more after an image of the same species at the same station. One trap night was defined as a continuous 24-hour

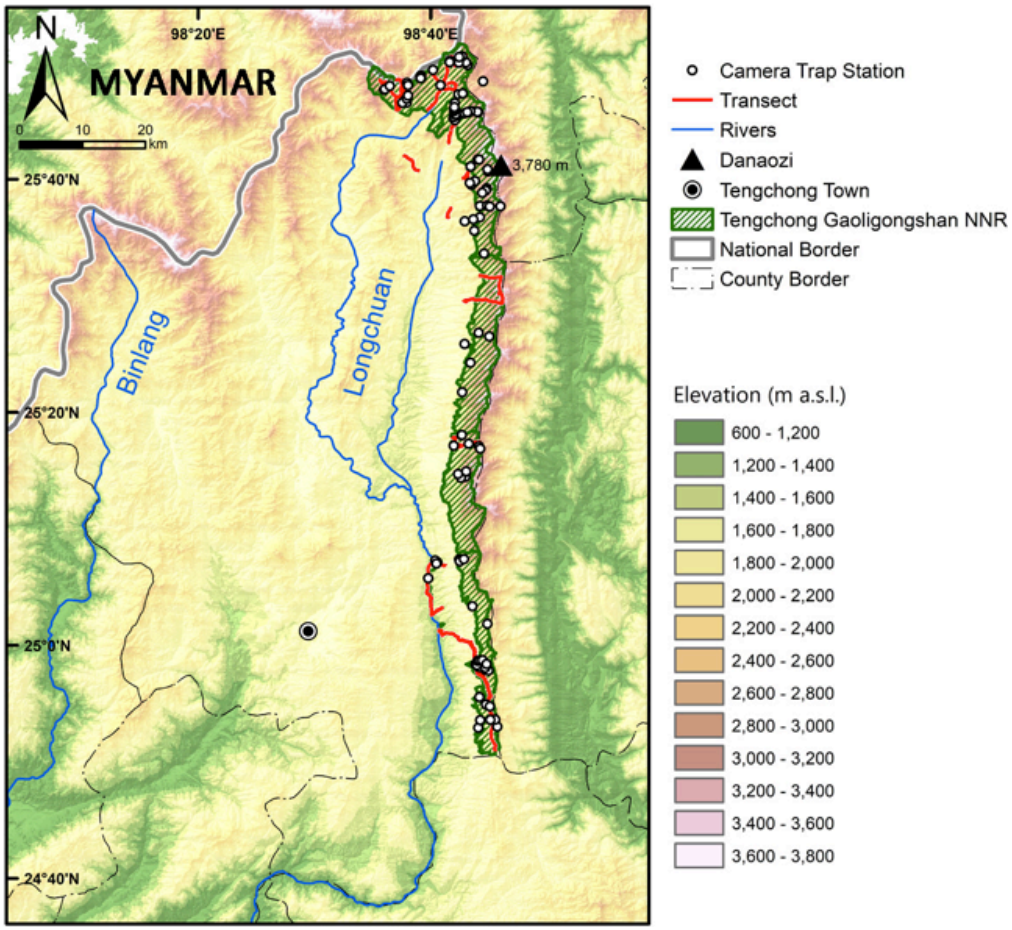

Figure 1. Camera trap stations and non-random transect surveys in Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China, 2014–2018.

period of camera operation. To understand the species richness and conservation value of mammals in TC-GLGS, we compared our camera trap data with that from two protected areas in neighbouring countries with similar geographic, climatic, and biogeographic affinities: Namdapha National Park in northeastern India and Hkakaborazi National Park in northern Myanmar.

RESULTS

Between April 2014 and May 2018, there were 147 camera trap stations set for 14,814 trap nights. Together with 180.76km of transect lines, 46 species of non-volant mammals were recorded; of these, there were five primates, 12 carnivores, and 10 ungulates. This included three globally Endangered species (Phayre's Langur *Trachypithecus phayrei*, Red Panda *Ailurus fulgens*, and Forest Musk Deer *Moschus berezovskii*), six Vulnerable species (Gaoligong Hoolock Gibbon *Hoolock tianxing*, Stump-tailed Macaque *Macaca arctoides*, Asiatic Black Bear *Ursus thibetanus*, Sambar *Rusa unicolor*, Takin *Budorcas taxicolor*, and Chinese Goral *Naemorhedus griseus*), and six Near Threatened species (Assamese Macaque *Macaca assamensis*, Marbled Cat *Pardofelis marmorata*, Tufted Deer *Elaphodus cephalophus*, Burmese Red Serow *Capricornis rubidus*, Chinese Serow *Capricornis milneedwardsii*, and Black Giant *Squirrel Ratufa bicolor*) (IUCN 2018). The Burmese Red Serow *Capricornis rubidus* was newly recorded in China and nine species were new to the Tengchong County (Yellow-bellied Weasel *Mustela kathiah,* Stripe-backed Weasel *M. strigidorsa*, Common Palm Civet *Paradoxurus hermaphroditus*, Marbled Cat *Pardofelis marmorata*, Gongshan Muntjac *Muntiacus gongshanensis*, Orange-bellied Himalayan Squirrel *Dremomys lokriah*, Spotted Giant Flying Squirrel *Petaurista marica*, Asiatic Brush-tailed Porcupine *Atherurus macrourus*, and Forrest's Pika *Ochotona forresti*).

