The Ecology of the Bhutan takin *Budorcas whitei* in Jigme Dorji National Park, Bhutan.

Sangay

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy.

14th June, 2018

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Certification

Statement by the Candidate

I wish to hereby state that the work embodied in this thesis titled "Ecology of the Bhutan Takin *Budorcas whitei* in Jigme Dorji National Park, Bhutan" forms my own contribution to the research work carried out. This work has not been submitted for any other degree of this or any other University. Whenever the references have been made to the previous work of others, it has been clearly indicated as such and included in the bibliography.

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ENDORSEMENT

A/Prof. Karl Vernes Date: 14th May 2018

Dr. Rajanathan Rajaratnam Date: 14th May 2018

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Summary

The Bhutan takin *Budorcas whitei*, a large gregarious forest-dwelling ungulate, is endemic to Bhutan and categorized as 'vulnerable' by the IUCN Red List of Threatened Species. The word 'takin' is used hereafter to denote both singular and plural. Prior to my work, there had been only one study on this species which investigated its diet within its summer habitat. Prior to beginning my field research on takin, I assessed its current distribution and conservation status in Bhutan from information gathered through publications, field surveys, interviews and unpublished reports. The assessment resulted in documenting some interesting facts such as establishing the Bhutan takin as endemic to Bhutan; the takin's site fidelity to hot spring and salt lick areas, and their distribution along the river valleys which are important landscape features for habitat selection. I identified additional threats to the takin like anthropogenic disturbance and disruption to migration routes, threats posed by domestic livestock including dogs, and the risk of zoonoses disease transmission.

I examined takin migratory movement between their winter and summer habitat, and their summer habitat use in the Tsharijathang Valley of Jigme Dorji National Park, Bhutan, from 2013-2015 using GPS collars. Bhutan takins are seasonal migrants from warm broad-leaved forest to alpine meadow within the altitude range of 1500 m to 5550 m asl (meter above sea level, hereafter using 'm' instead of 'm asl'). GPS-collars were placed on 13 adult takins (7 males and 6 females) to document these seasonal movements. Because of animal welfare concerns, sub-adult animals could not be collared. Takin, on average, travelled about 4 km per 24-hour period, about a third of which occurred at night. There was high site fidelity and overlap of habitat in their summer range that led to short distance travel which ultimately resulted in a smaller summer home range. The Minimum Convex Polygon (MCP) home range estimate for

takin in the summer habitat at a 95% isopleth ranged between 3.35 - 14.21 km^2, while the kernel utilization distribution (KUD) estimate ranged between 7.55 to 27.4 km^2. A male takin (TM2724) collared on 8 July 2013 provided partial data on takin migration from its summer range to its winter range before the GPS collar ran out of memory on 27 September 2013. However, this inaugural migration data showed that the animal travelled 26.68 km in the rugged mountainous terrain in three days, and part of which was along a ridgeline between 5007 to 5374 m. The male migrated to the area around Zomling, Lingzhi and Barshong, Naro of Thimphu district.

Habitat use by the Bhutan takin in their summer (alpine meadows) and winter (broadleaf forest) habitats was examined by comparing floristic composition in the areas that were used by takin compared to those that were not used. A collective total of 58 plots were laid in the summer habitat (30 plots, 15 each in the used and unused area) and in the winter habitat (28 plots, 14 each in the used and unused area). Principal component analysis (PCA) showed that the first three principal components explained about 70 percent of the total variance between used and unused sites. PC1 had significant loadings from variables like altitude, herb count and herb mean height, PC2's significant variables were tree count and tree mean DBH while PC3 had significant loadings from shrub mean height. Analysis of variance using distance matrices showed that there were significant differences between the used and unused plots in both habitats (summer $F_{1, 28} = 69.36$, $p < 0.01$; winter $F_{1, 26} = 3.89$, $p < 0.01$). The analysis of data from the summer habitat showed significant difference between used and unused plots that was driven by differences in plant species and diversity, with used plots having significantly more trees and shrubs which the takin prefers as cover and for rest during midday.

Local knowledge and perceptions by people towards the takin was assessed by conducting face-to-face semi-structured interviews on 169 residents of Jigme Dorji National Park from the Laya Geog (takin summer habitat; 91 residents) and Khatey and Khamey Geogs (takin winter habitat; 78 residents). Most respondents knew the takin was the national animal and a significantly higher proportion also knew its protected status. There was a significant difference in knowledge based upon respondents' residence whereby residents in the takin's summer habitat possessed more knowledge on the vulnerable status of takin. The summer habitat has affluent residents that benefit from collection of the prized medicinal Chinese caterpillar fungus or 'Cordyceps' *Ophiocordyceps sinensis*; this in turn allows them better access to media (e.g. television and radio) that expose them to pertinent information and campaigns surrounding the takin. Most respondents expressed positive feelings towards the takin and supported its protection.

This strong positive attitude and awareness by residents is promising but it is strongly recommended that the park develops diverse education programs targeting different age groups and learning capabilities in continuing to maintain local support and stewardship. Conservation of the takin, however, is not without its challenges and requires a commitment to reduce anthropogenic disturbance such as land use change from road construction, infrastructure for power transmission lines, unregulated harvesting of natural resources notably the prized cordyceps, competition for foraging resources from domestic livestock, and most critically, the spread of zoonotic disease transmission from domestic livestock. Understanding habitat use by takin and associated preferred habitat variables amidst various anthropogenic threats is integral towards ameliorating damage to takin habitat and preventing further loss. Furthermore, the Jigme Dorji National Park management should reinforce the implementation of the tripartite

Tsharijathang Agreement whereby domestic livestock are not grazed in the Tsharijathang Valley a month prior to the takin's arrival. The valley needs urgent protection as a declared takin sanctuary to provide a safe habitat for takin during their breeding season. This valley attracts different congregating herds from several wintering habitats around Thimphu, Paro, Gasa and Punakha, and it is crucial to facilitate the current genetic exchange to increase population vigor for the long-term survival of the takin, Bhutan's national animal.

Chapter 1: General Introduction

Takin *Budorcas* sp. are a closely related suite of large, social, forest-dwelling ungulates native to East Asia. Taxonomically, they are classed in the family Bovidae within the subfamily Caprinae (horned ungulates), and within the tribe Ovibovini that also includes the muskox (*Ovibos moschatus*). The name takin comes from the Mishmi language of Arunachal Pradesh, India. The animal was first described in 1850 from specimens collected at Mishmi, India as *Budorcas taxicolor* (Hodgson, 1850). Takin have long been considered to occur as a number of geologically distinct subspecies. However, recently they were reclassified into four seperate species by Leslie (2011). The Mishmi Takin (*B. taxicolor*; Hodgson 1850) is recorded from Tibet (China), formerly Assam, now within the state of Arunachal Pradesh (India) and Myanmar. The Sichuan takin (*B. tibetana*; Milne-Edwards 1868) occurs in Gansu and Sichuan (China); the Golden takin (*B. bedfordi*; Thomas 1911) is found at Shaanxi (China); and the Bhutan takin (*B. whitei*; Lydekker 1907) is restricted to Bhutan, although there are some unverified claims that this species is also present in Tibet (China) and Sikkim (India) (Dasgupta et al., 2010; Mahar et al., 2011).

The Bhutan Takin, locally known as *Drong Gyem Tsey* is Bhutan's national animal, declared as such by the Royal Government in November 1985 (DoF, 1987). The Bhutan takin had this status bestowed upon because of its uniqueness, and of the historic and mythical significance the animal has to the people of Bhutan. In popular Bhutanese mythology, revered Buddhist saint Lam Drukpa Kuenley is purported to have created the takin by performing a divine cloning of a goat and a cow and ordering the animal to go and graze on the mountainsides. Despite its

significance, the Bhutan takin is the least studied large mammal in the Kingdom (Rogers and Panwar, 1988; Sangay et al., 2016).

Historically, takin are known from fossilized remains at Yushe, Shaanxi Province, China and Ethiopia, dated to the late Pliocene period. The Yushe fossil sample was described by Teilhardi and Trassaert in 1938 and was later named as *Budorcas teilhardi* (Young 1948). Another fossil sample from Ethiopia was described as *Budorcas churcheri* by Gentry (1996), and with this find, the takin's historic range extended to the Middle East. A fossil of an extinct subspecies *Budorcas taxicolor lichii* dated to the Holocene period was discovered at Anyang in Henan Province, China. These samples were differentiated on the remains of horn core features and measurements (Li, 2006).

Takin are large 'vulnerable' ungulates native to temperate and sub-tropical forests in East Asia. They primarily range in Bhutan, China, northeast India and northern Myanmar. As seasonal migrants, they range within altitudes from 1500 m to 5550 m (Sharma et al., 2015; Sangay et al., 2016). Within Bhutan, takin are known to range throughout the northern territories above 27.5^{o} N and particularly present in the associated river valleys. Jigme Dorji National Park contains the majority of the takin population in the country. The animal breeds in its summer habitat and the pregnant 'cow' migrates from the summer habitat and gives birth to a calf after 7-8 months of gestation in February and March. Takin are generalist herbivores and their diet comprise grasses, herbs, bamboo and the leaves of shrubs and trees; they are recorded to consume about 68 to 161 different plant species (Schaller et al., 1986; Wangchuk, 1999; Zeng et al., 2001).

All takin have full legal protection. In Bhutan, the takin is legally listed under Schedule I of the Forest and Nature Conservation Act of Bhutan 1995 (RGoB, 1995). Takin in India are protected

under the Indian Wildlife (Protection) Act, 1972 (GoI, 1972) and in China, all takin species are listed as Class I species under the National Wildlife Law (1988) (PRoC, 1989). The IUCN Red List (Version 2012.2) lists the takin (as a single species with several subspecies) as Vulnerable (A2cd) (Song et al., 2008).

Formal conservation of the Bhutan takin began in 1974 when the Royal Government issued protective measures such as restricting habitat use to domestic livestock and human by vacating its summer habitat a month prior to takins' arrival to afford care and protection (Wollenhaupt, 1991a). To provide greater protection, three wildlife sanctuaries were established in northern Bhutan around this time: Laya Wildlife Sanctuary, Gasa Wildlife Sanctuary and Jigme Dorji Wildlife Sanctuary (MoTIF, 1974). These three wildlife sanctuaries were consolidated into a single wildlife sanctuary as Jigme Dorji Wildlife Sanctuary in honour of the Third King, Jigme Dorji Wangchuck. The sanctuary was upgraded to national park status in 1993 and named as Jigme Dorji National Park (Thinley & Tharchen, 2015). Nevertheless, concern for the species grew with Jackson (1981) recommending a full survey of takin in the wild, and Blower (1986) expressing concern that the takin could be at risk if effective measures were not taken to protect it. In 1987, the World-Wide Fund for Nature (WWF) similarly suggested a further study on the species, stating at the time that the lack of accurate information was impeding conservation efforts. Similar concerns were expressed by Wollenhaupt (1991a and b) on the need to urgently undertake research to study the takin's biology, ecology and migration, as well as investigate the population status because existing information was scant.

In recent times, the need to study and assess the conservation status of takin has intensified because of rapid human infrastructure development in takin habitat (Thinley & Tharchen, 2015; DoFPS, 2015) and other anthropogenic threats such as the rapid increase in the number of

Cordyceps *Ophiocordyceps sinensis* collectors since 2004 (Wangchuk et al.,2013; Wangchuk & Wangdi, 2015). Consequently, it has become critical to document the movement pattern of migrating takin and assess the habitat conditions and areas used during migration.

Placing GPS collars on the takin was deemed as the best method to document its movement and fulfill the gap on movement ecology. Additionally, ancillary information on key habitat variables was examined to understand and explain habitat use in both its summer and winter habitats. Local people's perception towards the takin was assessed by conducting semi-structured questionnaire surveys administered face-to-face to residents in the takin's winter and summer ranges. All necessary legal permissions were sought including approvals for human ethics (HE14-264) and animal ethics (AEC13-012) from the University of New England's Ethics Committee.

During this study, 169 park residents were administered semi-structured questionnaire interviews to assess their perception on the takin. Additionally, in two years (June 2013- July 2015), 13 adult takins were collared of which 7 were males and 6 were females. After collaring, animals were tracked in the summer habitat and the downloaded data varied from a week to a maximum of 81 days from early June to the end of September 2014. Attempts were made to track collared animals in their winter habitat with limited success.

Specific aims of the study

The broad aim of this study was to elucidate aspects of the ecology of Bhutan takin, especially in relation to their movement, migration and behavior, and additionally, assessing local people's attitude towards takin in Jigme Dorji National Park (JDNP).

For this purpose, the thesis is arranged as follow:

- Chapter 2 reviews the current knowledge of takin and assesses the conservation status of Bhutan takin using information gathered through field surveys, interviews and unpublished reports.
- Chapter 3 presents a comparative assessment of vegetation differences in areas that were used versus those that were not used by takin in both summer and winter habitats, thus providing information critical for understanding the habitat use and associated preferred habitat variables amidst various anthropogenic threats.
- Chapter 4 documents the movement ecology of takin during migration, and within their summer habitat in the Tsharijathang Valley of JDNP, thereby providing the first detailed study of the takin's movement patterns and habitat usage in Bhutan.
- In Chapter 5, I assess the perceptions of local people towards takin and related conservation policies using a semi-structured questionnaire survey. The results from these surveys document JDNP residents' attitudes toward any conservation efforts in the Park, which is vital for successful conservation of takin in JDNP.
- In Chapter 6, I discuss key findings from the thesis with a synthesis that frames better species conservation and an action plan for the long-term survival of Bhutan takin, as well as making recommendations for future studies to better understand takin ecology and movement patterns in Jigme Dorji National Park.

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STATEMENT OF AUTHOR'S CONTRIBUTION

We, the Research PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

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Chapter 2: Current distribution and conservation status of the endemic and vulnerable Bhutan Takin *Budorcas whitei* Lydekker, 1907 (Artiodactyla, Bovidae).

A picture of takin at Tsharijathang, summer habitat in Jigme Dorji National Park, Bhutan. © Tiger Sangay.

2.1. Abstract

The Bhutan takin *Budorcas whitei* is endemic to Bhutan and it is categorized as vulnerable by the IUCN Red List of Threatened Species. While the other takin subspecies have been studied in China (Golden takin *B. bedfordi*; Sichuan takin *B. tibetana*) and India (Mishmi takin *B. taxicolor*), only one study has focused on the Bhutan takin. In this chapter, we report the current distribution and conservation status of the Bhutan takin using the information gathered through field surveys, interviews and unpublished reports. Bhutan takin are seasonal migrants, occurring between 1500 m to 5550 m, preferring areas in close proximity to river valleys and geothermal outlets (hot springs). Takin avoid areas that are disturbed by road construction and power transmission lines, and where they have to compete for forage with domestic livestock. Takin conservation in Bhutan requires: (1) a commitment to reduce disturbances from domestic livestock through better herding and animal husbandry practices, (2) environmentally friendly road construction, inclusive of wildlife corridors, (3) establishment of satellite offices and regularizing anti-poaching patrol systems, (4) development of education programs to enlist support for takin conservation, and (5) encouragement of more research on the ecology and management needs of the species.

Keywords: Bhutan, Budorcas, conservation, habitat, management, takin.

2.2. Introduction

The takin *Budorcas taxicolor* (Hodgson, 1850) is a threatened forest-dwelling bovid native to the temperate and subtropical forests in East Asia. It primarily occurs in Bhutan, China, northeast India, and northern Myanmar (Neas & Hoffmann, 1987; Shackleton, 1997) with four extant subspecies previously described (Fig. 2.1). Each of these four subspecies is now considered a full separate species (Leslie, 2011), and henceforth, recognized as such in this manuscript. The golden takin *B. bedfordi* and the Sichuan takin *B. tibetana* are both confined to China. *B. bedfordi* occurs in southern Shaanxi while *B. tibetana* is distributed southerly from the Sichuan-Gansu provincial border to the border with Yunnan Province (Song et al., 2008). The Mishmi takin *B. taxicolor* ranges from southeast Tibet to the north-western Yunnan in China, with the central part of its range occurring in Arunachal Pradesh (India) and northern Myanmar (Song et al., 2008; Dasgupta et al., 2010; Mahar et al., 2011). The Bhutan takin *B. whitei* is now thought to only occur in Bhutan, despite the IUCN listing this species distribution as also overlapping with that of the Mishmi takin (Song et al., 2008).

