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Galliform diversity in south-west Yunnan, China, with notes on Blood Pheasant *Ithaginis cruentus* and White Eared Pheasant *Crossoptilon crossoptilon* biology

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Summary.—We describe gamebird community structure and beta diversity at two sites in the Chinese Himalayas, and describe aspects of the biology of Blood Pheasant *Ithaginis cruentus* and White Eared Pheasant *Crossoptilon crossoptilon*. We deployed cameras from October 2011 to January 2014 at 34 sites in two areas (Langdu and Gehuaqing) within the Three Parallel Rivers UNESCO World Heritage Site (Diqing Autonomous Prefecture, Yunnan). Five of the eight species of gamebirds recorded in this study were pheasants. Despite habitat similarity, beta diversity showed little overlap, with only a single Galliform, Temminck's Tragopan *Tragopan temminckii*, shared between the two sites. Novel information on temporal presence and activity patterns is reported for *I. cruentus* and *C. crossoptilon*, as well as population sex ratios for *I. cruentus*. Additional information for *I. cruentus* (altitudinal migration, flock demography) and *C. crossoptilon* (habitat and altitude association, breeding biology, flock demography) are compared with other studies, and their conservation implications are discussed.

Gamebirds such as pheasants, partridge and quail (Galliformes) are keystone species in Himalayan ecosystems for their role in maintaining forest dynamics by digging and seed dispersal / predation syndromes, as well as their meat and eggs being an important protein source for numerous species. However, gamebirds are often threatened by non-sustainable harvest for food, plumage and the live bird trade, as well as destruction and degradation of the forests on which they largely depend (Fuller & Garson 2000).

Studies of Himalayan avian community structure (e.g., Elsen *et al*. 2017, Srinivasan *et al*. 2018) have been restricted to passerines rather than larger gamebirds. Although community ecology studies of gamebirds are available (e.g., Brooks *et al*. 2001), these have been in relatively homogenous regions such as lowland tropical forest, which contrasts sharply with heterogeneous montane environments such as the Himalayas. Nevertheless, both tropical lowland and Himalayan forests can support high species diversity (Cai *et al*. 2018).

Pheasant communities in the Himalayas are logistically challenging to study due to remote sites, high altitudes leading to hypoxia, and the elusive nature of pheasants in the wild. Consequently there are significant gaps in data for many species, including Blood Pheasant *Ithaginis cruentus* and White Eared Pheasant *Crossoptilon crossoptilon* (McGowan & Kirwan 2019, McGowan *et al*. 2019). Nonetheless, there have been some in-depth studies of these two species, among others, in these high-altitude environments (e.g., Li 1981, Lu 1986, Jia *et al*. 1999, 2004, 2005, Lu *et al*. 2006).

The objective of this study was to assess Galliform community structure and beta diversity (simply defined as similarity of species composition between regions) at two sites in the Chinese Himalayas *c*.125 km apart. Additionally, we describe aspects of the biology of *Ithaginis cruentus* and *Crossoptilon crossoptilon*.