Of the 46 recorded species, 34 were detected by

Table 1. Transect sites and survey dates in Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China, 2014–2018.

	Transect/ coordinates	Survey dates	Elevation covered (m)	Sampling effort (km) Daytime / spotlighting
1	Xiaodifang--Datiandi 24.845°N, 98.759°E – 25.019°N, 98.679°E	24–26.iv.2014, 24.ix.2014, 7–8.xii.2014, 10–12.iii.2015, 3.x.2015, 22.iii.2016, 10–11.v.2017, 22–23.v.2018, 24-26.v.2018	1,300–2,450	30.27 / 12.88
2	Longchuan River Protected Riparian Forest 25.054°N, 98.685°E – 25.114°N, 98.688°E	9–11.v.2016, 25–26.vi.2017	1,300–1,350	16.13 / 4.07
3	Linjiapu-Nanzhaigongfang, Qushi Section 25.286°N, 98.701°E – 25.288°N, 98.738°E	28–29.iv.2014, 9–10.xii.2014, 16–18.v.2015, 18.vii.2015, 5–6.x. 2015, 8–9.i.2016, 4–7.v.2017	2,050–3,185	7.22 / 2.82
4	Nanzhaigongfang ridge, Qushi Section 25.288°N, 98.738°E – 25.275°N, 98.738°E	7.v.2017	3,180–3,280	2.38 / 1.13
5	Daying--GLGS main ridge 25.491°N, 98.712°E – 25.502°N, 98.766°E	10–12.iii.2015	1,910–3,430	16.46 / --
6	Mt. Danaozi, Jietou Section 25.667°N, 98.696°E – 25.692°N, 98.735°E	24.ix.2014	2,270–3,300	5.69 / --
7	Datang Big Tree Rhododendron, Datang Section 25.715°N, 98.692°E – 25.761°N, 98.701°E	27–28.iv.2014, 25.ix.2014, 13–15.iii.2015, 12.v.2016, 24–26.v.2018	1,950–2,460	8.63 / 2.69
8	Danlonghe 25.608°N, 98.691°E – 25.622°N, 98.696°E	27.iv.2014, 19.vii.2015	1,930–1,970	3.09 / --
9	Fanshanchu State-owned Forest 25.675°N, 98.651°E – 25.698°N, 98.627°E	26.ix.2014, 17.vii.2015, 12.v.2016	1,870–2,120	4.02 / 1.66
10	Boundary marker #8, Zizhi Section 25.763°N, 98.618°E – 25.806°N, 98.625°E	27.ix.2014, 29.ix.2014, 13.xii.2014, 19–20.v.2015, 17.vii.2015, 6–8.x.2015, 7–8.i.2016, 24–26.iv.2017, 8–10.v.2017	2,120–3,050	12.02 / 5.26
11	Boundary marker #9, Zizhi Section 25.762°N, 98.661°E – 25.819°N, 98.670°E	28.ix.2014	2,080–2,650	7.96 / --
12	Dongbinghe, Zizhi Section 25.794°N, 98.682°E – 25.802°N, 98.695°E	21–22.v.2015	2,200–2,750	5.65 / 1.89
13	Pinghe, Zizhi Section 25.831°N, 98.693°E – 25.833 N, 98.706°E	21–24.xi.2017	2,450–2,700	9.11 / 0.87
14	Sanjiaojia, Zizhi Section 25.783°N, 98.616°E – 25.812°N, 98.597°E	21–25.xi.2017, 24–26.v.2018	2,200–3,000	5.70 / 1.31
15	Zhongheyakou, Zizhi Section 25.828°N, 98.708°E – 25.842°N, 98.715°E	21–25.xi.2017	2,600–3,200	9.16 / 2.69
			Total	143.49 / 37.27

camera traps, 10 by direct observation alone, and two by tracks and signs alone (Sambar and Mishmi Takin). The three species most frequently camera trapped during our survey were Malayan Porcupine *Hystrix brachyura*, Northern Red Muntjac *Muntiacus vaginalis*, and Assamese Macaque *Macaca assamensis*.