The takin is a socially aggregating generalist herbivore that migrates between sub-tropical forests as low as 700 m in winter to sub-alpine regions up to 5550 m in summer (Smith & Xie, 2008; Sharma et al., 2015). Migratory routes often traverse several transitional vegetation types at mid-altitudes ranging from conifer forests to broad-leaved forests. These varied habitat types are sources of an equally diverse diet for the takin that comprises grasses, herbs, bamboo, and the leaves of shrubs and trees. For example, the diet of takin in China has been shown to comprise 138 plant species (Schaller et al., 1986) and 161 plant species for the golden takin (Zeng et al., 2001) while Bhutan takin in Jigme Dorji National Park (JDNP) consumes at least 68 different plant species (Wangchuk, 1999).

Mineral supplements are critical for the takin's growth as they are for other bovids, forcing herds to travel great distances to reach mineral licks. Takin is a generalist which grazes and browses. Since the majority of their diets consist of fiber – they utilize some minerals from hot springs and salt licks to help digest the diet. These herds congregate in large numbers – about 100-200 individuals at these licks – often remaining there for several days (Ali & Santapau, 1959; Neas & Hoffmann, 1987; Smith & Xie, 2008; Sharma et al., 2015).

Because takin are poorly studied, there are no reliable estimates of their global population size. Of the four species, the golden takin has been best studied with regard to population, and its population size is estimated at between 1200 – 1300 animals (Schaller, 1985; Shackleton, 1997), although other authors (Zeng et al., 2002; Ma & Wang, 2008) report higher numbers of between 3000 and 5500 animals. Several thousand Sichuan takin are thought to inhabit the Qionglai and Min Mountains (Schaller, 1985; Shackleton, 1997) while the Mishmi takin's population is estimated at about 3500 animals in China (Song et al., 2008) and about 220-300 animals in India (Dasgupta et al., 2010; Mahar et al., 2011); while the best estimate of the Bhutan takin population size in Bhutan is 500-700 animals (Sharma et al., 2015). Based on these various estimates, there are approximately 7000 to 12000 wild takin across the range of the four recognised species.

The IUCN Red List of Threatened Species (version 2012.2) lists the takin as 'Vulnerable' (A2cd) based on a probable population decline of at least 30% over the last three generations, which equates to approximately 24 years (Song et al., 2008). In China, all takin species are listed as Class I species under the National Wildlife Law (1988) which prohibits the hunting of wildlife species that are rare or facing extinction (PRoC, 1989). In India, the takin is listed under

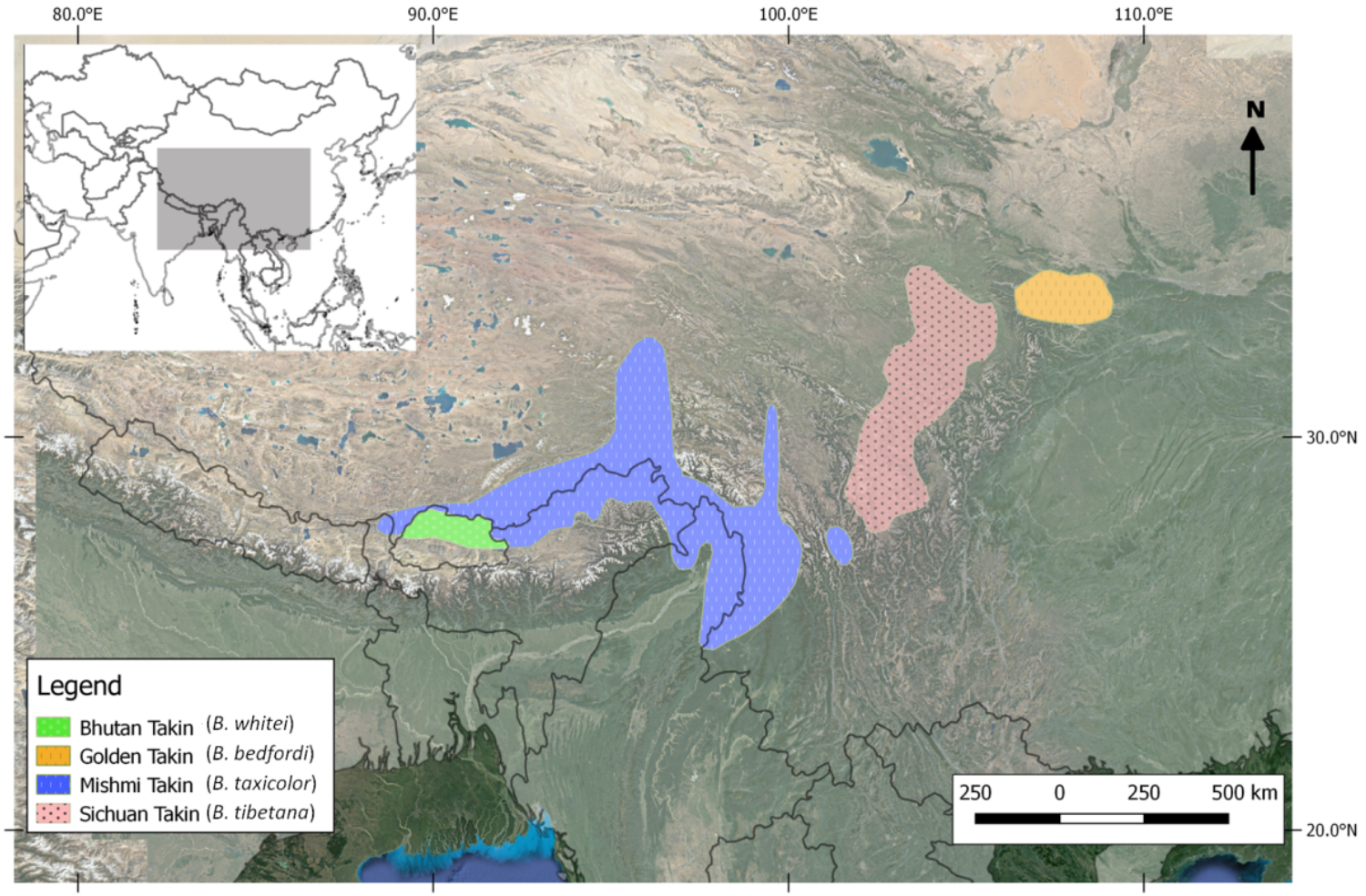

Figure 2.1 The current distribution of the four takin species in South Asia (Leslie, 2011). Individual species distribution range adapted

Schedule I of the Indian Wildlife (Protection) Act (1972), which bans the hunting and trade of listed animals (GoI, 1972). In Bhutan, the takin is totally protected under Schedule I of the Forest and Nature Conservation Act of 1995 (RGoB, 1995), and it is the national animal of Bhutan.

Although legislatively well protected, the takin faces many threats throughout its range. Despite stringent protective legislation, takin are hunted illegally for trophies and meat in India (Mishra et al., 2006; Aiyadurai et al., 2010; Dasgupta et al., 2010; Mahar et al., 2011). Furthermore, habitat throughout the takin's range has been lost to deforestation and habitat disturbance. The Bhutan takin is also seriously threatened through competition for grazing habitat with domestic livestock, and the potential for interspecific zoonotic disease cross transmission (Shackleton, 1997).

This chapter reports the distribution and conservation status of the takin in Bhutan and makes recommendations for appropriate conservation measures. Our review, which is the first to focus on the Bhutan takin, lays the foundation for dedicated conservation and management programmes in Bhutan.

2.3. Methods

We assessed the distribution and status of the Bhutan takin from British expedition reports, contemporary biodiversity field surveys and management reports, and interviews with (JDNP) the rural residents and public servants in early 2015. These interviews revealed information on the takin's locational data, residents' knowledge and perception of the takin, as well as cultural

significance and conservation threats. Residents (n = 170) from diverse occupational groups (farmers, yak herders, public servants and school children) were interviewed in the Laya Geog within the takin's summer habitat, and from the Khatey and Khamey Geogs within their winter habitat (Fig. 2.2).

2.4. Results

2.4.1. Distribution and habitat association

Takin historically ranged throughout the northern territories of Bhutan, resulting in the Royal Government in 1974 declaring three protected areas in the north of the country: Laya Wildlife Sanctuary, Gasa Wildlife Sanctuary and Jigme Dorji Wildlife Sanctuary in 1974 (MoTIF, 1974). These protected areas were later consolidated as the Jigme Dorji Wildlife Sanctuary (MoTIF, 1974; Wollenhaupt, 1990) before being designated as Jigme Dorji National Park in 1993 (Fig. 2.2). Takin are present in the valleys of Bhutan's major rivers (Fig. 2) (Wangchuk et al., 2008), and associated with hot springs in Bhutan notably Tsharijathang (Wangchuk et al., 2008) (Fig. 2.2; Image 1), and monasteries which are located in remote rural areas (Fig. 2.2)

Takin also frequent natural salt lick sites such as Shingju in Laya and Ralam in Lingzhi (Sharma et al., 2015) (Figure 2.2). Takin have been historically known from the Pemaling area in Tashiyangtse (Figure 2.2), but because there are no hot springs or salt licks in the area, it is unlikely that a resident population of takin can be supported (J. Wangyal, personal communication, July 21, 2011).

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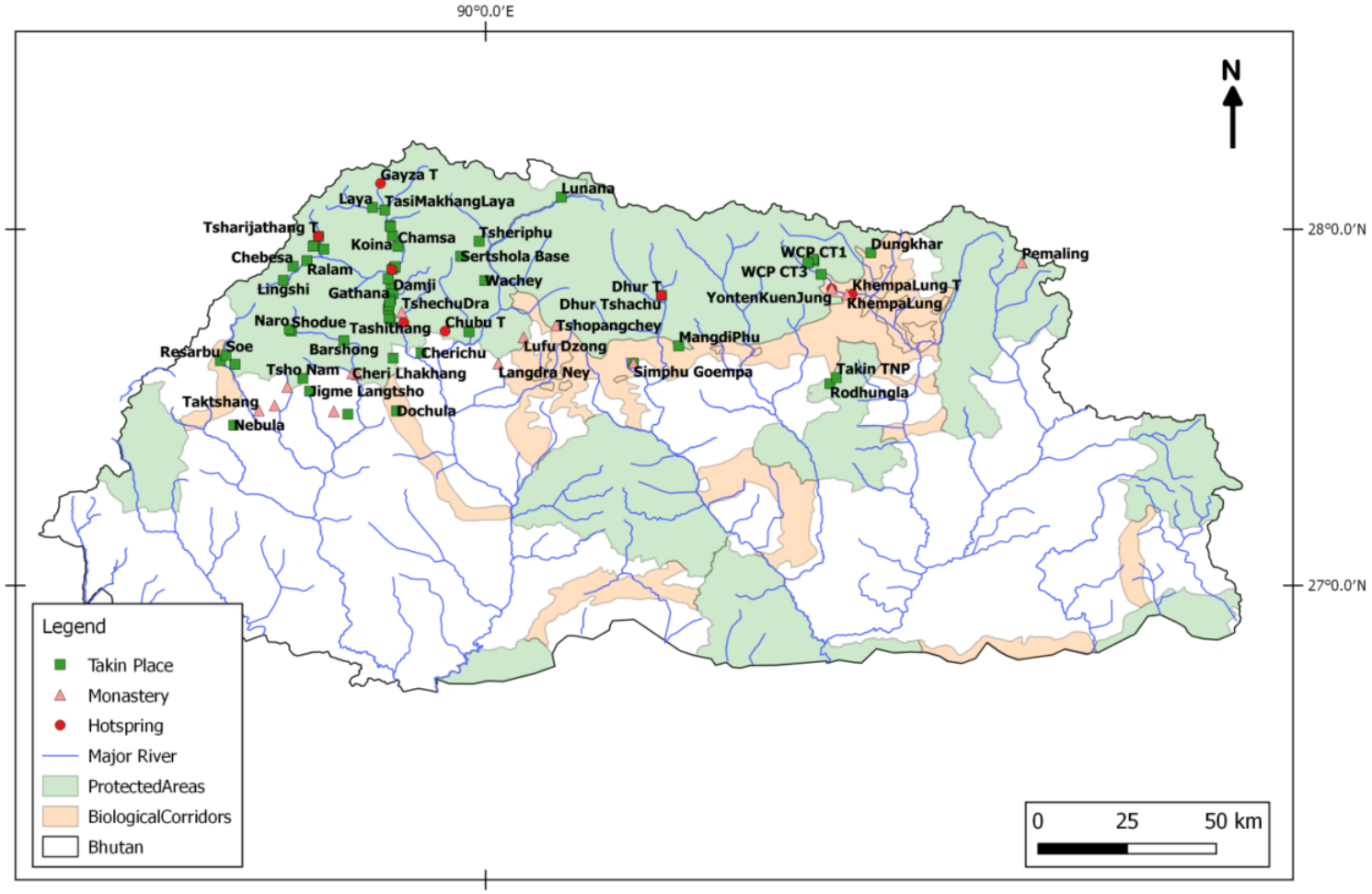

Figure 2.2 Current distribution of the Bhutan takin *Budorcas whitei* along major river valleys, near hot springs (minerals), and Buddhist monasteries (refuges). All the point locations on the map represents either a takin or takin herd observed or reported, as well as captured on camera traps in the area.

Takin have strongly featured in the popular Bhutan myth of divine cloning by the 'Divine Madman' Lam Drukpa Kuenley, reinforcing the takin's cultural and religious significance in Bhutan. Although takin are shy animals and prefer to inhabit remote areas away from high density human habitation (Sharma et al., 1995), they are often recorded near Buddhist sacred sites such as monasteries which offer protection (Figure 2.2).

Image 1: A herd of Bhutan takin utilizing the mineral rich hot spring at Tsharijathang, Jigme Dorji National Park, Bhutan. © Tiger Sangay.

Development activities have possibly contributed to changes in the movement patterns of migrating takin. Takin have been recorded in new areas such as the Dochula pass (T. Phuntsho, personal communication, September 28, 2011), and in Phrumsengla National Park, where they were first captured by a camera trap in 2011 (Wangchuk, 2011) (Figure 2.2). They have also

been recorded at Khenpajong in Lhuntse (U. Tenzin, personal communication, March 12, 2014), Mangdiphu, Gagar and Sinphu Goempa in Trongsa (K. Sonam, personal communication, August 8, 2013), while a dead takin was recorded at 2549 m in Bjakhatap, Mangdiphu (G. Dorji, personal communication, April 21, 2013) (Figure 2.2), camera trapped in Thomthom in Wangchuck Centennial National Park (Dhendup et al., 2016). Takin are known to range throughout northern territories above 27.5oN and in the river valleys. The Jigme Dorji National Park has the main stream population of takin in Bhutan.

The only known captive population of Bhutan takin is at Motithang Takin Preserve, which was established as a small zoo at Motithang (Figure 2.2) on the outskirts of Bhutan's capital city of Thimphu in 1979. This small (3.3 ha) fenced enclosure currently houses about 31 takins.

2.4.2. Awareness and conservation perception

The majority (87%; *n* = 149) of interviewed respondents from the respective Geogs (local government areas) within the takin's summer and winter habitat were aware of the takin's status as the national animal (Figure 2.3). Also, (80%; *n* = 139) of respondents were aware of its legislative protection and provision. Similarly, 87% of the respondents (*n* = 149) claimed to like the takin while 92% (*n* = 158) strongly agreed that the takin warranted protection because of its national significance. Attacks by Takin on people are exceedingly rare with only one documented fatal attack on a grazer in Sikkim (Sharma et al., 2015). In our study, takin was not perceived as a threat by the majority (68%; *n* = 117) of respondents, and none of the respondents reported any attacks.

Additionally, 81% (*n* = 139) of respondents were willing to support takin conservation measures, of which, 20% (*n* = 36) said they would not harm or kill takin, while 20% (*n* = 34) advocated the

protection and management of takin habitat. A further 17% (n = 29) were willing to assist conservation efforts while 15% (n = 26) were willing to support takin conservation by becoming informants on illegal activities, and through labour contribution and awareness creation (9%; n = 15).