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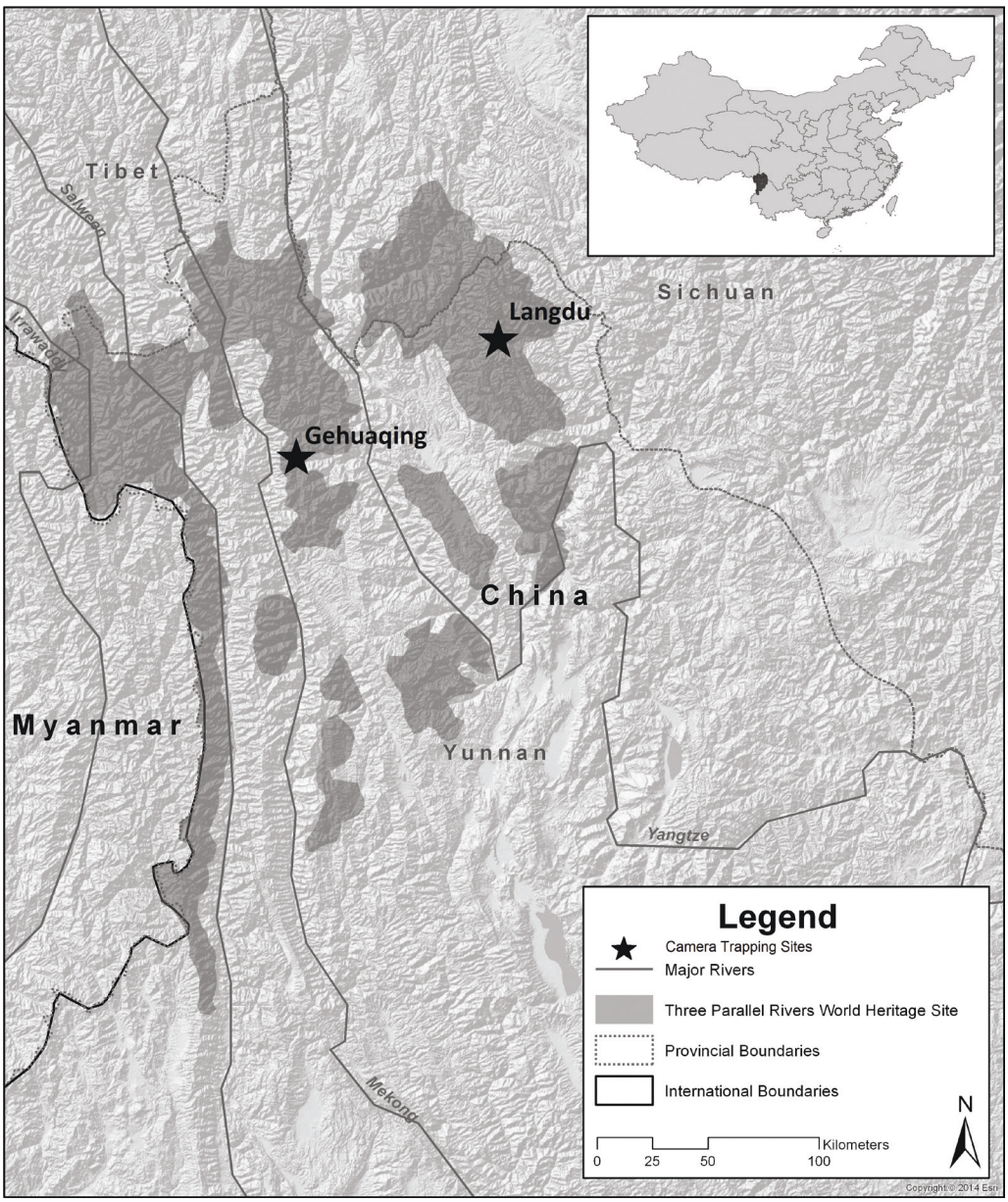

Figure 1. Map of study region showing location of Langdu and Gehuaqing, Yunnan, China.

Methods

Study area.—The study took place in two areas within the Three Parallel Rivers UNESCO World Heritage Site in Diqing Autonomous Prefecture, Yunnan, China: (1) near the Hong Shan part of the World Heritage Site, near Langdu village in Shangri-La county (28°14.87′N, 99°58.28′E); (2) in the southern part of Baimaxueshan National Nature Reserve near Gehuaqing village in Weixi county (27°35.74′N, 99°17.43′E). Hereafter these sites are referred to as Langdu and Gehuaqing, respectively (Fig. 1; Buzzard *et al*. 2018). These two

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sites were selected as each comprised a connected series of intact natural habitats over a range of elevations, believed to be representative of the two regions.

The sites presented differing conservation management regimes as Langdu was not subject to forest guard patrols, although hunting was officially illegal, whereas Gehuaqing benefitted from active conservation management, including regular patrols by forest guards. Langdu was primarily inhabited by Tibetan herders who raise mainly yaks (*Bos gunniens*) and yak-cow hybrids, plus some horses (*Equus caballus*) and mules. Gehuaqing was primarily inhabited by farmers of the Lisu Minority who mainly raise pigs and engage in apiculture, but are well known as skilled hunters.