A checklist of mammal species recorded in our survey can be found in Table 2, and a selection of recorded species are illustrated in Images 1 and 2. Accounts of species of special interest (i.e., globally threatened, new Tengchong records, or rare for GLGS) are provided below. Detailed information for most recorded species can also be found in Chan & Bi (2016).

Accounts on selected species

Gaoligong Forest Hedgehog *Mesechinus wangi* (Not Assessed)

This Gaoligongshan-endemic species was recently described, although the existence of a hedgehog in southern GLGS was known by scientists and reserve staff as early as 2003 (Ai et al. 2018). It has only been recorded from Tengchong County and the surrounding areas, which is at least 1,000km south of any known distribution of its congeners. It is also the only *Mesechinus* species found in subtropical forest and it occurs at elevations above 2,100m. One individual was camera trapped on 16 October 2014 at 24.976°N & 98.741°E; another image was obtained on 19 November 2017 at 24.970°N & 98.747°E. An individual was found at night in disturbed mid-montane moist evergreen broadleaf forest at ca. 2,100m in August 2017.

Rhesus Macaque *Macaca mulatta* (Least Concern)

Only recorded in forests under 2,000m. It appears to be restricted to the lower elevation band between 1,300m and 2,000m in Tengchong, similar to observations elsewhere in the eastern Himalaya (Mishra et al. 2006). This distribution pattern may be in part due to competition with the two larger-sized macaque species common in higher elevations.

Table 2. Mammals recorded during our 2014–2018 survey in Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China. CT: camera trap; DO: daytime observation; SL: spotlighting; TS: tracks and/or signs; TD: trophy and/or carcass; encounter rates: number of notionally independent images per 1,000 trap nights.

Species	IUCN status	Evidence	Encounter rates
Gaoligong Forest Hedgehog *Mesechinus wangi*	--	CT, DO	0.14
Elegant Water Shrew *Nectogale elegans*	LC	DO, TD	--
Northern Treeshrew *Tupaia belangeri*	LC	CT, DO	3.24
Stump-tailed Macaque *Macaca arctoides*	VU	CT, DO	9.38
Assamese Macaque *Macaca assamensis*	NT	CT, DO	13.77
Rhesus Macaque *Macaca mulatta*	LC	CT, DO	1.22
Phayre's Langur *Trachypithecus phayrei*	EN	CT, DO	1.28
Gaoligong Hoolock Gibbon *Hoolock tianxing*	VU [1]	DO	--
Asiatic Black Bear *Ursus thibetanus*	VU	CT, DO, TS	1.49
Red Panda *Ailurus fulgens*	EN	CT, DO, TS	2.90
Yellow-throated Marten *Martes flavigula*	LC	CT, DO	11.75
Yellow-bellied Weasel *Mustela kathiah* *	LC	CT	0.14
Siberian Weasel *Mustela sibirica*	LC	CT, DO	0.14
Stripe-backed Weasel *Mustela strigidorsa* *	LC	DO	--
Ferret badger *Melogale* sp. [2]	LC	CT, TD	1.76
Spotted Linsang *Prionodon pardicolor*	LC	CT	3.38
Common Palm Civet *Paradoxurus hermaphroditus* *	LC	CT	0.47
Masked Palm Civet *Paguma larvata*	LC	CT, SL	6.75
Leopard Cat *Prionailurus bengalensis*	LC	CT, SL	5.47
Marbled Cat *Pardofelis marmorata* *	NT	CT	3.78
Eurasian Wild Pig *Sus scrofa*	LC	CT, TS	3.38
Forest Musk Deer *Moschus berezovskii*	EN	CT	1.22
Tufted Deer *Elaphodus cephalophus*	NT	CT	3.65
Northern Red Muntjac *Muntiacus vaginalis*	LC	CT	16.34
Gongshan Muntjac *Muntiacus gongshanensis* *	DD	CT	0.20
Sambar *Rusa unicolor*	VU	TS	--
Mishmi Takin *Budorcas taxicolor*	VU[3]	TS	--
Chinese Goral *Naemorhedus griseus*	VU	CT	1.62
Burmese Red Serow *Capricornis rubidus* **	NT	CT, TD	0.27
Chinese Serow *Capricornis milneedwardsii*	NT	CT	2.30
Pallas's Squirrel *Callosciurus erythraeus*	LC	CT, DO	--
Swinhoe's Striped Squirrel *Tamiops swinhoei*	LC	DO	--
Orange-bellied Himalayan Squirrel *Dremomys lokriah* *	LC	CT, DO	--
Perny's Long-nosed Squirrel *Dremomys pernyi*	LC	CT, DO	--
Asian Red-cheeked Squirrel *Dremomys rufigenis*	LC	CT, DO	--
Black Giant Squirrel *Ratufa bicolor*	NT	CT, DO	3.31
Hairy-footed Flying Squirrel *Belomys pearsonii*	DD	SL	--
Gray-headed Giant Flying Squirrel *Petaurista caniceps*	LC	SL	--
Spotted Giant Flying Squirrel *Petaurista marica* *	LC	SL	--
Yunnan Giant Flying Squirrel *Petaurista yunnanensis*	DD	CT, SL	--
Paticolored Flying Squirrel *Hylopetes alboniger*	LC	TD	--
Chinese Bamboo Rat *Rhizomys sinensis*	LC	DO	--
Asiatic Brush-tailed Porcupine *Atherurus macrourus* *	LC	CT	8.51
Malayan Porcupine *Hystrix brachyura*	LC	CT, TS	18.29
Forrest's Pika *Ochotona forresti* *	LC	CT	0.07
Yunnan Hare *Lepus comus*	LC	SL, DO	--