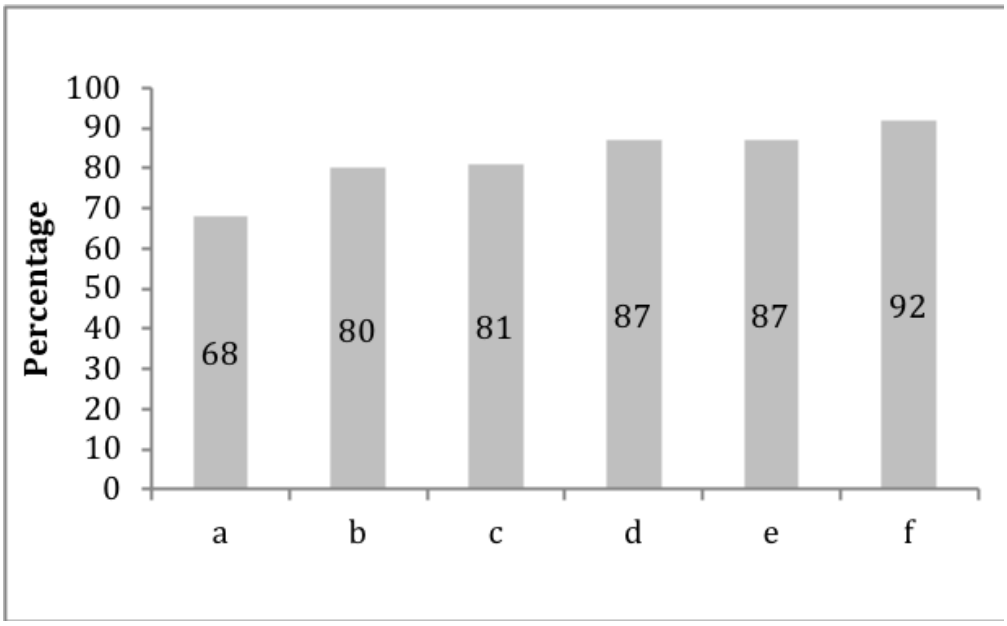

Figure 2.3 Degree of park residents' perceptions of the Bhutan takin, as determined from questionnaire interviews in Jigme Dorji National Park (a = takin perceived as not being a threat; b = aware that takin is legislatively protected; c = would support takin conservation; d = aware that the takin is the national animal; e = liked the takin; f = the takin warrants better protection).

2.5. Discussion

2.5.1. Taxonomic distribution

Although the Bhutan takin was claimed to exist in Sikkim (India) and is still listed as such by the IUCN red list (Song et al., 2008), our research uncovered this information to be incorrect. The confusion began from an event, when Tongsa Penlop of Bhutan (who later became the 1st

Hereditary King) presented a takin calf to visiting Commissioner John C. White in 1906. The calf later died in Sikkim, India, after eating poisonous aconite *Aconitum sp.* and the dead takin calf was incorrectly recorded as having come from Sikkim without specifying the true place of origin (Bailey, 1907).

However, there have been two other reports of takin sightings in Sikkim in 1995: a solitary takin was seen walking with a flock of sheep at Padamchen, and another sighting was made of a takin in Kyongnosla Alpine Wildlife Sanctuary (Dasgupta et al., 2010; Mahar et al., 2011). Without conclusive evidence of a resident takin population despite these isolated sightings, Dasgupta et al., (2010) and Mahar et al., (2011) concluded that takin is absent in Sikkim. Wollenhaupt (1990) also reported that Bhutan constitutes the westernmost range of global takin distribution (Figure 2.1).

There is also no distinct geographic boundary between the Bhutan takin and the Mishmi takin (Song et al., 2008; Dasgupta et al., 2010; Mahar et al., 2011) (Figure 2.1). Takin have been recorded in the Tawang district of Arunachal Pradesh, India near Bhutan's eastern border. However, these records are anecdotal, relying on indirect evidence based on footprints, dung and resting sites (Dasgupta et al., 2010), with no clear indication of species. Until the specific genetic relationship between the Bhutan and Mishmi takin can be resolved, we consider the Bhutan takin as endemic to Bhutan.

2.5.2. Disturbance and disruption to migration routes

Jigme Dorji National Park (JDNP) is considered core habitat for takin in Bhutan (Thinley & Tharchen, 2015). However, JDNP has experienced on-going disturbance from road construction since 2001 with scheduled roadwork yet to be completed. A prime example of disturbance to

takin migration is the current farm road construction from Gasa to Laya which commenced in 2014 (Wangmo, 2013). As takin are shy animals, construction activities associated with this road are likely to have disrupted takin migration over the short term, and the completed road has the potential to impact future takin migration (Thinley & Tharchen, 2015).

Developmental activities related to road and power infrastructure have also led to the destruction of vast tracts of primary forest that serves as habitat for other wide ranging threatened Himalayan species such as tiger *Panthera tigris*, Himalayan black bear *Ursus thibetanus*, musk deer *Moschus* sp., serow *Capricornis thar*, goral *Naemorhedus goral*, and wild dog *Cuon alpinus* (Thinley & Tharchen, 2015). These activities have been on-going since 2012 with no clear policy on timeline for completion. Whilst managers of JDNP have exercised vigilance over infrastructure development, it is evident that stronger policies surrounding habitat disturbance and mitigation of impacts are required for infrastructure development in the Bhutan's national parks.

2.5.3. Impacts from domestic livestock

The JDNP park management has impressed upon park residents the importance of the Tsharijathang valley as a prime takin sanctuary (L. Tharchen, personal communication, February 20, 2014; (Image 2). As a result of dialogue sessions and community consultation, JDNP park management, the local government and the local community signed an agreement to exclude domestic livestock in Tsharijathang annually from April, a month prior to the migratory takin's arrival, until August when takin migrate to lower altitudes. However, this exclusion period overlaps the collection season for Cordyceps *Ophiocordyceps sinensis*, a highly prized medicinal caterpillar fungus that generates significant rural cash income. Consequently, livestock are left unattended and free-ranging in the valley despite this agreement.

Image 2 The alpine meadow at an altitude of 4000m at Tsharijathang in Jigme Dorji National Park, Bhutan where takin congregate in the summer. © Tiger Sangay.

2.5.4. Impacts from domestic dogs

Domestic dogs in Bhutan number about 116,000 individuals, of which approximately 40% are free ranging stray dogs (Rinzin et al., 2016). Takin are naturally wary of domestic dogs and become visibly alert to the presence of a barking dog up to 500 meters away (T. Sangay, personal observation, June 5, 2012). The Tsharijathang valley in which takin spends each summer has many abandoned yak herding dogs which have gone feral. Additionally, Penjor (2015) reports increased predation by both feral dogs on domestic livestock in Lunana, JDNP.

Free ranging dogs have been noted to chase female Takin and dependent calf into the Tsharijathang River, causing females to abandon calves.

2.5.5. Disease transmission

Bhutan takin live and migrate through a landscape frequently used by domestic livestock (cows, horses, dogs and cats) in winter and share their summer alpine habitat with yaks, horses and dogs (Wangchuk et al., 2015). Zoonotic diseases are a serious issue for any conservation efforts (Shackleton, 1997; Wangchuk et al., 2015) as our rural populace are ignorant of this issue and associated consequences to wild species through potential cross transmission. The issue of disease transmission in JDNP is further influenced by the fact that locals restock their livestock from communities elsewhere in Bhutan without any screening for diseases that might be transmitted from domestic livestock to wild takin. For instance, Wangdi (2014) found that in the Tsharijathang Valley, yaks originating from Laya had a high prevalence of hypodermosis (warble fly infection) of up to 16%.

Other potential disease threats to the takin include the bacterial based black quarter *Gangraena emphysematosa* disease, for which, an outbreak was reported in the takin's winter habitat at the Khatey and Khamey Geogs in the Gasa Dzongkhag of JDNP in 2015 (NCAH, 2015). Sharma et al., (2015) reported the presence of threadworm *Strongyloides sp.* in takin fecal samples, and a blood test on takin during our study tested positive for Anaplasma.

Furthermore, most yak herding dogs harbour the dog tapeworm *Taenia multiceps*. In yak and other sympatric species, the tapeworm's intermediate stage can cause *Coenurus cerebralis*, a destruction of brain and spinal cord tissue that results in a neurological condition called 'gid' or 'staggers' (Wangdi, 1996).

2.5.6. Predators

Natural predators in takin's winter habitat are the tiger, common leopard *Panthera pardus*, wild dog, and black bear, while Wangchuk et al. (2015) reported the presence of snow leopard *Panthera uncia* and wolf *Canis lupus* in the summer habitat. In our study, we discovered two takin carcasses resulting from bear predation at Kabina, Gasa. Both carcasses showed similar predatory characteristics of a bear i.e. the prey's hide was rolled up toward its head as the bear progressed feeding from the hind. There was also a report of a male takin killed by a tiger around Barshong, Lingshi (T. Phuntsho, personal communication, September 28, 2011). Tshewang (1999) has also reported up to 12 wild pigs *Sus scrofa* following a takin herd at Khawza possibly in search of post-natal discard (T. Zangpo, personal communication, March 16, 2014) and sick or weak calves.

2.5.7. Conservation awareness

The strong awareness by JDNP residents on the national status of takin and acknowledgement of efforts to conserve it, can largely be attributed to park management's festival-based conservation programmes on takin, red panda and Mount Jomolhari (Bhutan's highest mountain). These festivals have educated residents through innovative approaches involving songs, dances (traditional and mask), plays, posters, exhibits, and flyers. These conservation awareness campaigns are underpinned by a national commitment to conserve nature and associated ecosystem services, valued at USD 15.5 billion a year (Kubiszewki et al., 2013).

2.6. Recommendations

2.6.1. Conservation awareness

In order to increase stewardship and encourage community support for JDNP park management efforts, priority should be given to developing an information and interpretation centre for park visitors and residents to raise awareness of JDNP's biodiversity and the presence of the takin, Bhutan's national animal. It is imperative that funds are secured to continue the takin festival especially in the prominent communities of Laya, Lingzhi, Lunana, Khatey and Khamey within the takin's summer and winter habitat, where local residents have indicated their awareness and willingness to conserve takin.

2.6.2. Animal husbandry

Domestic livestock in Bhutan are grazed freely and takin share the landscape with yak, cattle, horses and dogs. As such, improved animal husbandry through better herding practices and effective corralling (Sangay & Vernes, 2008; Sangay et al., 2016) is needed to mitigate the threat from the cross-transmission of zoonotic diseases. The agreement to exclude livestock from Tsharijathang valley where takin congregate during their summer migration has been ineffective, due to a lack of enforcement. Increased vigilance by JDNP personnel can be achieved through a manned satellite office at Tsharijathang during summer. This must be coupled with a stricter enforcement of existing penalties on errant livestock grazers; with a possibility of increasing the current penalty rates (USD 2.25 per animal per day) as a firm deterrent against illegal grazing. Livestock grazers should be encouraged to use allocated grazing areas outside the Tsharijathang Valley throughout the duration of the takin's presence during summer.

2.6.3. Road construction

Clear planning guidelines on road construction should be implemented in JDNP to mitigate habitat fragmentation and disruption to takin migration routes. The Gasa-Laya farm road will specifically disrupt takin migration routes at Chamsa, Koina, and Tongshudra. As such, wildlife corridors and relevant road construction strategies like maintaining gentler slope gradients must be implemented at these localities to facilitate the movement of takin and other large mammals, without the construction of retaining walls where possible.

2.6.4. Anti-poaching issues

Anti-poaching activities should focus on known takin summer hotspots like Tsharijathang, and the Singju and Ralam salt lick areas following discovery of illegal trapping and snaring in our study. Because summer coincides with the lucrative Cordyceps collection with a marked increase in human activity, anti-poaching should also cover known collection localities like Ridrushi, Tabdrushi, Gokula, and Chebesa. A manned satellite office at Tsharijathang during summer will facilitate adequate anti-poaching activities in addition to monitoring illegal livestock grazing.

2.6.5. Research

Priority research is needed on takin population ecology focusing on demography and fecundity. Additionally, zoonotic disease hotspots in takin habitat within JDNP must be spatio-temporally mapped to better prepare for disease outbreak through post outbreak intervention strategies. The impact of habitat degradation from Cordyceps collection within takin habitat must be investigated. Research on impact of feral yak herding dogs on native wildlife at Lunana is an urgent priority.

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Chapter 3: Floristic composition in the summer and winter habitats of the Bhutan takin *Budorcas whitei* in Jigme Dorji National Park, Bhutan.

Manuscript for submission to the Journal of Natural History

A takin herd preparing for a night rest near Mochu River at Kabina (winter habitat), Jigme Dorji National Park, Bhutan. © Tiger Sangay.

3.1. Abstract

We examined habitat use by the Bhutan takin *Budorcas whitei* in its summer (alpine meadow) and winter (broadleaf forest) habitats by comparing floristic composition (species richness and diversity of trees, shrubs and herbs) of areas that were used to those that were unused by the animal. Principal component analysis (PCA) showed that the first three principal components explained about 70 percent of the total variance between used and unused sites, with herb count, altitude, herb mean height, tree count, tree mean DBH, and shrub mean height have significantly influenced the loading of the principal components. Analysis of variance using distance matrices showed that there are significant difference between the used and unused plots in both habitats, summer $F_{1, 28} = 69.355$, $p < 0.01$ and winter $F_{1, 26} = 3.8928$, $p < 0.01$). Further, the similarity percentage test showed influence contributed by different variables on used and unused plots; in summer habitat the determinant variables are herb mean height (73%), tree mean DBH (66%) and shrub mean height (47%) and in the winter habitat, regeneration (72%), shrub mean cover (62%) and tree mean DBH (50%). Understanding habitat use and associated preferred habitat variables amidst various anthropogenic threats is integral towards managing takin habitat to ensure the long-term survival of Bhutan's national animal.

Key words: Bhutan, *Budorcas whitei*, plot, seasonal habitat, takin, used, unused, vegetation.

3.2. Introduction

Takin *Budorcas* sp. are the largest ruminants in Asia (Wangchuk, Wegge & Sangay, 2015). Bhutan's national animal, the endemic Bhutan takin *Budorcas whitei*, is listed as 'vulnerable' by IUCN (Song, Smith & MacKinnon, 2008) and is disjunctly distributed in the northern part of the country. It seasonally migrates from sub-tropical warm broadleaf forests approximately 1500 m in winter to high alpine meadows at about 5550 m in summer (Smith and Xie, 2008; Sharma et al., 2015; Wangchuk et al., 2015; Sangay et al., 2016). Mating takes place in its summer range and the birth of calves occurs in its winter range after migration from high altitude.

Takin's summer and winter habitats, including migratory routes, have experienced an exacerbated degree of anthropogenic threats in recent years. For instance, Tsharijathang Valley which is the primary summer habitat for takin in Jigme Dorji National Park, also supports several hundred domestic yaks that graze there from September to March, with numbers substantially increasing in recent times (Wangchuk et al., 2015). Additionally, during summer, several hundred 'Cordyceps collectors' with their domestic animals traverse the valley, searching for the highly lucrative Chinese caterpillar fungus *Ophiocordyceps sinensis*, and they negatively impact takin through their activities (Wangchuk, Norbu & Sherub, 2013; Wangchuk and Wangdi, 2015). Similarly, the winter habitat of takin has permanent human settlements whose residents rely on the use of natural forest resources such as firewood, non-timber forest products and grazing areas for their domestic livestock (Thinley & Tharchen, 2015).

Takin are primarily browsers (Schaller et al., 1986; Zeng et al., 2001; Sharma et al., 2015), foraging for herbs, bamboo, and the leaves and bark of shrubs and trees early in the morning and late in the afternoon, with some grasses included in the diet (Schaller et al., 1986; Wangchuk, 1999). Foraging on bark is facilitated by its broad mouth, flexible lips, and strong teeth (Schaller

et al., 1986; Zeng et al., 2001), while taller vegetation is physically trampled for browsing (Neas and Hoffmann 1987; Schaller et al., 1986; Zeng et al., 2001). Schaller et al. (1986) noted at least 138 plant species consumed by the Sichuan takin *B. tibetana* and Zeng et al., (2001) documented 161 food plant species for the golden takin *B. bedfordi*. The Bhutan takin consumes at least 68 different plant species (Wangchuk, 1999).