Elevation at Langdu spanned 4,000–4,800 m, whereas at Gehuaqing habitat sampled ranged from 3,050–3,600 m. In both areas, habitat was primarily forest dominated by conifer trees including spruce (*Picea* spp.), firs (*Abies* spp.) and juniper (*Juniperus* spp.), as well as hardwoods including birch (*Betula* spp.), oaks (*Quercus* spp.), and rhododendrons (*Rhododendron* spp.). Distinct vegetation changes occurred with elevation and aspect (whether the slope is north- or south-facing). As elevation increased, trees and shrubs diminished in height and alpine meadows occurred at their upper limits, above which rock and scree were the dominant land cover.

Camera trapping.—To document presence we used heat- / motion-activated camera traps (Bushnell Trophy Cam) for >3 years, spanning October 2011–January 2014. We deployed cameras in all seasons, at 34 sites (22 at Langdu, 12 at Gehuaqing) separated from each other by at least 500 m along wildlife trails or routes likely to be used (Table 1). For subsequent pictures of the same species, we considered independent captures as those that occurred at least one hour apart (Rovero & Marshall 2009). We calculated relative abundance index values by dividing the value of independent captures by the number of trap-days where the species was confirmed as present. We estimated the age of *Crossoptilon crossoptilon* by sending camera-trap images to aviculturists familiar with the species' developmental growth stages, and polled them to estimate ages of offspring in the images.

Results

Beta diversity.—Five of the eight species of Galliformes recorded were pheasants, with an additional two to three species of large passerines (Table 2). Despite habitat similarity between the two sites, beta diversity showed little overlap, with only a single Galliform (Temminck's Tragopan *Tragopan temminckii*) shared between the two sites. Five species (Chinese Grouse *Bonasa sewerzowi*, Buff-throated Partridge *Tetraophasis szechenyii*, Tibetan Snowcock *Tetraogallus tibetanus*, Blood Pheasant and White Eared Pheasant) were found only at Langdu, and two (Koklass Pheasant *Pucrasia macrolopha* and Lady Amherst's Pheasant *Chrysolophus amherstiae*) were exclusive to Gehuaqing (Table 2). A sixth species, Sclater's Monal *Lophophorus sclateri*, was visually detected at Langdu (PJB unpubl.) but not captured by a camera-trap.

BLOOD PHEASANT *Ithaginis cruentus*

A total of 36 independent photographs of Blood Pheasants were taken at six different camera-trap sites representing primarily a component of *Rhododendron* forest, including (n = 1 unless otherwise noted) mixed *Rhododendron* forest (n = 2 sites), mixed *Rhododendron*–conifer forest, *Rhododendron*–oak scrub, *Rhododendron* forest scrub and mixed conifer–broadleaf forest. Microhabitat characteristics varied and comprised forest (sparse to dense, at times mesic) to mesic clearings (covered by moss and some sticks), understorey completely lacking to present at edges, with substrate (moss, dried leaves and twigs, pebbles and boulders). Topography was level to sloping and *Ithaginis* occurred at 4,028–4,407 m.

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TABLE 1
Location, altitude, habitat and number of trap-days of 20 camera traps at Langdu (L) and Gehuaqing (G), Yunnan, China.