* represents new record for Tengchong County.
** represents new record for China.
[1] Assessed under Eastern Hoolock Gibbon *Hoolock leuconedys* in the current IUCN Red List.
[2] Large-toothed Ferret Badger *Melogale personata* and Small-toothed Ferret Badger *Melogale moschata* are widely distributed in tropical and subtropical Asia, and both could occur in Tengchong; the only reliable way to visually distinguish the two species is by cranial and dental examination (Abramov & Rozhnov 2014).
[3] All subspecies (*B. t. taxicolor*, *B. t. bedfordi*, *B. t. tibetana*, and *B. t. whitei*) assessed under Takin *Budorcas taxicolor* in the current IUCN Red List.

Stump-tailed Macaque *Macaca arctoides* (Vulnerable)

Htun et al. (2008) marked the northern distribution limit of this species at 25°N in China where Tengchong sits. TC-GLGS supports a healthy population of the species based on the relatively high encounter rate. A recent camera trap survey in the nearby Lushui County (25.417–26.150 ^{0}N) detected this species (Chen et al. 2016), marginally expanding its latitudinal limit further north.

Phayre's Langur *Trachypithecus phayrei* (Endangered)

An estimated population of around 500 individuals persists in the southern part of TC-GLGS. The biggest troop recorded had at least 70 individuals. Its relative rarity in the northern portion is possibly a combination of past hunting pressure and the fact that Tengchong is at its northern distribution limit in China (Chen et al. 2016; Gao et al. 2017).

Gaoligong Hoolock Gibbon *Hoolock tianxing* (Vulnerable)

This recently described gibbon is proposed to be listed as Endangered under the IUCN Red List criteria; however, more robust data on the conservation status of different subpopulations of *H. tianxing* is needed (Fan et al. 2016). A survey conducted in 2016 recorded at least 17 gibbons in six family groups in Tengchong, and the subsequent survey confirmed an additional group; the current population stands at 20 gibbons in seven groups. The Tengchong population is of particular research and conservation importance because it is both the northernmost and the largest subpopulation in China (Chan et al. 2017).

Asiatic Black Bear *Ursus thibetanus* (Vulnerable)

Bears in eastern and southeastern Asia are subject to high hunting pressures (Robinowitz & Khaing 2002; Mishara et al. 2006). In TC-GLGS, the Asiatic Black Bear remains widespread and not uncommon despite the disappearance of other large carnivores. Feeding and other signs from this species were commonly seen during fieldwork, and it was recorded in 13 camera trap stations. Breeding was confirmed by an adult with cub camera trapped in November (Image 1e). There are human-bear negative interactions resulting in casualties on both sides annually.

Red Panda *Ailurus fulgens* (Endangered)

The Red Panda is widespread and common in TC-GLGS. It mostly occurs in the higher-elevation mixed broadleaf forest with dense bamboo undergrowth just below the treeline. Their droppings, containing only coarse plant fragments with distinctive shape and colour, were frequently seen in this preferred habitat.

Yellow-bellied Weasel *Mustela kathiah* (Least Concern)

A new record for Tengchong. One individual was camera trapped on 14 May 2016 at 25.802^{0}N & 98.700^{0}E, making it the northernmost record for GLGS. Another camera trap image was obtained on 08 November 2016 at 25.120^{0}N & 98.708^{0}E. We obtained three additional camera trap images of a *Mustela* fitting the size and colouration of *M. kathiah*; however, the possibility of those being Stripe-backed Weasels cannot be excluded.