Our study in Jigme Dorji National Park in Bhutan is the first of its kind in documenting, quantifying, and assessing floristic differences and habitat structure between used and unused areas in the takin's summer and winter ranges. Understanding habitat use and preferred habitat variables amidst various anthropogenic threats, is integral towards managing takin habitat to ensure the long-term survival of Bhutan's iconic national animal.

3.3. Method

3.3.1. Study area

Jigme Dorji National Park (JDNP) (27°40' - 28°15'N, 89°05' - 90°20'E) (Figure 3.1) is in northwestern Bhutan and supports the largest population of Bhutan takin. Vegetation surveys here recorded 1434 species of vascular plants (138 trees, 240 shrubs, 47 climbers, and 1009 herbaceous species) belonging to 144 families (Rawat & Wangchuk, 2000; Thinley & Tharchen, 2015). There are six dominant forest types in JDNP: warm broadleaved forests (1000 - 2300 m), cool broadleaved forest (2000 - 2900 m), mixed conifer forest (2700 - 3200 m), fir forest (3300 - 3800 m), juniper/rhododendron forest (3700 - 4200 m), and alpine scrub forest (4000 - 4600 m) (Rawat& Wangchuk, 2000; Thinley & Tharchen, 2015; FRMD 2016). Wangchuk et al., (2015) further identified and mapped the takin's summer habitat at Tsharijathang valley (Figure 3.1) into six broad vegetation types of fir forest, juniper forest, birch forest, willow shrub, alpine scrub and alpine meadow.

Our vegetation assessment in takin habitat was conducted in two phases: 10-11th March 2015 in the takin's winter range at Kabina in the Khamey Geog, and from 15-16th July 2015 in the takin's summer range at Tsharijathang Valley (Figure 3.1). Summer and winter habitats had distinct geo-physical traits: Tsharijathang valley is located at an altitudinal range of 3613 – 4704 m with temperature ranges between -17.7 to 20.3^{o}C, whereas the winter habitat at Kabina is located at altitudinal range of 1494 – 2641 m with temperatures ranging between 0.2 to 29.7^{o}C.

3.3.2. Data collection

We identified 'used' and 'unused' areas in the takin's summer and winter habitats from the locations of radio-collared individuals and the presence of indirect signs (tracks, footprints, and dung) during field surveys. Areas in which takin forage were designated as 'used' whereas proximal areas not utilized by takin were designated as 'unused'. 'Used' and 'unused' areas in winter and summer habitats were near (approximately one kilometer apart) within a specific forest type. Survey transects were established to traverse an altitudinal gradient in 'used' and 'unused' areas within the summer and winter habitats to document the cross section of vegetation types within these areas using vegetation survey formats (see Annexure 1). We established 25 x 25 m survey plots along transects, with a minimum inter-plot spacing of 200m (Figure 3.2). Standardized rapid vegetation surveys (Ngawang et al., 2004; Dorji, Vernes & Rajaratnam, 2011) were conducted within each of the 25 x 25 m plots. The full 25 x 25 m plot was used to sample tree species, while a 5 x 5 m nested and centrally located subplot, sampled shrub and herb diversity (Figure 3.2). Regeneration data were collected within a second randomly located 1 x 1 m subplot within the parent 25 x 25 m plot (Figure 3.2). We established a total of 58 plots comprising 15 plots in both 'used' and 'unused' areas within the summer habitat, and a total of 14 plots in both the 'used' and 'unused' areas within the winter habitat.

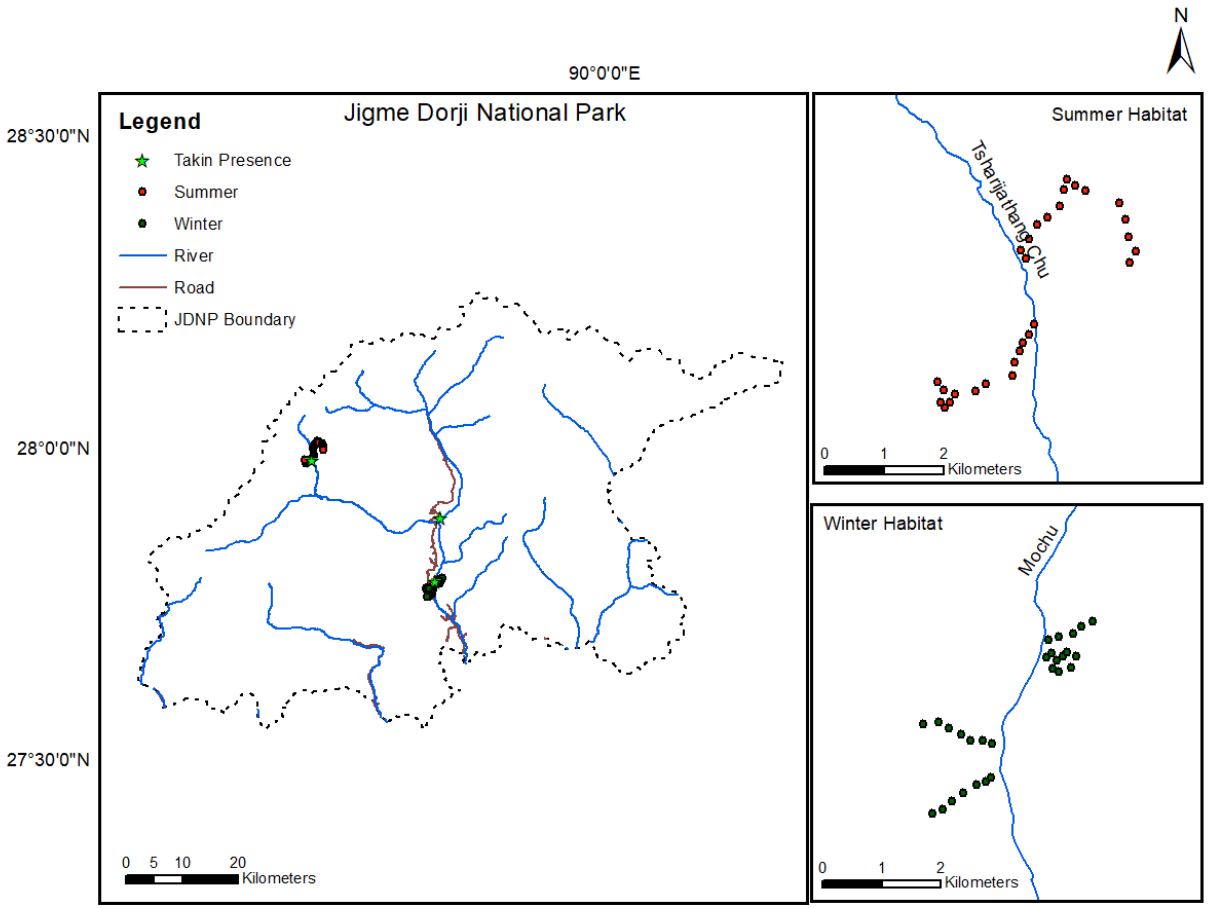

Figure 3.1 Map showing the study areas and associated vegetation survey plots in the takin's summer and winter habitat in Jigme Dorji National Park (JDNP), Bhutan

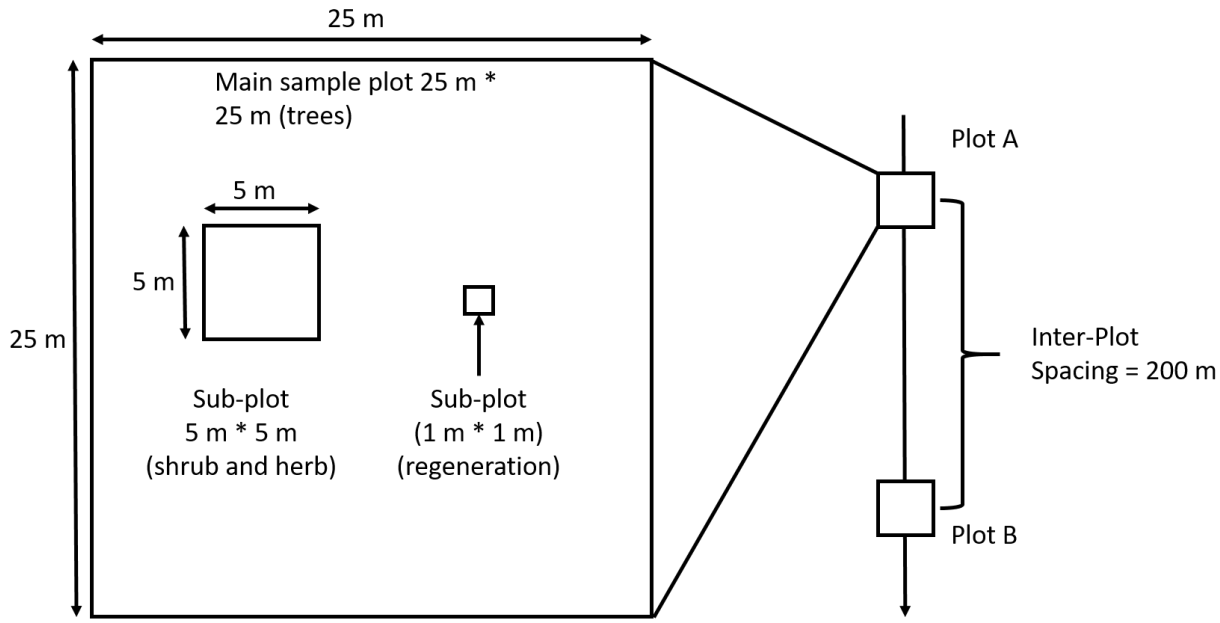

Figure 3.2 Schematic layout of the 25 X 25 m, 5 X 5 m, and 1 X 1 m vegetation survey plots in 'used' and unused' areas along survey transects within the Bhutan takin's summer and winter habitats in Jigme Dorji National Park, Bhutan.

Vegetation species in each plot and subplot were identified with the help of relevant field guides for Bhutan flora (Grierson & Long, 1983), flowers (Polunin & Stainton, 1984; Stainton, 1997), orchids (Gurung, 2006), and high altitude medicinal plants (Wangchuk, Samten & Ugyen, 2009). All additional measurements on plot specific variables such as altitude, slope, aspect, disturbance, and major forest types were collected following Ngawang et al., (2004).

3.3.3. Data analysis

Characterization and differentiation between the four different habitat area types [i.e. Summer - Not Used (SN), Summer - Used (SU), Winter - Not Used (WN), and Winter – Used (WU)] was undertaken using a few different statistical approaches. To assess floristic diversity encompassing the three sub-type vegetation habitats (tree, shrub and herb), we calculated an

overall Shannon's diversity index (*H'*) (Shannon, 1948) and Simpson's Index (*D*) (Simpson, 1949) for 'used' and 'unused' areas within summer and winter habitats using the R package 'vegan' version 2.4-4 (R Core Team 2017; Oksanen et al., 2017).

A multivariate principal component analysis (PCA) was additionally run to describe the variation in measured vegetation and environmental variables in 'used' and 'unused' areas within the takin's summer and winter habitats. Initial variables used in the PCA were: altitude, tree count, tree mean diameter at breast height (MDBH), tree mean height (MH), shrub count, shrub mean height (MH), shrub mean count (MC), herb count, herb MH, herb MC, regeneration, and disturbance. However, a review of pairwise correlations and the normality of individual variables resulted in the exclusion of tree MH, shrub MC, and herb MC from further analyses. The PCA was then run in R (R Core Team 2017) using the package 'psych' version 1.7.5. (Revelle, 2017). To compare differences between the four habitat-area types, a visual inspection of the scree-plot as well as a review of the cumulative proportion of explained variance was used to determine the number of principal components (PCs) that were presented. A standard biplot of PC1 vs PC2 was produced using the R package 'devtools' version 1.13.2 (Wickham & Chang, 2017) and 'ggbiplot' version 0.55. (Vu, 2011) to provide a visual display of the PCA estimates. Finally, we analysed the data within the R package 'vegan' (Oksanen et al., 2017) using the 'adonis' function that undertakes a permutational multivariate analysis of variance using distance matrices, to assess the similarities between used and unused plots in the summer and winter habitat. We then used the 'simper' (similarity percentage) function to discern how different these plots are explained by the test.

3.4. Results

3.4.1. Floristic composition

Rapid vegetation surveys documented a total of 40 tree species, 51 shrub species and 95 herb species from the 58 plots within our JDNP study areas. Shannon's Diversity Index (*H'*) and Simpson's Index (*D*) diversity indices showed subtle differences between the summer and winter habitats in terms of overall floristics. At the summer habitat, the tree species were more diverse in used area (*H'* = 1.43; *D* = 0.72) while the unused area did not have any tree. Shrub species were more diverse in used area (*H'* = 2.87; *D* = 0.96) over unused area (*H'* = 1.79; *D* = 0.83) while herb species were more diverse in unused area (*H'* = 3.38; *D* = 0.97) over used area (*H'* = 3.08; *D* = 0.96). Whereas in winter habitat, the tree species were more diverse in used area (*H'* = 3.64; *D* = 0.89) over unused area (*H'* = 3.40; *D* = 0.93). Shrub species were more diverse in unused area (*H'* = 2.58; *D* = 0.95) over used area (*H'* = 0.91; *D* = 0.76) and herb species were more diverse in unused area (*H'* = 3.07; *D* = 0.96) over used area (*H'* = 3.00; *D* = 0.95).

3.4.2. Multivariate analyses

A Principal Component Analysis (PCA) indicated that the first 3 principal components (PC) accounted for approximately 70% of the variability found in used and unused areas within the takin's winter and summer habitat (Table 3.1). Results showed that PC1 explained 31% of the total variation and reported the highest loadings for herb count, altitude, and herb mean height – with herb mean height having comparable magnitude but at the opposite direction to the first two variables (Table 3.1). PC2 accounted for 26% of the total variance with highest loadings on tree count and tree mean diameter at breast height. PC3 explained an additional 13% of the total variance and was dominated by the loading for shrub mean height.

A biplot of PC1 versus PC2 (Figure 3.3) shows the position of measured variables related to used and unused areas within the winter and summer habitats that were surveyed. There is clear distinction between SU, SN, WU and WN plots.

Table 3.1 Principal Component Analysis (PCA) scores for habitat variables in surveyed vegetation plots at Jigme Dorji National Park, Bhutan. Scores in bold were significantly correlated with the Principal Component in each instance.

Variable	PC1	PC2	PC3
Altitude	**-0.49**	0.17	-0.17
Tree Count	0.00	**-0.58**	-0.13
Tree MDBH	-0.16	**-0.58**	-0.07
Shrub Count	-0.34	-0.35	0.34
Shrub MH	-0.07	-0.03	**0.85**
Herb Count	**-0.49**	-0.14	-0.09
Herb MH	**0.49**	-0.12	0.22
Regeneration	0.14	-0.19	0.03
Disturbance	-0.34	0.33	0.23
Proportion of Variance (%)	30.98	25.63	13.24
Cumulative Proportion (%)	30.98	56.61	69.85

3.4.3. Analysis of variance using distance matrices and a similarity percentage

The permutational multivariate analysis of variance using a distance matrix (ADONIS) test showed that there are significant difference between the used and unused plots in both habitats, in winter habitat ($F_{1, 26} = 3.8928$, $p < 0.01$ with 13% of the sum of squares explained by usage, whereas in summer habitat $F_{1, 28} = 69.355$, $p < 0.01$ with 71% of the sum of squares explained by the usage. The test confirms the results of PCA and biplot wherein the summer used plots are separated widely which indicates diverse species and communities difference in the plot while the summer unused plots are closely knitted showing low diversity and the communities relatedness. Similarity percentage (SIMPER) showed the discriminating variables between the used and unused plots using Bray-Curtis dissimilarities. In the winter habitat the cumulative

contributions of the most three influential variables between the used and unused were regeneration (72%), shrub mean cover (62%), tree mean DBH (50%) and herb mean height (26%). Similarly, in the summer habitat it was herb mean height (73%), tree mean DBH (66%) and shrub mean height (47%).