Camera	# Ind. photos	Location	Latitude	Longitude	Habitat	Altitude (m)	Days
ctrp2		L	28°24.35′N	99°96.45′E	mixed conifer	4,243	161
ctrp3		L	28°24.09′N	99°97.15′E	*Rhododendron* / oak	4,290	164
ctrp4		L	28°24.12′N	99.96.65′E	*Rhododendron* / oak	4,313	164
ctrp5		L	28°24.32′N	99°96.65′E	*Rhododendron* / oak	4,217	160
ctrp8		L	28°25.81′N	99°97.61′E	*Rhododendron* / oak	4,333	19
ctrp10		L	28°23.97′N	99°97.62′E	meadow	4,040	66
ctrp11	6	L	28°23.58′N	99°97.30′E	mixed conifer	4,133	66
ctrp12		L	28°25.84′N	99°97.25′E	meadow	4,265	66
ctrp14	3	L	28°23.72′N	99°98.27′E	mixed conifer	4,029	64
ctrp15	4	L	28°23.50′N	99°97.95′E	mixed conifer	4,196	64
ctrp17	3	L	28°24.59′N	99°98.53′E	*Rhododendron* / oak	4,151	134
ctrp18	9	L	28°24.52′N	99°98.71′E	mixed conifer	4,173	134
ctrp19	24	L	28°24.45′N	99°98.92′E	*Rhododendron* / oak	4,164	134
ctrp 22	12	L	28°23.19′N	99°97.63′E	mixed conifer	4,407	132
ctrp23	8	L	28°23.59′N	99°97.54′E	mixed conifer	4,148	132
ctrp24	1	L	28°24.95′N	99°99.24′E	meadow	4,359	122
ctrp25	2	L	28°25.05′N	99°98.19′E	mixed conifer	4,148	116
sl1		L	28°25.11′N	99°94.31′E	alpine	4,579	140
sl2		L	28°25.26′N	99°94.15′E	alpine	4,763	130
sl3	1	L	28°25.32′N	99°94.17′E	alpine	4,815	143
sl4		L	28°28.86′N	99°93.43′E	alpine	4,692	120
sl6	1	L	28°27.78′N	99°93.05′E	alpine	4,670	173
ghq1	1	G	27°59.66′N	99°31.55′E	*Rhododendron*	3,403	28
ghq3	2	G	27°59.24′N	99°31.78′E	*Rhododendron*	3,356	29
ghq5		G	27°59.43′N	99°27.19′E	conifer / hardwood	3,318	26
ghq6	1	G	27°59.42′N	99°26.57′E	conifer / hardwood	3,246	26
ghq7		G	27°59.54′N	99°26.20′E	*Rhododendron*	3,187	27
ghq8	1	G	27°59.88′N	99°31.01′E	conifer / hardwood	3,190	120
ghq9		G	27°60.61′N	99°31.06′E	*Rhododendron*	3,442	120
ghq10		G	27°60.96′N	99°30.62′E	*Rhododendron*	3,606	120
ghq12		G	27°59.81′N	99°30.37′E	conifer / hardwood	3,176	120
ghq13		G	27°59.26′N	99°26.22′E	conifer / hardwood	3,055	118
ghq15	1	G	27°59.94′N	99°26.20′E	conifer / hardwood	3,369	118
ghq16		G	27°59.71′N	99°26.15′E	conifer / hardwood	3,244	118

This species shows sharp elevational migration, being present only mid spring to early autumn (April–October), retreating to lower elevations in winter. While peak occurrence

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TABLE 2
Species presence, abundance and trap-days at Langdu (22 sites) and Gehuaqing (12 sites), Yunnan, China.

Species	Scientific name	Trap-days	Langdu Ind. events	No. of individuals	No. of sites	Trap-days	Gehuaqing Ind. events	No. of individuals	No. of sites
Chinese Grouse	*Bonasa sewerzowi*	66	1 (0.015)	1 (0.015)	1				
Buff-throated Partridge	*Tetraophasis szechenyii*	400	6 (0.040)	8 (0.015)	3				
Tibetan Snowcock	*Tetraogallus tibetanus*	173	1 (0.006)	2 (0.012)	1				
Blood Pheasant	*Ithaginis cruentus*	592	36 (0.061)	46 (0.077)	6				
Koklass Pheasant	*Pucrasia macrolopha*					146	2 (0.013)	2 (0.013)	2
Temminck's Tragopan	*Tragopan temminckii*	143	1 (0.007)	1 (0.007)	1	58	2 (0.034)	2 (0.034)	2
White Eared Pheasant	*Crossoptilon crossoptilon*	836	15 (0.018)	53 (0.063)	7				
Lady Amherst's Pheasant	*Chrysolophus amherstiae*					120	2 (0.016)	1 (0.008)	1
Giant Laughingthrush	*Garrulax maximus*	402	15 (0.037)	18 (0.045)	3				
Long-tailed Thrush	*Zoothera dixoni*	134	1 (0.007)	1 (0.007)	1				
unidentified thrush	*Zoothera* sp.					26	1 (0.038)	1 (0.038)	1

Relative abundance index values are shown in parentheses and were computed by dividing the value of independent captures or number of individuals by number of trap-days where the species was confirmed as present.

was in August–September, records declined dramatically to just one in October, followed by none in November–March (Fig. 2).