Siberian Weasel *Mustela sibirica* (Least Concern)

Siberian Weasel was camera trapped on 07 and 12 January 2016 at 25.758^{0}N & 98.716^{0}E. Wang (2003) opined that Siberian Weasel in Yunnan is an undescribed taxon, but did not provide further details. Our camera trap images show animals superficially similar to *M. s. moupinensis* from western Sichuan Province, with reddish-brown coat and a long black-tipped tail (Gao 1987). Online images of Siberian Weasels from northeastern India show animals with similar pelage and identified as *M. s. subhemachalana* (Choudhury 2016). A taxonomic study of these forms including the Tengchong population is warranted.

Stripe-backed Weasel *Mustela strigidorsa* (Least Concern)

A new record for Tengchong. One individual was observed in the riparian evergreen broadleaf forest at 25.753^{0}N & 98.704^{0}E on 28 April 2014 (Chan & Zhao 2014). As with other weasel species, Stripe-backed Weasel is likely to be under-recorded in Tengchong due to low detectability by camera traps and simply by being "an inconspicuous denizen of chronically under-surveyed regions" (Abramov et al. 2008).

Common Palm Civet *Paradoxurus hermaphroditus* (Least Concern)

A new record for Tengchong. Recorded at four camera trap stations in the southern part of TC-GLGS. Our record at 25.116^{0}N marks its northernmost distribution in GLGS.

Marbled Cat *Pardofelis marmorata* (Near Threatened)

A new record for Tengchong. We obtained 54 notionally independent records at 12 camera trap stations, all north of 25.733^{0}N. Our camera trap data shows that Marbled Cat is more diurnal than the sympatric Leopard Cat.

Forest Musk Deer *Moschus berezovskii* (Endangered)

All musk deer are heavily hunted throughout their ranges and are in serious decline (Robinowitz & Khaing 2002; Mishra et al. 2006). This species was thought to have been possibly extinct in TC-GLGS. Camera traps recorded the species at six camera trap stations, all north of 25.733^{0}N.

Tufted Deer *Elaphodus cephalophus* (Near Threatened)

This species appears to prefer higher elevation broadleaf forest in TC-GLGS—it was only recorded between 2,296m and 3,113m. Repeated camera trapping and field surveys failed to record the species in northern Myanmar (Harris & Jiang 2015), but camera trap images from TC-GLGS obtained on the international border suggest that the species must occur across the border in the high mountains of Kachin State in Myanmar.

Image 1. Mammals recorded in the Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China, 2014–2018: a—Stump-tailed Macaque *Macaca arctoides* | b—Assamese Macaque *Macaca assamensis* | c—Phayre's Langur *Trachypithecus phayrei* | d—Gaoligong Hoolock Gibbon *Hoolock tianxing* | e—Asiatic Black Bear *Ursus thibetanus* | f—Red Panda *Ailurus fulgens* | g—Spotted Linsang *Prionodon pardicolor* | h—Marbled Cat *Pardofelis marmorata*. © GLGS NNR & KFBG.

Gongshan Muntjac *Muntiacus gongshanensis* (Date Deficient)

A new record for Tengchong. One male and one female were camera trapped on 04 May 2018, at 25.759^{0}N & 98.719^{0}E; a female was camera trapped on 07 May 2018 at the same site. Similar to observations in northeastern India (Choudhury 2009) and southeastern Tibet (Schaller & Rabinowitz 2004), the Northern Red Muntjac was also camera trapped at the same site, indicating that the habitats of the two muntjac species have some overlap. Gongshan Muntjac is reported to occur in western Yunnan between 25–28.167 ^{0}N (Timmins & Duckworth 2016), but we could not find any published record from Tengchong at 25^{0}N. Our finding is the first verifiable record of the species in Tengchong.

Sambar *Rusa unicolor* (Vulnerable)

According to interviews with local inhabitants, this large deer is close to local extirpation following rampant hunting in the 1980s–2000s. We had no camera trap record but tracks and droppings of this species were found at 25.527^{0}N & 98.744^{0}E in moist evergreen broadleaf forest on 12 March 2015. Targeted survey should be conducted to clarify its distribution and status in Tengchong.