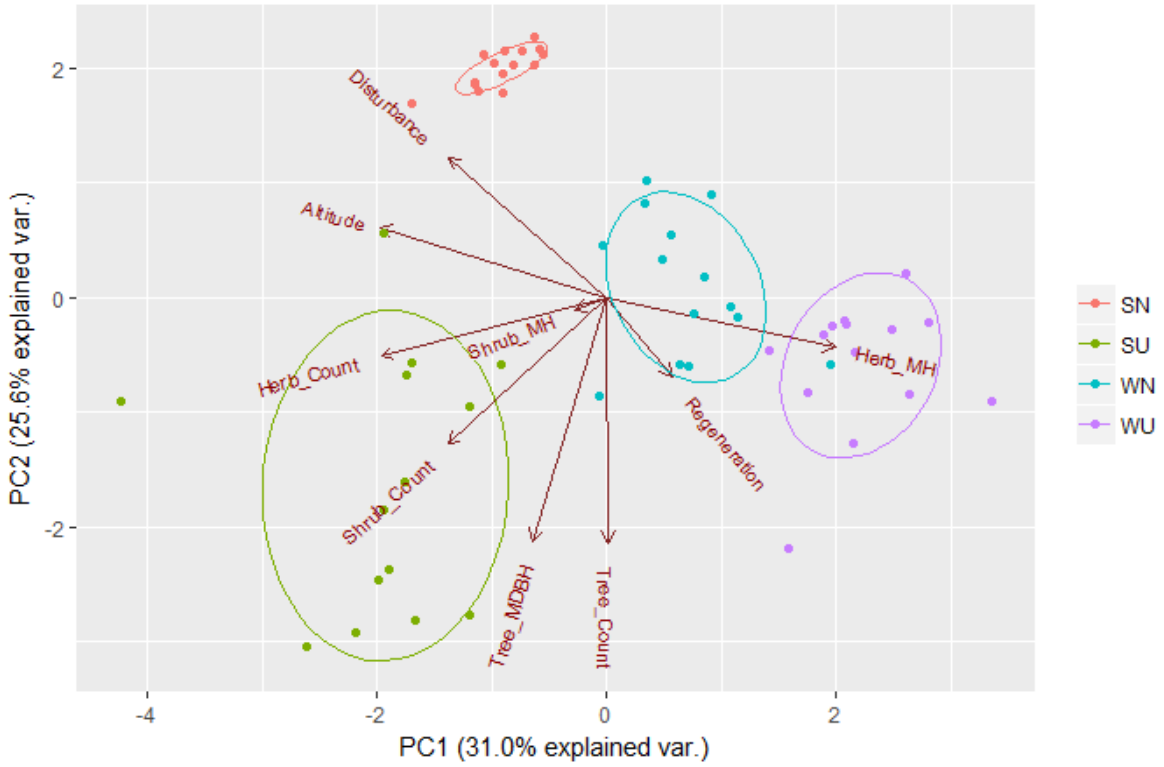

Figure 3.3 Biplot of PC1 and PC2 from a Principal Component Analysis (PCA) showing the relative distribution of vegetation and environmental variables in surveyed habitat-area plots at Jigme Dorji National Park, Bhutan. Note: SN = Summer-Unused; SU = Summer-Used; WN = Winter-Unused; WU = Winter-Used; MDBH = Mean Diameter at Breast Height; MH = Mean Height.

3.5. Discussion

It has been well-established that the Bhutan takin uses distinctive summer and winter habitats and undertakes an annual seasonal migration between these habitats (Sangay et al., 2016). These habitats have separate environmental traits such as aspect, altitude, latitude, terrain, temperature, and rainfall which influence habitat distinctiveness (Shaheen et al., 2012, Xu et al., 2017). Vegetation species richness and distribution varied between altitudes, i.e., there is a decrease in species with an increase in altitude (Gairola, Rawal & Todaria, 2008; Shaheen et al., 2012). Our results closely followed this premise, whereby the overall floristic comparison between the Bhutan takin's summer and winter habitats indicates that the vegetation community was more diverse in the lower-altitude winter habitat compared to the higher altitude summer habitat. Our diversity indices confirmed that overall tree and shrub diversity decreases with altitude while herb diversity increases with altitude (Rawat & Wangchuk, 2000; Vetaas & Grytnes, 2002). However, there was a decrease in herb mean height with an increase in altitude. The SIMPER test also showed significant influence of herb mean height on the used and unused areas of summer habitat's dissimilarities of 73% indicating distinct communities' composition. This could be possibly attributed to the location's altitudinal and latitudinal gradients which influences the area's climatic condition such as temperature, humidity, precipitation, snow, heat (level of photosynthetic active radiation) (Xu et al., 2017).

Vegetation species richness are influenced by external anthropogenic disturbance from domestic animals and human's resource extraction (Tenzin & Hasenauer, 2016), which in turn, dictated the takin's preference of specific areas within its habitat. The takin are faced with reduced availability of foraging resources in Bhutan, affected practically by free ranged domestic livestock to graze and browse in local forests, including those forested habitats within national

parks and protected areas (Moktan et al., 2008, Wang et al., 2015). The 'used' habitat in winter, which is buffered by the major Mochu River has acted as a barrier to human impact and it had more matured trees comprised of closed canopies whereas the unused areas had a fewer number of trees as a result from timber harvested for house building (Moktan et al., 2009; Palden, 2015), with less oak (*Quercus* sp.) because that is the preferred fuelwood species in Bhutan (Covey et al., 2015). Such harvesting has created openings in the canopy and permitted light to enhance growth of other species (Choden & Ohsawa, 2011) but it represented sub-optimal forage for takin. Unused areas in the winter habitat also has a motorable road that aided the extraction and transport of timbers (Waiba, 2015) that further disturbed the relatively shy animal.

Despite occasional grazing, the takin is primarily a browser and shrubs form a major part of its diet (Wangchuk et al., 2015). In the winter habitat, (*Elastostema* sp.) was the dominant shrub in the used areas compared to the unused areas. It is prime winter forage for takin which have been observed to browse extensively on (*Elastostema* sp.) dominated areas whilst avoiding other locations which are extensively grazed by free ranging cattle (Norbu, 2000). A similar dedicated patch used of habitat by browsing elk has also been described by Seidel & Boyce (2015).

In addition to domestic yak grazing in the summer habitat at Tsharijathang, the takin is faced additional interspecific grazing competition from blue sheep (*Pseudois nayaur*) (Chophyel, 2009; Wangchuk et al., 2015). In recent years, excessive domestic horse grazing after legalization of Cordyceps collection (Wangchuk & Wangdi, 2015) has further impacted forage availability for the takin in its summer alpine meadows (Hull et al., 2014b; Wang et al., 2015). Despite being a versatile forager that can feed on a variety of trees, shrubs and herbs (Schaller et al., 1986), takin foraged in areas heavily grazed by domestic livestock and dominated by grasses and herbs that are important foraging resource to sustain the takin in its summer habitat.

Since 1992, the number of families grazing their yak in the Tsharijathang Valley have increased substantially from just four families prior to 1992, to 13 in 1992 and then 21 in 2001 (Wangchuk, 1999). The increased socio-economic affluence of these families (i.e. through yak herding combined with Cordyceps collection) has enabled the purchase and use of power chainsaws to increase the harvest of fuelwood from rhododendron trees in the alpine scrub habitat (Katel & Schmidt-Vogt, 2011). Wangchuk et al., (2014) found that a rhododendron took 169 years with an annual increment of 0.6 ± 0.04 mm/year to achieve a trunk diameter of 8 cm. Alarmingly, these authors projected that at the current extraction rate, all the rhododendron forests in the alpine scrub forest within the takin's summer range habitat may be harvested by 2023 (Wangchuk et al., 2014). This will have a severe impact on the takin given that our results show a preference for areas with a high tree cover in the summer habitat to shade them from the heat during the day and for shelter during the night (Tshewang et al., 2015).

It is critical that areas used by the takin in both the winter and summer habitat are adequately protected to ensure their survival in JDNP. Stricter regulations on timber harvesting (Dorji, Rajaratnam & Vernes, 2012) need to be enforced in addition to limiting free ranging livestock herding, particularly in the lower altitude winter habitat, by encouraging better husbandry practices like tethering and corralling (Rajaratnam et al., 2016). Furthermore, an agreement with yak herders to prohibit livestock from entering the Tsharijathang Valley (the takin's summer habitat between May to September) a month prior to the arrival of migrating takin, should be strictly reinforced and monitored. Local Bhutanese and foreign tourists trekking in this habitat should also be educated through signage and briefings by JDNP park staff to avoid trampling and disturbing vegetation in the areas used by the takin, to prevent damage to foraging resources and maintain floristic integrity and health of key takin habitat.

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Chapter 4: Migration patterns, movements and the home range of the Bhutan Takin *Budorcas whitei* in its summer habitat within Jigme Dorji National Park, Bhutan.

Manuscript prepared for submission to a relevant journal

A collared male takin TM2892 at Tsharijathang (summer habitat) Jigme Dorji National Park, Bhutan. © Tiger Sangay.

4.1. Abstract

The Bhutan takin *Budorcas whitei* is a large, gregarious and forest-dwelling ungulate that migrates annually between warm broad-leaved forests in winter at an altitude of 1500 m to open alpine meadows at 4500 m in summer. Using GPS collars between 2013 and 2015, we monitored the movement patterns and home range of the Bhutan takin in its summer habitat in the Tsharijathang Valley of Jigme Dorji National Park, Bhutan. Our results showed that the Bhutan takin, on average, travelled about 4 km a day, about a third of which was covered at night. Its home range was estimated based on GPS locations from six takins and minimum convex polygon (MCP) and kernel utilization distribution (KUD) models were used at the 95% isopleth of the summer habitat. The MCP model estimated a home range of 8.92 ± 1.51 km^2 (n = 6) while the KUD estimated a home range of 14.7 ± 2.8 km^2 (n = 6). All collared takins in the summer habitat utilised a combined area of about 2740 ha.

Keyword: altitude, Bhutan, *Budorcas whitei*, home range, migration, takin, seasonal movement, Jigme Dorji National Park.

4.2. Introduction

Migration is a strategic and functional movement by social and gregarious species to optimize resource use by tracking spatiotemporal resource changes in food, shelter, and mates (Dingle & Drake, 2007). Animal migration can be a cyclic round trip or a predictable annual seasonal movement between localities (Dingle & Drake, 2007), and may be impacted by environmental factors such as weather, habitat type and human land use (Dodge et al., 2013). Migration is a common survival strategy in order to access better forage, and to avoid predation and anthropogenic threats (Fryxell & Sinclair, 1988: McNaughton, 1990: Sakuragi et al., 2003; Zeng et al., 2008; Takii et al., 2012; Gaidet & Lecomte, 2013) often triggered by environmental cues like photoperiod (length of sunlight), temperature, and snow depth, or biotic factors such as predation (Fryxell & Sinclair, 1988; Dingle, 2006; Dingle & Drake, 2007; Goodenough et al., 2010).

Migration can span large areas of inhospitable terrain and is often metabolically demanding (Wilcove, 2008). In such cases, animals migrate between a less hospitable habitat for a more hospitable one, sometimes covering a distance of a few thousand kilometers. Such migrations are often divided into smaller laps or stopovers to revive, feed and restore their energy; this sort of movement pattern is adopted by most migratory birds (Strandberg & Alerstam, 2007).

Seasonal migration is a common behaviour engaged by temperate alpine ungulates moving between high altitude mountainous areas in the summer and low altitudes during winter (Zeng et al., 2008; Sangay et al., 2016). Examples of temperate ungulates that engage in annual migration between low and high altitudes include elk *Cervus elaphus*; caribou *Rangifer tarandus* (Wilson et al., 2016; Nicholson et al., 2016); Mongolian gazelle *Procapra gutturosa* (Leimgruber et al., 2001, Ito et al., 2013), Tibetan antelope *Pantholops hodgsoni* (Lain et al., 2007), saiga *Saiga*

tatarica (Singh et al., 2010), and wild yak *Bos mutus* (Berger, 2014). One of the drawbacks of ungulate migration is a tendency to follow same migration routes on an annual basis (Goodenough et al., 2010). Often such routes are easy trap sites to target migrating animals by poachers.

In Himalayan Bhutan, altitudinal migrants are relatively common and span across a range of vertebrate groups. For example, black-necked cranes *Grus nigricollis* migrate from an over-wintering site in the Phobjikha Valley (2950 m) in Bhutan to the Tibetan Plateau (4200 m) in China (Lhendup & Webb, 2009; Sherub et al., 2017); Satyr tragopan *Tragopan satyra* migrate from Ura, Bumthang (3186 m) to Ungar in Lhuntse, Bhutan (1970 m) (Norbu et al., 2013); and Bhutan takin *Budorcas whitei* migrate within Bhutan from a winter range in cool broadleaf forest around Kabina (1494 m) to the Tsharijathang Valley (4160 m) during summer (Sangay et al., 2016). Similarly, domestic livestock in Bhutan such as cattle *Bos indicus*, Mithun *B. frontalis* and yak *B. grunniens* also migrate by shifting their local residency according to the vegetation productivity and climatic conditions from lower valleys in winter to high alpine meadows in summer (Gyamtsho, 2000; Norbu, 2002, Ura, 2002, Wangchuk, 2002).

The Bhutan takin is a large forest-dwelling ungulate endemic to Bhutan (Sangay et al., 2016). Takin are sexually dimorphic with males being approximately a third larger and with slightly heavier horns then females. An adult cow weighs around 250 to 300 kg while bulls weigh from 300 to 500 kg (Neas & Hoffmann, 1987; Wangchuk et al., 2008; Menon, 2009). Bhutan takin mate between late June and early July at alpine meadows where they congregate in summer (Neas & Hoffmann, 1987; Wangchuk, 1999; Menon, 2009). Takin begin to migrate to the winter habitat in late July, when the environment becomes cold and is covered by thin sheet of frost. The migrant cows are pregnant give birth in February and March of the following year in the

winter habitat after 7 – 8 months gestation (Shackleton, 1997; Sharma et al., 2015). The current population of takin in Bhutan is estimated at only 500 - 700 individuals (Sharma et al. 2015; Sangay et al., 2016); accordingly, the Bhutan takin is classified as vulnerable by the IUCN (www.iucn.org) and listed in Appendix II of CITES (www.cites.org).

95% of Bhutan's topographical landscape is characterised as mountainous, and a short north to south cross-section of approximately 50 km can encompass an altitudinal variation from 80 m to 7500 m. Such a considerable altitudinal variation results in a rapid transition of terrestrial habitat types that range from sub-tropical forest, through to warm broadleaf forest, temperate broadleaf forest, mixed conifer forest, fir forest, scrub forest and alpine scree (FRMD, 2016). In the lead up to summer, Bhutan takin migrate from warm broadleaf forests at an altitude as low as 1500 m to alpine meadows as high as 5550 m (Sangay et al., 2016).

This chapter documents the seasonal migration of takin from their summer to winter habitats, as well as detailing other characteristics of migration and seasonal activity relating to daily distance moved, home range size, activity patterns, and habitat cover. The knowledge generated contributes to a better understanding of takin ecology and migration, thereby improving takin management and conservation of its habitat in Bhutan.

4.3. Materials and methods

4.3.1. Study Area

This study was conducted between July 2013 and July 2015 in the takin's summer habitat at Tsharijathang Valley in the northwest of Jigme Dorji National Park (Figure 4.1). The Park was initially declared as a wildlife sanctuary in 1974 and was later upgraded to National Park status

in 1993 (Thinley & Tharchen, 2015). It is the second largest park in the country and encompasses an area of 4316 km^2. The park hosts a thriving population of endangered tiger *Panthera tigris*, snow leopard *Panthera uncia* and other iconic faunal species such as Himalayan musk deer *Moschus sp*., clouded leopard *Neofelis nebulosa*, marbled cat *Pardofelis marmorata*, Asiatic wild dog *Cuon alpinus*, red panda *Ailurus fulgens*, Himalayan black bear *Ursus thibetanus*, sambar *Rusa unicolor* and white-bellied heron *Ardea insignis.*

Tsharijathang, located about four trekking days away from the nearest road, is a river valley and has a hot spring. The place was determined as a better site to conduct collaring for two reasons: it is a place where takin congregate from different winter habitats near the hot spring and is an open flat alpine meadow that offers better visibility for animal monitoring.