Ithaginis was active at dawn (06.00 h) until after nightfall (19.00 h). Bimodal peaks of activity were 08.00–10.00 h, with a stronger peak in late afternoon / early evening (16.00–19.00 h; Fig. 3). It was active during temperatures from -3ºC to 22ºC (mean = 7.5ºC), and snow was visible on the ground in some photos. A limited sample size (n = 7), suggests the species was not more active during any particular phase of the moon, with three photos (43% combined) during both new / near new moon and half-moon cycles, and a single photo (14%) during a full moon.

Flock size was 1–4 birds, with a mean of 1.2 (n = 36). The total ratio of adult males to females was 32:14 (2.3 males / female; per Karanth *et al*. 2011). The commonest social group was solitary adult males (n = 21, 58%) followed by lone adult females (n = 7, 19%), male–female (presumably bonded) pairs (n = 4, 11%), adult male 'pairs' (n = 2, 6%) with single records (3%) of adult female pairs and a quad of three adult males and one adult female.

WHITE EARED PHEASANT *Crossoptilon crossoptilon*

Fifteen independent photographs of White Eared Pheasant were taken at seven different camera-trap sites representing primarily *Rhododendron* or conifer forest, including (n = 1 unless otherwise noted) *Rhododendron*–oak scrub (n = 2), mixed *Rhododendron*–conifer forest, mixed conifer forest, mixed conifer–broadleaf forest, mixed forest and high-elevation meadow. Microhabitat characteristics comprised primarily forest (open to dense), lacking or with a dry leaf litter / herbaceous understorey, and substrate from dried leaves and twigs, to pebbles and boulders on bare ground bordering forest edge. Open habitats were mesic, from moss-covered clearings to herbaceous slopes with rocky outcrops. Topography was level to sloping and *Crossoptilon* was recorded at 4,028–4,359 m.

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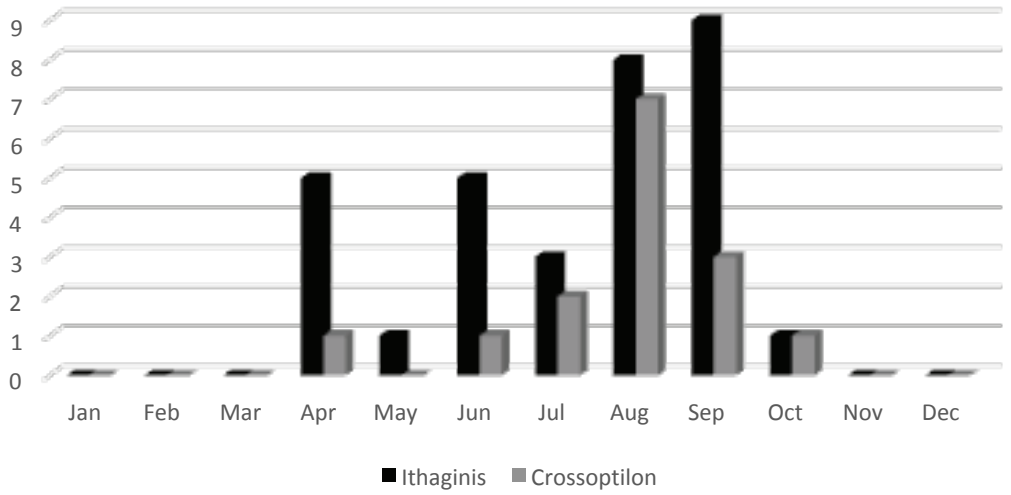

Figure 2. Seasonal presence of Blood Pheasant *Ithaginis cruentus* and White Eared Pheasant *Crossoptilon crossoptilon* at Langdu, Yunnan, China.