Mishmi Takin *Budorcas taxicolor* (Vulnerable)

The IUCN Red List considered the takin as a single species with four subspecies (Song et al. 2008). We followed Groves & Grubb (2011) and Wilson & Mittermeier (2011) and treated the four as full species; the GLGS population is Mishmi Takin *B. taxicolor*. There are two disjunct populations of Mishmi Takin in China, one in southeastern Tibet and another in GLGS (Song et al. 2008); the current distribution in GLGS extends from Gongshan in the north (28.317^{0}N) to Tengchong in the south (24.033^{0}N). Historically, it was also reported further south in the Yingjiang County (24.033^{0}N) (Yang & Du 2006), but this southernmost population is believed to be locally extinct. This is a high-altitude species living along and above the tree line in TC-GLGS. Ai (1996) estimated that around 300 individuals lived in southern GLGS, but the population seems to be in decline. We failed to camera trap any during the survey but found fresh tracks, droppings, and feeding signs. Monitoring and scientific study is needed to shed light on the causes of the observed range retraction and population decline, especially in view of climate change.

Burmese Red Serow *Capricornis rubidus* (Near Threatened)

A new record for China. The first animal was camera trapped in the winter of 2014 (date and time unavailable due to camera malfunction) at 25.797^{0}N & 98.634^{0}E. A single animal was camera trapped on 24 August and 28 October 2017 at 25.761^{0}N & 98.724^{0}E. An adult was directly observed and video-recorded at the same site on 25 November 2017. It had also been camera trapped in the nearby Lushui County of GLGS, but the animal was misidentified as Chinese Serow *Capricornis milneedwardsii* (Chen et al. 2016). A scientific paper is being prepared to report this discovery (Chen Yixin, pers. comm., March 2018).

Orange-bellied Himalayan Squirrel *Dremomys lokriah* (Least Concern)

A new record for Tengchong. A high elevation squirrel in TC-GLGS; the highest count was 13 individuals at Nanzhaigongfang (25.288^{0}N & 98.738^{0}E, 3,150m) on 06 May 2017, which represents the southernmost distribution of *D. lokriah* in China. According to Li & Wang (1992), the Tengchong subspecies is *D. l. subflaviventris.* Population decline has been reported in northeastern India because of hunting and habitat loss (Dollo et al. 2010). High altitude forests in TC-GLGS are well-protected and the squirrel is not hunted locally, but the impact of climate change should be monitored.

Asian Red-cheeked Squirrel *Dremomys rufigenis* (Least Concern)

It is restricted to lower altitude forests in TC-GLGS, with 10 notionally independent camera trap records at 25.114^{0}N & 98.675^{0}E and two observation records during our study. One individual was photographed at Linjiapu at 25.286^{0}N & 98.701^{0}E on 28 August 2016. Two animals were photographed together at 25.016^{0}N & 98.682^{0}E on 10 May 2016. The only previous Tengchong record is of an old specimen from Jietou section at 25.317^{0}N, which marks the northernmost distribution in GLGS (Chen & Qu 2010).

Spotted Giant Flying Squirrel *Petaurista marica* (Least Concern)

Sometimes recognized as a subspecies of *P. elegans* (Choudhury 2016; Wilson et al. 2016). We followed a molecular study which pointed out that *P. e. marica* from China and northern Indo-China is distinctive and should be elevated to full species status (Li et al. 2013). New record for Tengchong with the only record at Dahaoping Section at 24.972^{0}N & 98.730^{0}E, which marks the

Image 2. Mammals recorded in the Tengchong Section of Gaoligongshan National Nature Reserve in Yunnan Province, China, 2014–2018: a—Forest Musk Deer *Moschus berezovskii* | b—Tufted Deer *Elaphodus cephalophus* | c—Red Muntjac *Muntiacus muntjak* | d—Burmese Red Serow *Capricornis rubidus* | e—Orange-bellied Himalayan Squirrel *Dremomys lokriah* | f—Yunnan Giant Flying Squirrel *Petaurista yunnanensis* | g—Asiatic Brush-tailed Porcupine *Atherurus macrourus* | h—Malayan Porcupine *Hystrix brachyuran*. © GLGS NNR & KFBG.

northernmost global distribution for this species.

Yunnan Giant Flying Squirrel *Petaurista yunnanensis* (Data Deficient)

This is the most common and widespread flying squirrel species in TC-GLGS. The species was formerly considered a subspecies of *P. philippensis*, but recent genetic studies indicate that it is taxonomically distinct (Li et al. 2013). Yunnan Giant Flying Squirrel is not yet assessed by the current IUCN Red List, and its full distribution range and population trend are unknown (Wilson et al. 2016). Tengchong is the type locality for the species; more survey and basic research to clarify its distribution, population status, and natural history are needed to clarify its conservation needs.

Asiatic Brush-tailed Porcupine *Atherurus macrourus* (Least Concern)

A new record for Tengchong. It was relatively widespread and common in this survey. It was captured at 17 out of the 147 camera trap stations; therefore, the lack of previous records seems surprising. Our record at 25.766^{0}N also marks the northernmost of its distribution in GLGS.