4.3.2. Takin capture and collaring

Thirteen takins (6 females and 7 males) were captured between July 2013 and July 2015. Persistent efforts were made to capture adult individuals from different herds with a preferred equal sex ratio of collared animals (Table 4.1). Takin were captured by delivering an anaesthetic cocktail of drugs comprising 1.2 mg carfentanil, 12 mg detomidine and 225 mg ketamine per animal through a Palmer Cap-Chur dart gun (Harrington & Richardson, US). Typically, this anaesthetic drug took approximately 5 minutes to take effect. A GPS collar was fitted to each captured animal; it took approximately 40 minutes, on average, to handle the animal and fit the collar. During handling, various morphological measurements and biological samples were taken including skin/tissue, blood, fecal, and ectoparasite samples. An anaesthetic reversal dose consisting of 200 mg naltrexone and 60 mg atipamezole was administered either intravenously or intramuscularly. Depending on the way the reversal drugs were administered, it usually took about 5 to 10 minutes for the drugs to take effect, and for the animal to be back on its feet.

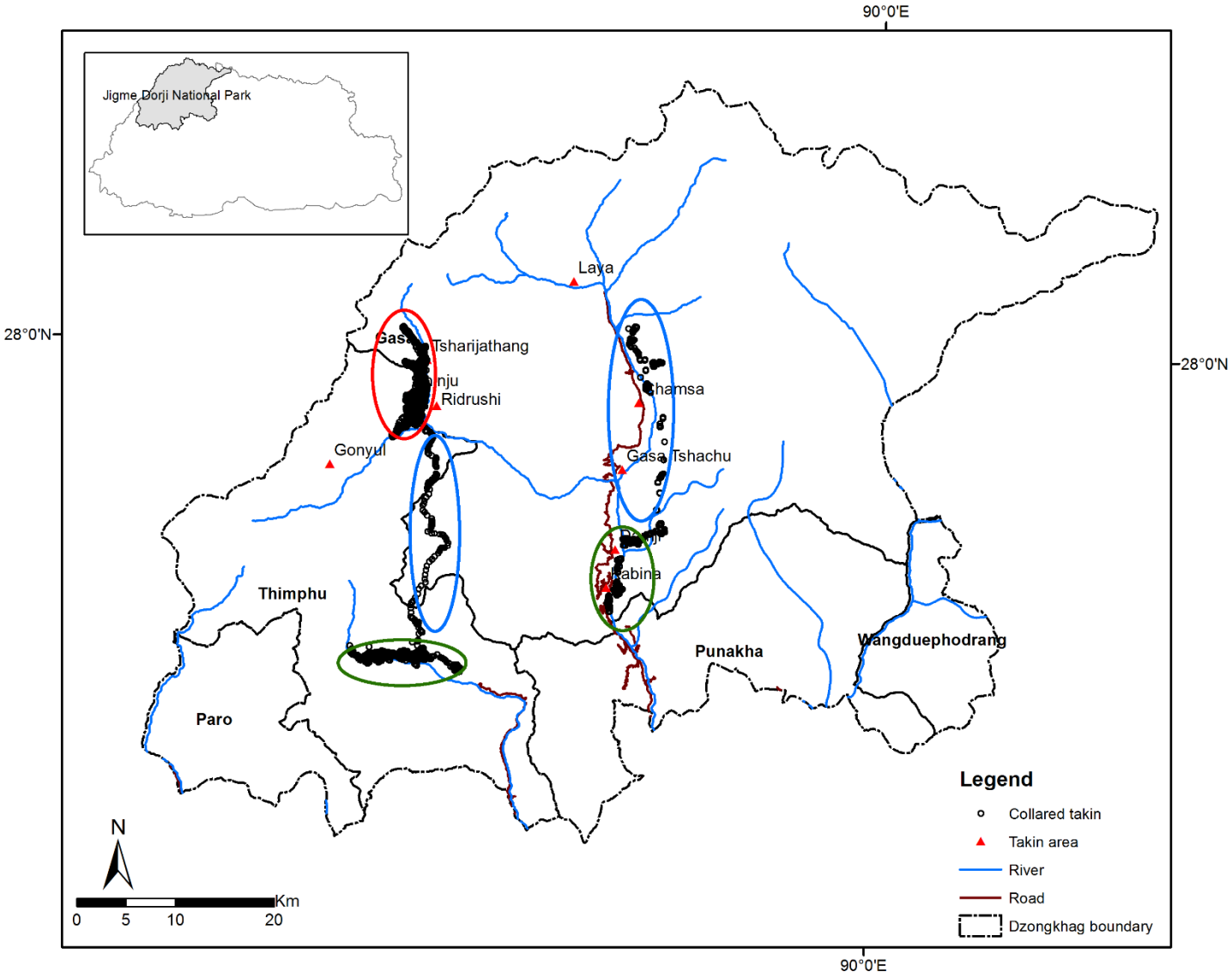

Figure 4.1 Map showing locations of collared takin in Jigme Dorji National Park, Bhutan. Red ellipse refers to the summer habitat, green ellipses to the winter habitat, and blue ellipses refer to migration routes

All animal handling protocols were approved by the Animal Ethic Committee of the Univ of New England (AEC13-012) as well as approved by the US National Zoo's Animal Care Use Committee (NZP-IACUC 12-18). The research was also technically cleared by the Scientific Technical Committee of Council for RNR Research of Bhutan (CORRB/TCO/D 2/354) and, additionally, received royal consent from His Majesty the Fourth Druk Gyalpo conveyed through the Director General of Forests (WCD/Adm-09/2012/772).

Table 4.1 List of captured takins in Jigme Dorji National Park, Bhutan. Note: a weight esti was obtained when measuring chest girth with a specialised tape called a weight measurin (Hyperdrug, UK).

Year	Name	Date	Sex	Estimated Weight in Kg
2013	TM2895	8-07-13	Male	330
2013	TM2894	8-07-13	Male	264
2013	TM2724	8-07-13	Male	249
2013	TM2892	26-07-13	Male	246
2014	TM2898	8-04-14	Male	-
2014	TM2893	21-07-14	Male	-
2015	TF2887	12-04-15	Female	225
2015	TF2897	28-06-15	Female	202
2015	TF2889	5-07-15	Female	-
2015	TF2899	6-07-15	Female	220
2015	TM2886	9-07-15	Male	198
2015	TF2891	12-07-15	Female	206
2015	TF2940	13-07-15	Female	272

4.3.3. GPS collars and data acquisition

We used GPS/accelerometer collars (www.e-obs.dc, Munich, Germany) to record the location (GPS) and activity (accelerometer) of takin. Tags were custom made and weighed 950g which is less than 0.03% of the animal's average body weight. The collars recorded location, altitude, date, time and acceleration. To help locate collared takins, collars were programmed to ping once every 2 seconds for 1.5 hours every day. The tags deployed in 2013 and 2014 were programmed to take a GPS reading every 15 minutes and acceleration every second. Given the battery limitation and storage capacity issues, tags in 2015 were re-programmed to take a GPS reading every 15 minutes and acceleration every two minutes. To optimize the battery performance, tags were further programmed to search for satellites for a maximum of 150 seconds; if this search time was exceeded without locating satellites, the animal was deemed to be 'missing' and no GPS data were recorded for that spatio-temporal location.

Data were stored on board the collar and retrieved using a base station wherein the unit auto-triggered and read the stored data if the collared animal was in close proximity (i.e. <500 m). Data were downloaded from collared animals at the summer habitat when the animals congregated to drink at the natural hot spring in the valley, because this locality represented a reliable location at which to wirelessly connect to each collar and download the data stream. However, when takin did not visit the hot spring for more than a week, we scanned all possible known areas that takins were known to inhabit to download collar data.

Downloaded data were put through a decoder (a program to decode and extract data) or uploaded to a web-based data file manipulator at www.movebank.org. In both cases, data were extracted into a standard, useable data format. The point location data generated by the collared animals was processed using a custom written program in Visual Basic 6.0 'Animal Movement7'

(Microsoft Corp.) (Kortner, 2016). This program computes the size of the minimum convex polygon (MCP) and 95% MCPs following the removal of 5% outliers around the harmonic mean (Hooge & Eichenlaub, 1997), and calculates the daily range. In the R environment,the day and night was calculated and the lateral distance displaced between them using R packages such as 'RAtmosphere' (Biavati, 2014); 'xlsx' (Dragulescu, 2014); 'chron' (James & Hornik, 2017); 'rgdal' (Bivand et al., 2017).

4.3.4. Statistical analyses

Data were tested for normality and skewness using Shapiro-Wilks and Anderson-Darling normality tests in R ver. 3.4.2 (R Core Team 2017) to determine data distribution. Then, data were either analysed using paired or unpaired *t*-tests. Home range and associated analyses were done using the R package 'adehabitatHR' (Calenge, 2015). Within this package, the minimum convex polygon (MCP) and kernel utilization distribution (KUD) was used to estimate home ranges from locational data. These two models (MCP and KUD) are the most widely used animal home range estimation methods and they fulfill recommendations highlighted by Laver & Kelly (2008). In the case of utilization distribution (UD), home range was determined as the minimum area on which the probability to relocate the animal is equal to a specified value. Both home ranges were estimated at a 5% increment of relocations of the animal.

4.4. Results

4.4.1. Summary

We collared 13 animals over two full years (June 2013 - July 2015), during which, two animals were collared in the winter (forest) habitat and eleven animals were collared in the summer (alpine) habitat. Of these eleven animals, six were males and five were females. However, five

of these collared takins were excluded from the analysis because they were tracked for less than a week, and thus deemed to have insufficient data for further analyses. The success rate for GPS fixes was better in the summer habitat (range = 68% - 93%; mean = 85%) than the winter habitat where approximately 20% of GPS fixes could be obtained. The analysis is based on six of these animals for detailed movement analyses (Table 4.2). The results presented includes daily movement and migration distance, day and night movement, daily range and home range, altitudinal range, GPS fixes in different habitats, and activity patterns.

Table 4. 2 GPS fixes obtained from collared takin in their summer and winter habitat in Jigme Dorji National Park, Bhutan.

Tag ID	Collar Date	Last Location Date	# Days	GPS (15 mins)		Total	%
				Obtained	Missed		
TM2724	08-07-2013	27-09-2013	81	6989	549	7538	93
TM2886	09-07-2015	27-07-2015	18	1440	259	1699	85
TM2894	08-07-2013	29-07-2013	21	1719	321	2040	84
TF2891	12-07-2015	25-07-2015	13	1113	137	1249	89
TF2899	06-07-2015	27-07-2015	21	1819	133	1952	93
TF2940	13-07-2015	22-07-2015	9	589	274	863	68
TM2898*	09-04-2014	13-03-2015	72	1267	5178	6445	20

*animal collared at the winter habitat

4.4.2. Linear movements

In the summer habitat, takin moved a mean daily (24-hour period) distance of 4 ± 0.213 km (SE) (range: 1.3-10.3 km). There was no significant difference between the daily movement distances of female and male takin $t_{(124.39)} = -1.49$, $p = > 0.1$), and as such, daily movement data were

pooled between gender. However, approximately a third of takin daily movement occurred at night, but the distance covered in the day (0600 hrs – 1800 hrs) was significantly greater than the night (1801 hrs - 0559 hrs; $t_{(263.69)} = 5.90$, $p < 0.001$). Similarly, in the winter habitat and based on records from one collared individual, takin TM2898 travelled a daily distance of between 131 m and 4887 m, and about 13% to 28% of the distance travelled was during the night. In the summer habitat, the 'Movement' program also calculated individual distance between all GPS points from collared takins and found that the linear distance between the farthest GPS points were 5 km apart. This animal movement trajectory from the location data was subsequently plotted on a weekly basis to assess habitat use for analysis at multiple spatial and temporal scales but the Figure 4.2 below shows the takin TM2724's habitation on a weekly basis.

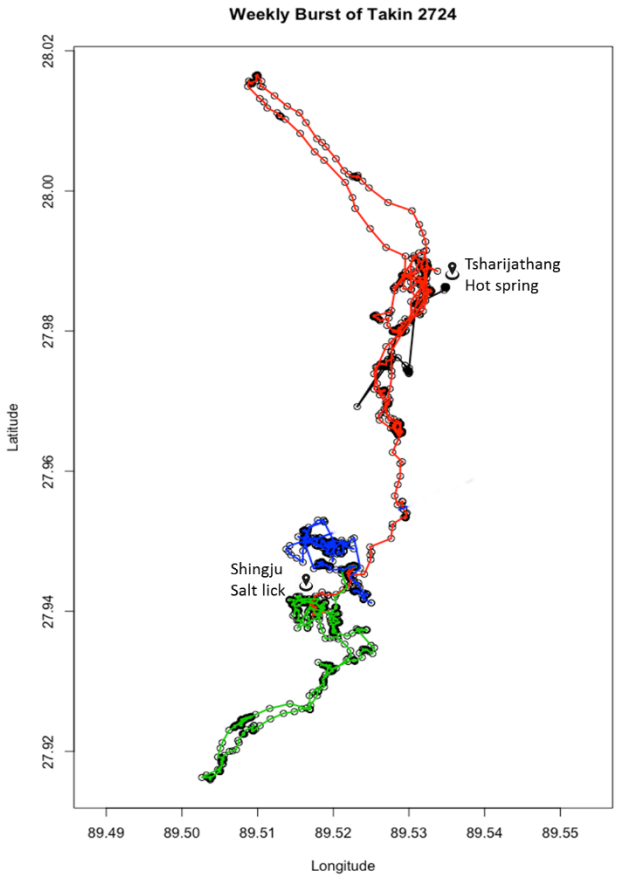

Figure 4.2 Weekly locational plots of a male takin (TM2724) showing its spatial and temporal movement in its summer habitat at Tsharijathang, Jigme Dorji National Park, Bhutan. The different colorations of movement trajectory show the animal's habitat use on different weeks (weekly burst).

There was no significant difference between the movement speeds of males and females $t_{(0.78)}$ = -1.34, $p > 0.1$). The mean movement speeds of takin = 0.4 ± 0.06 km/h (SE) and ranged from 0 – 22.6 km/h (Figure 4.3) but more than 75% of movement speeds are < 0.25 km/h.

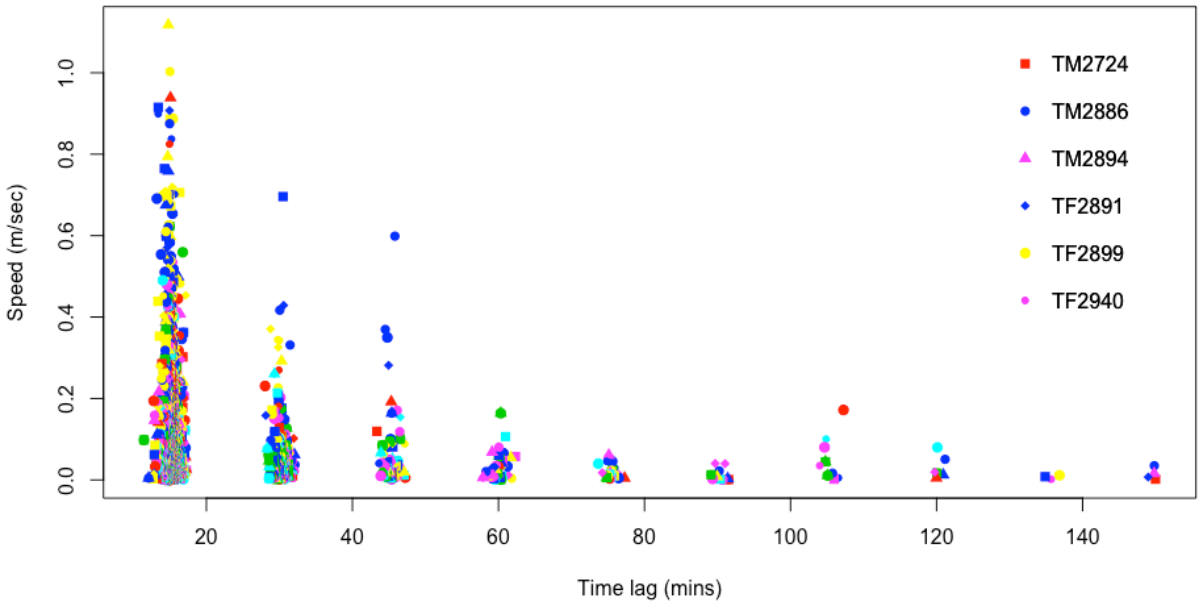

Figure 4.3 Movement speeds and time lag of collared takin recorded after every 15 minutes in their summer habitat in Tsharijathang, Jigme Dorji National Park, Bhutan.