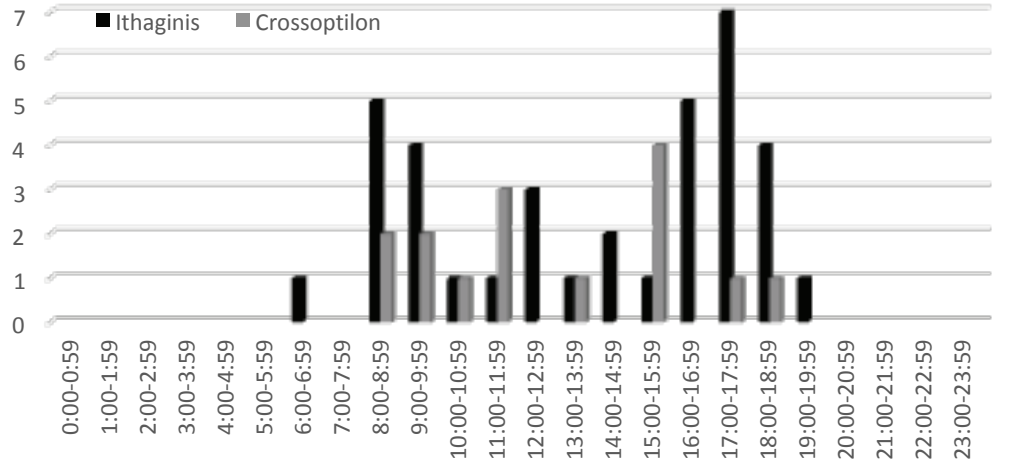

Figure 3. Activity patterns of Blood Pheasant *Ithaginis cruentus* and White Eared Pheasant *Crossoptilon crossoptilon* at Langdu, Yunnan, China.

Similar to *Ithaginis*, this species displayed a sharp elevational migration, being present only in April–October, moving to lower elevations in winter. Peak occurrence was during August, with at most one record each in the months of April–June and October (Fig. 2).

Crossoptilon was active from morning (08.00 h) until after nightfall (19.00 h). While a sharp peak of activity occurred in mid afternoon (15.00–16.00 h), it was primarily active in the morning (08.00–12.00 h; Fig. 3). The species was active during temperatures of 5–24ºC (mean = 9.6ºC), and snow was visible on the ground in some photos.

Photos were obtained between 27 July and 21 August of three different broods each of 2–4 young that were estimated to be four months of age (E. Benhardt, J. Berger, K. Landig, J. Pfarr *in litt*. 2019) foraging with 2–4 adults, suggesting hatch dates in late March–late April. Additionally, we obtained a photo of a copulation between a pair in the presence of three other adults on 11 August.

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Flock size was 1–13 birds, with a mean of 3.5 (n = 15). Total ratio of adults to subadults was 43:10 (4.3 adults / subadult). The most common social group was lone adults (n = 8, 53%) followed by both (n = 3 each, 20%) groups of 4–5 adults, and groups of adults (2–4) with subadults (2–4), with a single group of ≥ 13 adults (n = 1, 7%).

Discussion

Beta diversity.—At a site *c*.1,600 km north of Langdu in Qi-Lian Xian (Qinghai province), an extremely similar community of six species of gamebirds was recorded (Li 1981), comprising three of the same species (*Bonasa sewerzowi*, *Tetraogallus tibetanus*, *Ithaginis cruentus*), two congeners (Chestnut-throated Partridge *Tetraophasis obscurus*, Blue Eared Pheasant *Crossoptilon auritum*) and a partridge (Tibetan Partridge *Perdix hodgsoniae*), instead of *Tragopan temminckii*. Similar to our findings at Langdu, *Ithaginis* and *Crossoptilon* were the most abundant species (Li 1981).

In contrast, despite being just *c*.125 km distant and sharing similar physiognomic characteristics and forest attributes, gamebird species composition between Langdu and Gehuaqing was dramatically different, with only *Tragopan temminckii* shared between the two sites. Unless conservation management at Gehuaqing is ineffective, the factors responsible for the very different species composition were probably not a product of conservation management regimes, as Langdu, without any formal forest guards, harboured three times the number of Galliformes as Gehuaqing.