Forrest's Pika *Ochotona forresti* (Least Concern)

New record for Tengchong. According to Ge et al. (2012), *O. forresti* is the only *Ochotona* species in southern GLGS. One individual was camera trapped at 25.625^{0}N & 98.738^{0}E on 14 May 2015, which represents the southernmost record of its global range.

Yunnan Hare *Lepus comus* (Least Concern)

Tengchong is the type locality of Yunnan Hare, and the species mainly lives in shrubland and open habitats in lower elevations outside TC-GLGS. One individual was observed at 25.648^{0}N & 98.678^{0}E during spotlighting survey, another individual was observed during the daytime at 25.399^{0}N & 98.710^{0}E. According to our data and interview result, the Tengchong population is in decline due to land-use change and hunting. The conservation status of Yunnan Hare in Tengchong deserves some focused attention.

DISCUSSION

Importance of transect survey

The use of camera trap for wildlife research has become a mainstream tool for mammal research and surveys (Wemmer et al. 1996), particularly in research involving rare and/or secretive species (Cutler & Swann 1999; Rowcliffe & Carbone 2008). Some species, however, are strictly or mainly arboreal and therefore are rarely recorded by camera traps (e.g., Small-toothed Palm Civet: Duckworth & Nettelbeck 2008; Willcox et al. 2012). This highlights the importance of conducting non-random transect survey to compliment camera trapping in compiling a comprehensive mammal checklist for a study area.

Twelve of the 46 mammal species recorded (26.1% of total) were only detected by direct observations, which clearly illustrates the value of employing different methods in mammal surveys. Daytime observation is particularly effective to detect primates (e.g., Gaoligong Hoolock Gibbon), agile small mammals (e.g., weasels and squirrels), as well as open habitat and fossorial species (e.g., Chinese Bamboo Rat and Yunnan Hare). Spotlighting survey is, in our opinion, the only effective way to survey for flying squirrel diversity.

Rare or unrecorded species

Some species were rarely recorded, suggesting they are rare in TC-GLGS or that camera trap placement was ineffective at recording the presence of these species. While some are believed to be genuinely rare, such as Forest Musk Deer and Gongshan Muntjac, others are probably more abundant than our records show and simply evaded our survey methods. The three weasel species, for example, were rarely recorded, but villagers consider them not uncommon and reported that poultry-raiding is a regular event. Although most of our study areas are well-protected at present, past anthropogenic activities, particularly hunting, have greatly decimated populations of the more sensitive mammals in Tengchong. The complete absence of obligate large carnivores in TC-GLGS may be explained by a combination of the following factors: (1) our survey sites were at higher elevations in which biomass is naturally lower; (2) the almost complete clearance of extensive natural habitats below 2,000m means some species may be living at their upper elevation limits which restrain population growth; and (3) past rampant hunting in and around TC-GLGS has decimated populations of carnivores and has suppressed the ungulate populations.

We failed to detect 24 mammal species (excluding Chiroptera and Muridae) previously confirmed from Tengchong (Xue et al. 1995; Zhang 1997; Wang 2003; Chen & Qu 2010). Of these unrecorded species, some have specific niches which were not well-covered by our survey, such as Small Indian Civet *Viverra indica* and

Table 3. Mammal species, excluding Chiroptera, Muridae, and Cricetidae, previously recorded from Tengchong but absent in this study.

Species	Sources
Bengal Slow Loris *Nycticebus bengalensis*	Xue 1995
Chinese Pangolin *Manis pentadactyla*	Xue 1995; Zhang 1997
Indian Pangolin *Manis crassicaudata*	Wang 2003
Gray Wolf *Canis lupus*	Xue 1995
Red Fox *Vulpes vulpes*	Xue 1995
Racoon Dog *Nyctereutes procyonoides*	Xue 1995
Dhole *Cuon alpinus*	Xue 1995
Asian Badger *Meles meles*	Xue 1995
Hog Badger *Arctonys collaris*	Xue 1995; Zhang 1997
Eurasian Otter *Lutra lutra*	Xue 1995
Large Indian Civet *Viverra zibetha*	Xue 1995; Zhang 1997
Small Indian Civet *Viverra indica*	Xue 1995; Zhang 1997
Crab-eating Mongoose *Herpestes urva*	Xue 1995
Jungle Cat *Felis chaus*	Xue 1995
Asiatic Golden Cat *Pardofelis temminckii*	Xue 1995
Clouded Leopard *Neofelis nebulosa*	Xue 1995
Leopard *Panthera pardus*	Xue 1995; Zhang 1997; Chen & Qu 2010
Tiger *Panthera tigris*	Xue 1995; Chen & Qu 2010
Sumatran Rhinoceros *Dicerorhinus sumatrensis*	Wang 2003
Leaf Muntjac *Muntiacus putaoensis*	Wang 2003
Anderson's Squirrel *Callosciurus quinquestriatus*	Xue 1995
Forrest's Rock Squirrel *Sciurotamias forresti*	Xue 1995; Zhang 1997
Ward's Bamboo Rat *Rhizomys wardi*	Wang 2003
Hoary Bamboo Rat *Rhizomys pruinosus*	Xue 1995