4.4.3. Daily range and home range

The daily range of takin in the summer habitat was small, averaging 54 ± 7 ha (SE) (range = 0.2 ha - 488.7 ha) (Figure 4.4). About 87% of daily range sizes were less than 100 ha and only 5% were greater than 200 ha. There was no significant difference in daily range size between male and female takin $t_{(102)}$ = -1.42, $p > 0.1$).

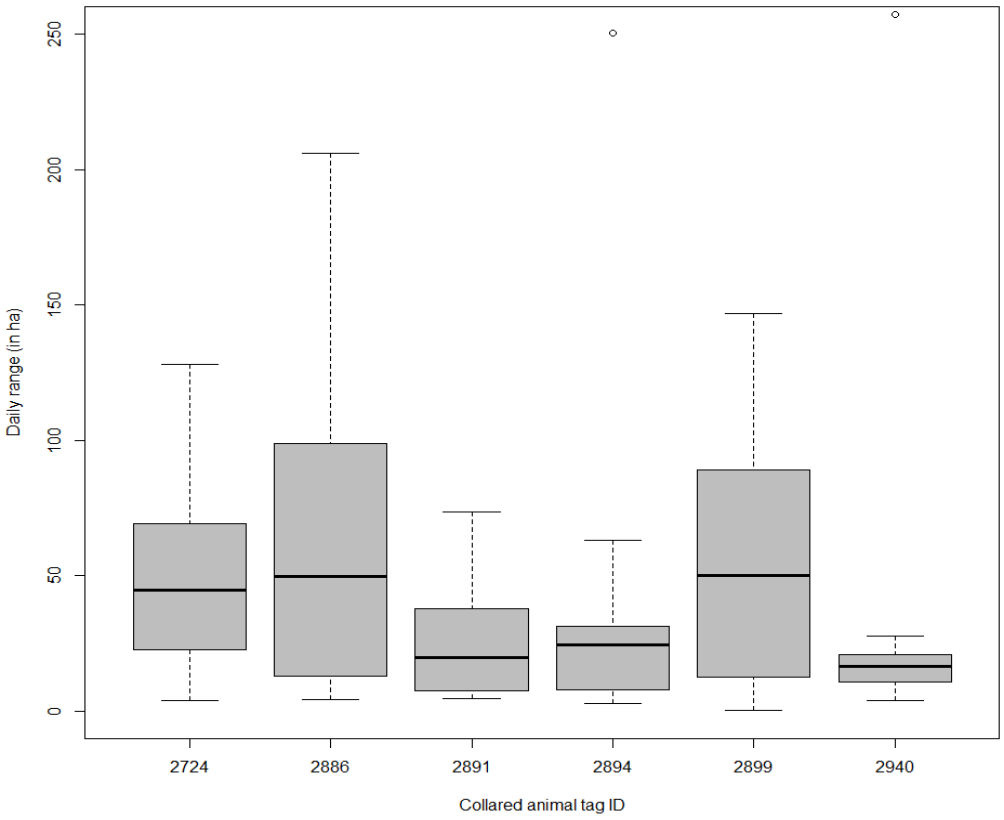

Figure 4.4 Box plot showing a takin's daily summer range in Jigme Dorji National Park, Bhutan.

The minimum number of GPS locations required to generate a home range estimate was assessed using a bootstrapping method. This exercise was performed with 150 iterations which resulted in requiring about 400 GPS locations to generate a summer home range (Figure 4.5).

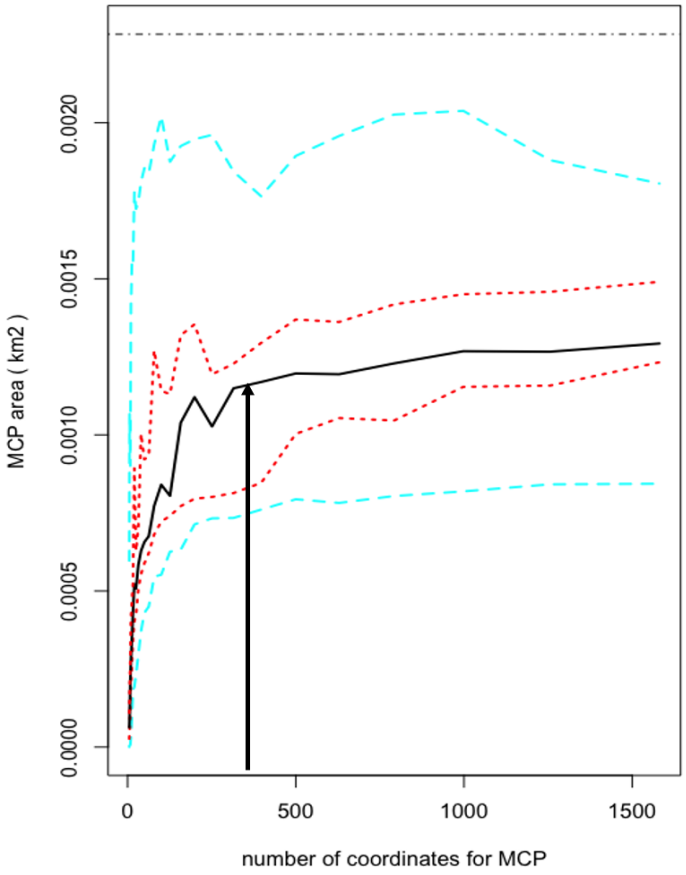

Figure 4.5 GPS locations of takin in their summer habitat bootstrapped with 150 iterations to estimate minimum GPS locations to generate a meaningful MCP home range.

Based on fulfilling the requirement of a minimum of 400 GPS locations, home ranges of six takin (Table 4.3) were estimated using minimum convex polygon and kernel utilization distribution at increments of 5% isopleths, from 5% to 95%. The 95% MCP home ranges for male takin averaged 11.5 ± 1.4 km^2 (SE); (range = 9.56 – 14.21 km^2). The 95% MCP home ranges for female takin averaged 6.4 ± 1.7 km^2 (SE); (range = 3.35 – 9.25 km^2) (Table 4.3). The 95% home range estimation using Kernel utilization distribution for males averaged 18.7 ± 4.3 km^2 (SE); (range = 13.86 – 27.40 km^2) and for females, it averaged 10.6 ± 1.8 km^2 (SE); (range = 7.55 to 13.87 km^2) (Table 4.4).

Table 4.3 Home ranges estimated from GPS locations of collared takin occurrence in their summer habitat using minimum convex polygon (MCP). Note: TF2891 is a takin female with an associated tag number while TM is a takin male; *n* = total GPS fixes; all home ranges are expressed in km^2 and isopleths are in increments of 5%.

Isopleth %	TF2891	TF2899	TF2940	TM2724	TM2886	TM2894
GPS	(*n*=1113)	(*n*=1819)	(*n*=589)	(*n*=1946)	(*n*=1440)	(*n*=1719)
5	0.12	0.06	0.01	0.14	0.01	0.16
10	0.21	0.19	0.03	0.16	0.14	0.29
15	0.46	0.31	0.05	0.21	0.20	0.39
20	0.60	0.74	0.08	0.84	0.46	0.49
25	0.61	1.00	0.09	1.00	0.97	0.55
30	0.91	1.40	0.09	1.30	1.51	0.62
35	1.25	1.67	0.10	2.24	2.10	0.75
40	1.51	1.75	0.11	2.46	2.23	0.84
45	1.94	2.73	0.15	2.67	2.50	0.98
50	2.84	4.00	0.22	3.06	3.55	1.24
55	3.01	4.28	0.50	3.69	3.86	1.57
60	3.65	4.29	1.43	4.00	3.93	2.31
65	3.71	4.38	1.61	4.91	4.00	2.58
70	3.79	4.57	1.83	5.08	4.06	2.75
75	4.41	6.50	2.15	6.80	4.44	5.55
80	5.02	7.65	2.28	7.92	6.58	6.24
85	5.41	8.47	2.42	8.66	7.84	7.52
90	5.62	8.84	2.50	8.92	8.59	10.07
95	6.43	9.25	3.35	14.21	9.56	10.72

Table 4.4 Home ranges estimated from GPS locations of collared takin occurrence in their summer habitat using Kernel utilization density. Note: TF2891 is a takin female with an associated tag number while TM is a takin male; *n* = total GPS fixes; all home ranges are expressed in km^2 and isopleths are in increments of 5%.

Isopleth %	TF2891	TF2899	TF2940	TM2724	TM2886	TM2894
GPS	(*n*=1113)	(*n*=1819)	(*n*=589)	(*n*=1946)	(*n*=1440)	(*n*=1719)
5	0.17	0.14	0	0	0.14	0
10	0.34	0.41	0.11	0.32	0.41	0.20
15	0.60	0.68	0.21	0.64	0.68	0.39
20	0.86	0.95	0.21	1.29	0.95	0.59
25	1.12	1.36	0.32	1.61	1.22	0.79
30	1.37	1.77	0.53	2.26	1.63	0.98
35	1.72	2.18	0.64	2.58	1.90	1.18
40	1.97	2.58	0.74	3.22	2.45	1.57
45	2.40	2.99	0.96	4.19	2.85	2.16
50	2.75	3.54	1.17	5.16	3.26	2.55
55	3.09	4.08	1.38	6.13	3.81	3.14
60	3.52	4.62	1.70	7.74	4.49	3.73
65	4.03	5.30	2.02	9.03	5.16	4.52
70	4.55	6.12	2.34	10.64	5.98	5.30
75	5.23	6.94	2.77	12.57	6.93	6.28
80	6.09	8.02	3.30	14.51	8.02	7.66
85	7.12	9.38	4.15	17.73	9.38	9.23
90	8.41	11.15	5.43	21.60	11.01	11.19
95	10.38	13.87	7.55	27.40	13.86	14.92

4.4.4. Altitudinal ranges and vertical movement

Migration of collared takins occurred between 1494 m and 5374 m (Figure 4.6). During summer, takin typically occupied an altitudinal range from 3633 m to 4425 m, although a lone male reached a height of 4986 m. The average altitude was 4137 ± 3.0 m (SE) for males and 3998 ± 3.2 m (SE) for females with a significant difference between gender $t\ (_{7344}) = -33.11$, $p < 0.001$). Since the study had only two collared animals, a male and a female from the winter habitat which resulted in the altitudinal range during their habitat in winter habitat. They have inhabited between 1494 and 2537 m.

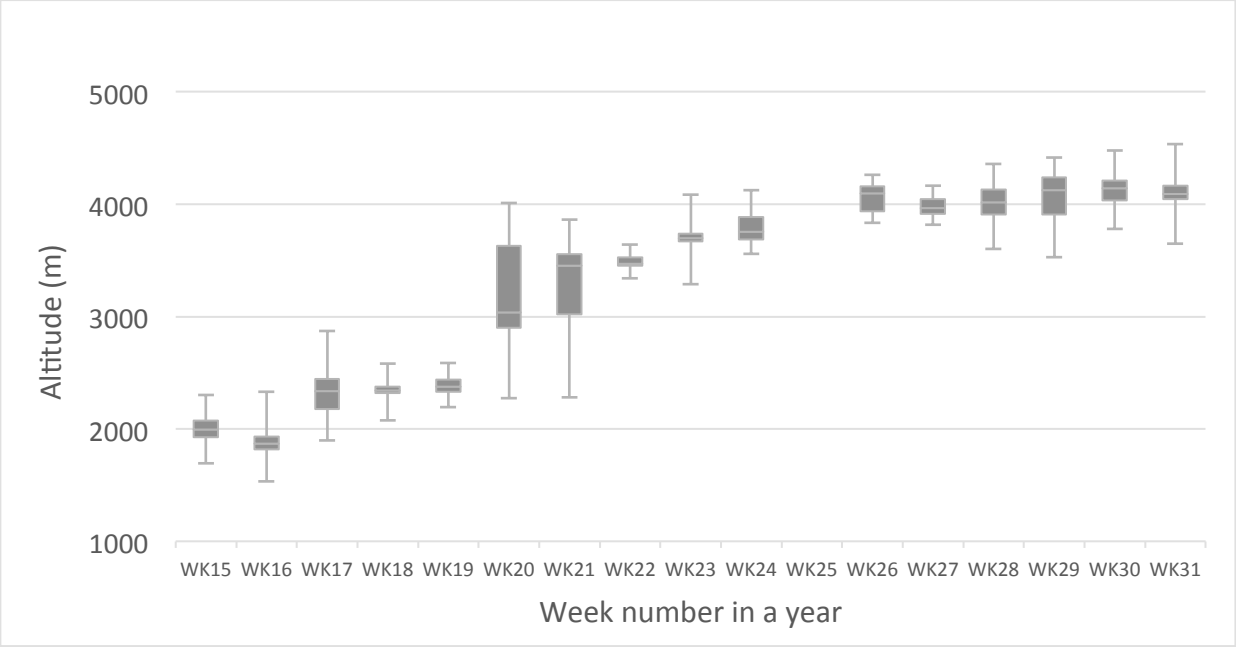

Figure 4.6 Boxplot showing altitudinal range of collared takins at their summer habitat in Jigme Dorji National Park, Bhutan. Note: WK15 is the week number 15 (i.e. from 9th April to 15 April).

4.4.5. Takin's activity pattern in the JDNP

Taking movement speed as a proxy for takin activity, takin activity in their summer range peaked in the morning from 5 am till midday, followed by several hours of rest until 4 pm when activity increased again until 7 pm (Figure 4.7). There was no significant difference in the pattern of activity between male and female takin in their summer habitat (*t*-test: $t_{(45.3)} = -0.82$, $p > 0.5$).

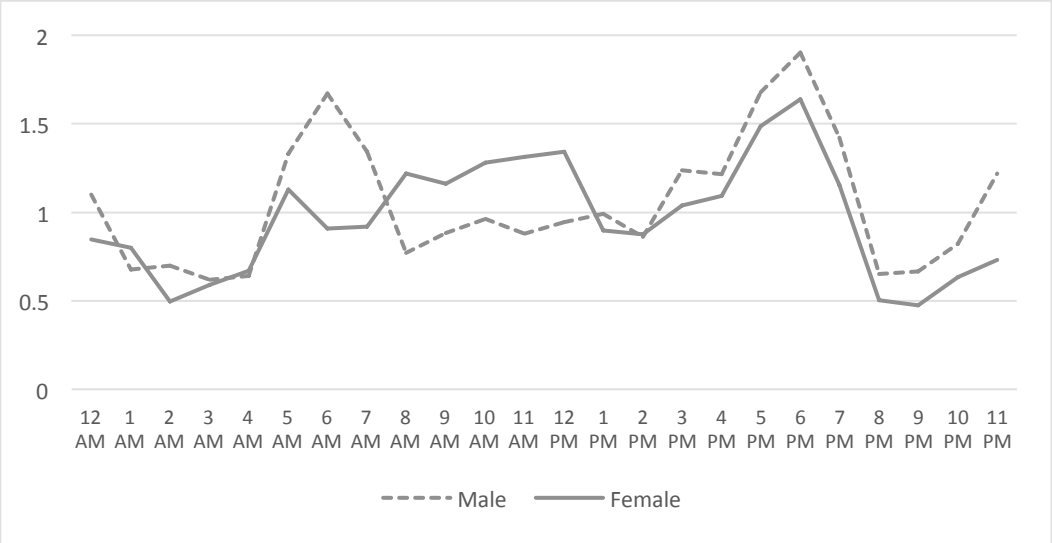

Figure 4.7 A comparison between male and female activity generated using movement speed as proxy of an activity.