One of the most relevant factors distinguishing Langdu from Gehuaqing was a difference of several hundred metres in elevation, with the Langdu site at 4,000–4,800 m and Gehuaqing at 3,050–3,600 m. This change in altitude results in different temperature gradients and plant species composition, which are strong factors determining avian community structure, as has been shown elsewhere in the Himalayas (Elsen *et al*. 2017, Srinivasan *et al*. 2018). Others (e.g., Thiollay 1996) have also found elevation to play a role in predicting species turnover in other montane regions.

One must also consider the cultural differences between Langdu and Gehuaqing (Li *et al*. 2016). Tibetans in Langdu are traditionally transhumance herders and Buddhists, and hunting is considered morally questionable. In contrast, gathering forest products and hunting is important in the Lisu culture, suggesting that they might have hunted some Galliform species to local extinction in Gehuaqing. In north-west Yunnan, such cultural differences had a significant influence on Musk Deer *Moschus* spp. distribution, for example, more than the protected status of an area (Li *et al*. 2016).

Ithaginis cruentus.—We report novel information on temporal presence, activity patterns and population sex ratios. Additional findings are compared with other studies, below.

From spring to early autumn *Ithaginis* was present at 4,000–4,400 m, whereas Lu *et al*. (2006) found this species at 3,400–3,700 m in south-west Shiqu county (Sichuan province). However, both of these ranges fall within the overall elevational range (3,200–4,700 m) provided by Delacour (1951) and MacKinnon & Phillipps (2000).

Delacour (1951) indicated that flocks of 10–20 splinter into monogamous pairs during the breeding season. Others have indicated *Ithaginis* occurs in small to large flocks numbering five individuals to as many as 70 post-breeding (Madge *et al*. 2002) or 8–19 with a mean of 10.67 (Lu *et al*. 2006). In contrast, the majority of our records were of lone individuals, followed by a small number of male–female pairs. This is probably due to our records being outside winter when larger flocks form.

Our population sex ratio data are novel being slightly more than two males per female during the breeding season. Others have found breeding pairs to associate with young

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bachelor flocks (Jia *et al*. 1999), or polyandrous groups of two males and a female rearing broods together (Ludlow & Kinnear 1944). One theory for the evolution of polyandry is a response to an abundance of males in a given population (Willson & Pianka 1963), such as the disparate sex ratio we observed of >2 males/female.

Crossoptilon crossoptilon.—Similar to *Ithaginis cruentus*, we report novel information on temporal presence and activity patterns for this species. Additionally, we report some notes on reproductive period; these and additional findings are compared with other studies.

Lu (1986) indicated that *C. crossoptilon* is found in coniferous forest during spring, whereas in the summer McGowan (1994) stated that it occurs in alpine meadows, and Madge *et al*. (2002) reported it in subalpine birch and *Rhododendron* scrub above the treeline. In contrast to these authors reports of the species being restricted primarily to one or two specific habitats in spring and summer, we found *Crossoptilon* associated with at least six different habitats during these seasons, some of which (e.g., subalpine coniferous and mixed forests) were thought to be used only in winter by McGowan (1994) and Madge *et al*. (2002). Jia *et al*. (2005) found this species to be negatively associated with distance to nearest permanent water and herb cover, but positively with shrub cover, tree cover and tree height.

While most prior references indicate *C. crossoptilon* occurs below 3,900 m (Delacour 1951, Lu 1986, MacKinnon & Phillipps 2000), we found it only above 4,000 m to nearly 4,400 m, i.e. closer to the max. summer altitudes of 4,300 m (Madge *et al*. 2002) or 4,600 m (McGowan 1994).

Very little to no reliable information is available for *C. crossoptilon* reproduction in the wild (McGowan 1994). It is presumed that monogamous pairs (Madge *et al*. 2002) split off from larger groups in spring (Delacour 1951) to nest and lay eggs in May–June (McGowan 1994). However, Lu (1986) noted small flocks during the breeding season, rather than just solitary birds and monogamous pairs (Delacour 1951). We observed the same pattern, with a copulating pair in a small flock, broods of young foraging with multiple adults, and flocks of up to 13 birds (mean = 3.5).