Jungle Cat *Felis chaus* of mixed agricultural landscape in lower elevations or Crab-eating Mongoose associated with lower elevation forests. The rest are either targets for the wildlife trade (e.g., Bengal Slow Loris, pangolins, and Eurasian Otter) or large carnivores, and we believe hunting is the primary reason of their absence (Table 3).

There is no reliable evidence suggesting the presence of Tiger *Panthera tigris*, Leopard *Panthera pardus*, Gray Wolf *Canis lupus*, and Sumatran Rhinoceros *Dicerorhinus sumatrensis* after the 1990s. The last confirmed record of Sumatran Rhinoceros in Tengchong was in 1949 (Wang 2003) and that of Tiger and Leopard were in 1983 and 1985, respectively (Chen & Qu 2010). The extinction of megafauna in Tengchong comes as no surprise as they are reported to be (near-)extinct in other sites of the eastern Himalaya with vast forest tracts and much lower human populations (Rabinowitz & Khaing 2002; Datta et al. 2008). Our data suggest that ungulate densities are relatively low in TC-GLGS, and prey depletion is one of the major factors affecting the survival of large carnivores (Datta et al. 2008). The Asiatic Black Bear is the only large carnivore that remains relatively widespread and common, which is a facultative carnivore and lives on a much broader diet. Nonetheless, local villagers occasionally reported big cat pugmarks, large carnivore scats with Muntjac hoof remains, and livestock kills in recent years. Mesocarnivores such as Clouded Leopard *Neofelis nebulosa*, Golden Cat *Catopuma temminckii*, and Dhole *Cuon alpinus* may survive in extremely low numbers. We found no fresh burrows of pangolins; pangolins were occasionally reported by local villagers, but their numbers must be exceedingly low, if still present. Other restricted-range and little-known small-sized species, such as Anderson's Squirrel *Callosciurus quinquestriatus* and Forrest's Rock Squirrel *Sciurotamias forresti*, were most likely overlooked by us or have highly restricted distribution not yet surveyed by us. Further survey should cover a wider range of elevations and microhabitats to increase detection probability to understand their conservation needs.

CONSERVATION IMPLICATIONS

This survey demonstrated that TC-GLGS remains an important site for the conservation of high-altitude mammals in the eastern Himalaya, comparable to similar sites in the neighbouring countries (Mishra et al. 2006; Than Zaw et al. 2008). The mammalian community of TC-GLGS appears to be recovering from past heavy disturbances, particularly hunting, but we failed to record any large carnivores except the Asiatic Black Bear, and densities of ungulates are relatively low compared to well-protected areas such as Hong Kong (Bosco Chan, unpublished data). Nevertheless, anthropogenic disturbances have significantly reduced after more than 30 years of protection; we observed abundant wildlife signs including those of the Asiatic Black Bear *Ursus thibetanus*. Evidence of hunting and logging were rarely found, and camera traps detected very low human traffic. Poaching and illegal logging still exist near the international border with Myanmar, often involving cross-border criminals based on the reserve forest crime database. Our camera traps also recorded some livestock grazing in the southernmost and northernmost sections of the reserve. A determined effort to stamp out poaching and livestock grazing will be helpful to the recovery of mammal populations in TC-GLGS, before reintroduction of large carnivores can be

considered.

Tengchong is located in the southernmost part of GLGS and is the northern distribution limit for many species from the Indo-Malayan biogeographic realm. Some of the missing species, such as Bengal Slow Loris, Small Indian Civet, Crab-eating Mongoose, and Jungle Cat, are adaptable species of predominantly low elevations and will greatly benefit from better protection effort of lower altitude forests below 2,000m (Duckworth et al. 2005; Jennings & Veron 2011).

Long-term monitoring and research on selected mammal species, such as the rare Gaoligong Hoolock Gibbon and Marbled Cat, high altitude species susceptible to climate change such as Mishmi Takin and Orange-bellied Himalayan Squirrel, and species vulnerable to high hunting pressure such as Forest Musk Deer and Sambar, should be conducted to assess management effectiveness. If needed, necessary conservation interventions should be effected.

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