The largest flock we observed was 13, consistent with others (e.g., MacKinnon & Phillipps 2000, Madge *et al*. 2002). However larger flocks of up to 30 are found in winter (Madge *et al*. 2002), and historically flocks of several hundred (Lu 1986) to 1,000 birds (Wang *et al*. 2012) have been reported, although these estimates are primarily from Buddhist monasteries where the birds are provided regular food by the monks in these regions.

Conservation implications.—While humans are the primary predators of Galliformes, other potential predators of adult and young birds and their eggs include several species recorded by our camera-traps (Buzzard *et al*. 2018). Macaques (*Macaca* sp.), Leopard Cat *Prionailurus bengalensis*, Yellow-throated Marten *Martes flavigula*, Masked Palm Civet *Paguma larvata*, domestic dog *Canis lupus familiaris* and Wild Boar *Sus scrofa* were present at both sites, and Yunnan Snub-nosed Monkey *Rhinopithecus bieti* only at Gehuaqing. Additionally, local people report that Snow Leopard *Panthera uncia* occurs at Langdu, although this has not been confirmed (Buzzard *et al*. 2017).

All of the gamebirds recorded in this study are currently classified as Least Concern (LC) by BirdLife International / IUCN (2018), with the exception of two Near Threatened species (*Bonasa sewerzowi* and *Crossoptilon crossoptilon*) found only at Langdu. *C. crossoptilon* was not only the most abundant species in our study, but was also observed to be breeding well. Although the species was treated as Vulnerable 25 years ago (Collar *et al*. 1994), it was considered abundant nearly 70 years ago (Delacour 1951). McGowan (1994) indicated the primary threats to be forest destruction and hunting.

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The robust population of Near Threatened species such as *C. crossoptilon*, coupled with the fact that Langdu harboured much higher abundance, as well as three times as many species, of Galliformes, is surprising given that conservation management is weak at Langdu compared to Gehuaqing, with no formal forest guard patrol in place. One possible explanation is the majority of Langdu occupants are Tibetans more focused on herding, whereas Gehuaqing inhabitants include the Lisu Minority who are traditionally hunters (Li *et al*. 2016). Supporting this, all but one of the photos at Gehuaqing were taken during crepuscular periods (n = 3) or at night (n = 5). Game species often shift their activity to darker photoperiods to avoid hunters who are more active by day (e.g., Brooks *et al*. 2001). In cases of communities actively harvesting wildlife (e.g., Gehuaqing Lisu), it is assumed that hunting has only increased over the decades of economic development since the 1970s. Additionally a collapse of traditional wildlife management practices (e.g., refuges, rotation and hunting seasons) may have been a contributing factor. Thus increased availability of firearms and markets led to a decline in biodiversity, which may have recovered somewhat since legal bans on guns and sales of wildlife came into effect in the 1990s.

Comparing species-presence data from a nearby site in north-west Yunnan, all of the species of pheasants photo-trapped herein, plus Silver Pheasant *Lophura nycthemera*, were also recently camera-trapped at Baima Snow and Wuliang Mountains (XL unpubl.). Of these seven species, nearly a century ago Beebe (1936) mentioned anecdotally that *Tragopan temminckii*, *Crossoptilon crossoptilon* and *Chrysolophus amherstiae* were present at sites in north-west Yunnan, while *Ithaginis* occurred nearby. It is surprising that Beebe (1936) did not mention the other three species recorded, as they were not rare in our study, comprising a combined 46% of photos (*Lophura nycthemera* n = 19, *Tetraogallus tibetanus* and *Pucrasia macrolopha* n = 7 each). Another historical example from the region is provided by Andrews & Andrews (1918), who repeatedly remarked how rare game was in the region, especially birds; nonetheless they recorded *Tragopan temminckii* and *Chrysolophus amherstiae*, plus Red Junglefowl *Gallus gallus* and *Lophura nycthemera*. Although not quantitative, the differences in species turnover over time provided in these simple analyses help to provide insight into historic hunting pressure in the region.

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