4.5. Discussion

4.5.1. Takin movement characteristics

We determined that takin at their summer habitat travelled, on average, about 4 km a day and about a third of the distances were covered during the night. This night movement were foraging visits to and from the mudflat which were possibly, the takin's adaptation to persistent disturbance at the mudflat from co-occurring diurnal domestic livestock such as yak, horses and dogs. This situation further reinforces the need to vacate livestock from the valley a month prior to takin's arrival as stipulated by Sangay et al. (2016). Takin travelled greater distances in the

summer habitat compared to winter habitat, a difference likely attributed to habitat characteristics. Summer habitat is in open alpine meadow enabling better ease of travel compared to the winter habitat in forested and steep, rugged, mountainous terrain. Longer daily movements in summer could be explained by takin regularly visiting hot springs (Wangchuk et al. 2015; Sangay et al. 2016) and optimising the benefit of abundant foraging resources (Dingle & Drake, 2007; Wang et al. 2010). Takin were also sighted near the salt lick at Shinju which is approximately 3.5 km southwest of the hot spring at Tsharijathang.

Our collared Bhutan takin summer home range (MCP = 8.92 ± 1.5 km^2; Kernel utilization distribution = 14.6 ± 2.7 km^2) was comparable to the Chinese Sichuan takin's summer home range of 1 - 15 km^2 (Guan et al., 2015). However, the Golden takin's summer home range estimated at 100% MCP in Qinling mountains was much larger at 32.4 ± 6.3 km^2 (Yan et al., 2017). Takin are sexually dimorphic, with males being 40% larger than females. Thus, it is not surprising that male home range are larger than females (Zeng et al., 2002; Yan et al., 2017). This difference can also be attributed to social grouping whereby females closely congregate with the herd while males exhibit greater independent travel away from the herd (Zeng et al., 2002). The work by Yan et al. (2017) on 10 Golden takins, however, did not show a difference between male and female home range. Additionally, all takin collared at the summer habitat in this study were active within a 5 km-long strip which corroborates the high overlap in distribution and habitat fidelity (Guan et al., 2015). For instance, TM2886 and TF2899 are clearly from the same herd, as these two animals occurred less than 100 m apart about 87% of time.

4.5.2. New insight on takin migration

My study uncovered new knowledge about takin migration and revealed the different habitats used by takin. For instance, a male takin (TM2724) gave the first partial glimpse of takin migration but unfortunately the collar ran out of memory on 27 September 2013. Its data showed that the animal began to migrate on 29th July and travelled 9 km on the first day, 3.7 km on the following day, and about 13.98 km on the third day in rugged mountainous terrain. The migration route undertaken by the TM2724 was completely different to the normal established route (Figure 4.8). This showcases the poor knowledge about takin migration because TM2724 migrated to a different area around Zomling, Lingshi, Barshong, and Naro of the Thimphu district (about 30 km from Tsharijathang) and not to Gasa as most local residents perceived. Furthermore, TM2724 migrated to the south-west, over a ridge line at 5007 – 5374 m which is a new finding. Similarly, a male TM2898 migrated from its winter habitat to summer habitat and went northeast possibly heading towards Wachey, Lunana but its collar ran out of memory mid-way near Laya Tashimakhang on 16 June 2014. In both these cases, the collared animals' migration patterns were contrary to local knowledge. My work demonstrates that it is critical to gather long term movement data over several years to better understand takin migration in JDNP.

4.5.3. Takin vertical movement and habitat

Bhutan takin migration occurred from the lowest altitude of 1494 m to the highest altitude of 5374 m with a pronounced vertical movement of about 3880 m. Previously, the lowest recorded altitudinal range of takin was about 700 m and highest was 4273 m for the Mishmi takin (Mahar, et al., 2012; Sharma et al., 2015).

Bhutan takin have an advantage of accessing foraging resources in pronounced vertical altitude variations over different habitat types. As a result, the Bhutan takin does not face a shortage of

food resources despite grazing competition from domestic livestock (Gyamtsho, 2000; Chophyel, 2009; Wangchuk et al., 2015) compared to Chinese takins which were observed to be physically weak during the winter possibly due to a shortage of foraging resources (Schaller, 1985). The Bhutan takin is a social animal that lives in herds of 150-200 in its open summer habitat (Wangchuk et al. 2015) but disbands into smaller herds to optimize foraging strategies in the forested winter habitat.

Vegetation cover influences takin habitat use and selection as they seek cover or shade to rest and ruminate around midday (Wangchuk et al. 2015). For this reason, takin prefer to forage at the Tsharijathang hot spring in the summer habitat because it has nearby juniper woodland to provide cover during midday. Additionally, there is the fir and rhododendron scrub forest to the west of the hot spring. Such behavior in seeking vegetation cover obstructed the collars' satellite communication and subsequent GPS fixes.

4.5.4. Patterns of migration

When examining the available data on migration performed by two males, TM2724 from its summer range to its winter range and TM2898 from its winter range to its summer range, it was observed that their migration was straight forward in traversing the altitude, unlike records of meandering migration patterns observed on Golden takin species (Zeng et al. 2008). The differences between these two males' migration were: TM2724 migrated continuously from its summer habitat to its winter habitat for three days, covering about 33.7 km. On one instance, this male travelled over 5000 m (range 5007-5374 m) for five hours from 8.45 pm to 1.45 am. However, the other male takin (TM2898) migrated slowly to its summer habitat by taking frequent foraging breaks along its migration route.

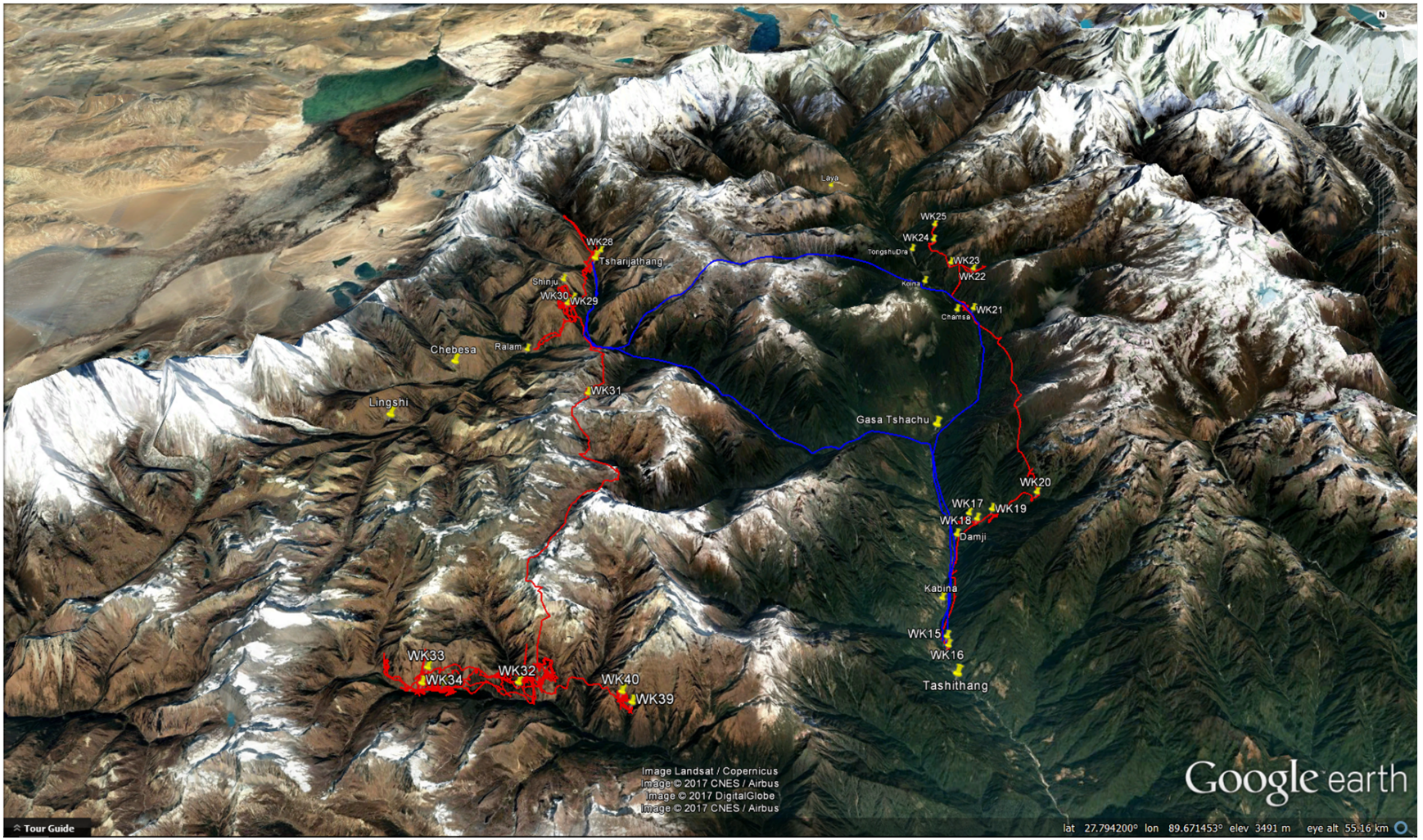

Figure 4.8 Map showing tracks of two collared takins (TM2724, red left; and TM2898, red right) and the local peoples' knowledge on takin migration routes in Jigme Dorji National Park, Bhutan. Yellow thumb tracks represent weekly tracks and some local places.

4.5.5. Data retrieval problem

The study was impeded by the inability to retrieve data from collared animals and presented results constitute the best available data given this limitation. This problem seems to have exacerbated from unaccounted animal behavior such as intraspecific fighting by head butting and threat displayed by rubbing their neck and nape on tree trunks or the ground (Walther, 1984). Such behaviour could have impacted the GPS collar that resulted in breaking external antenna. A broken antenna reduced a collar's effective communication range to less than a meter.

Furthermore, the data retrieval in the winter habitat and migration routes were extremely tedious and very difficult in the rugged steep terrain, as their wintering habitat and migration routes were not ascertained and varied considerably annually. Most of data download were done at the summer habitat when herds congregated. Of the 13 collared animals except for two males (TM2724 and TM2898) rest could not be re-tracked during their migration despite extensive search and thus data deficit.

4.6. Conclusion

Jigme Dorji National Park housed most of the takin population in Bhutan and the park's conservation programs should be aligned with takin conservation by its endemicity and status as the national animal. As such, the park should also take a firm decision to enforce the implementation of the tripartite agreement with resident livestock grazers and migratory yak grazers (Sangay et al., 2016), and gazette Tsharijathang Valley as a takin sanctuary to ensure uninterrupted passage of migrant takin and better foraging resources at their summer habitat. Such steps are critical for takin conservation to encourage them to continue established migration to the Tsharijathang Valley. Because the Tsharijathang takin population is a meta-population

made up by fusions of different herds and sub-populations from wintering habitats, there is a possibility that the different herds might not congregate at Tsharijathang if their foraging resources are impacted by anthropogenic disturbance. This would adversely impact vital genetic exchange which is a key to long-term takin conservation in Bhutan.

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STATEMENT OF ORIGINALITY

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STATEMENT OF AUTHOR'S CONTRIBUTION

We, the Research PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

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Chapter 5: Local knowledge and attitude towards the vulnerable Bhutan takin *Budorcas whitei* among residents living within its seasonal range.

A herd of takin in middle of Mochu river at Kabina (winter habitat), Jigme Dorji National Park, Bhutan.

5.1. Abstract

We assessed local knowledge of and attitudes towards a large, endemic bovid, the Bhutan takin *Budorcas whitei*, within its seasonal range in Jigme Dorji National Park, Bhutan. Using semi-structured questionnaires, data were collected in March 2015 from interviews with 169 Park residents. A conditional inference tree analysis was used to explore associations between demography, locality, and secondary response variables through questions relating to respondents' knowledge of the takin's status as a protected species, a Vulnerable species, and as the national animal. Most respondents knew the takin was Bhutan's national animal, and of those, a significantly high proportion also knew of its protected status. Significantly more respondents residing in the species' summer, rather than winter, range were aware of the takin's Vulnerable status. Most respondents expressed positive feelings towards the takin and supported its protection. This strong positive attitude in conjunction with awareness raising efforts, could be valuable for promoting the takin as a montane flagship species.

Keywords: Attitude, awareness, Bhutan, *Budorcas whitie*, conservation, Jigme Dorji National Park, perception, takin

5.2. Introduction

Bhutan lies within the Eastern Himalayan biodiversity hotspot (Myers et al., 2000) and supports a diverse mammal community comprising lowland Indo-Malayan species such as the tiger *Panthera tigris* and common leopard *Panthera pardus*, and upland Palaearctic fauna such as the snow leopard *Panthera uncia*, red panda *Ailurus fulgens*, and blue sheep *Pseudois nayaur*. Bhutan is also home to several endemic mammals, including Bhutan's national animal, the endemic Bhutan takin *Budorcas whitei* (Sangay et al., 2016). More than 80% of Bhutan's land area is naturally vegetated, with > 50% secured in a protected area network (Rajaratnam et al., 2016). Constitutionally mandated to maintain at least 60% of the total land area under native vegetation (RGoB, 2008), Bhutan is an integral conservation landscape in the Eastern Himalayan ecoregion (Olson & Dinerstein, 2002).

Bhutan is predominantly Buddhist, with religious tenets focusing strongly on interdependence between life forms (Brooks, 2010) and valuing the sanctity of life (Rajaratnam et al., 2016). Environmental protection is central to Buddhist philosophy (Zurick, 2006), shaping Bhutanese attitudes towards, and perceptions of, nature. Environmental protection underpins many cultural and religious festivals, reinforcing the value of nature to the Bhutanese people (Pommaret, 2006). More recently, local media has promoted a positive attitude towards nature, reinforcing traditional Bhutanese attitudes and perceptions (Rapten, 2001; Lhamo & Oyama, 2015).

Bhutan's rural populace are agropastoralists (Katel & Schmidt-Vogt, 2011) dependent on natural systems for fuelwood, fodder, water and other ecosystem services (Defries et al., 2010). Livestock and crop loss to wildlife can significantly affect the economic costs of living in a forested landscape rich in wildlife (Karanth et al., 2006; Sangay & Vernes, 2008, 2014). Such loss can lead to negative perceptions of nature and intolerance of wildlife (Oli et al., 1994;

Mishra, 1997; Sangay & Vernes, 2008, 2014) as demonstrated elsewhere, where wildlife consume crops (Gadd, 2005; de Pinho et al., 2014) and damage property (Rao et al., 2003). Although retaliatory killing of livestock predators and crop pests can be mitigated by compensation to affected farmers (Gadd, 2005; Sangay & Vernes, 2008, 2014; Karanth & Defries, 2010), wildlife conservation can succeed when accompanied by tangible benefits to rural communities (Kumssa & Bekele, 2014; Mamo, 2015). For example, Bhutan is a popular destination for tourists wanting to explore natural landscapes and the rich biodiversity within the country's protected areas, which are also key to conserving wildlife (TCB, 2016). Bhutanese rural communities benefit directly through porterage services, home stay lodges and sale of handicrafts. Understanding and shifting people's attitudes towards wildlife by advocating their positive contribution to livelihoods can enhance regional wildlife conservation (Mir et al., 2015).

The Bhutan takin is the national animal of Bhutan, yet poorly studied. It migrates seasonally between high altitude alpine meadows in summer and lower subtropical broadleaf forests during winter, coming into contact with agropastoralists engaged in activities such as collecting fuelwood and other forest products. There are, however, no reports of crop losses to takin throughout its range or any other negative interactions with people. Our study investigates knowledge, perception, and attitudes towards the Bhutan takin among the residents of Jigme Dorji National Park, a stronghold for the species. By addressing the human dimension of wildlife conservation, our study contributes towards a comprehensive conservation plan for the takin's long-term survival.

5.3. Methods

5.3.1. Study area

Our study was conducted in the 4,316 km^2 Jigme Dorji National Park in north-west Bhutan (Fig. 5.1). Habitat types and elevations range from subtropical warm broadleaf forest (1,000 – 2,300 m), evergreen oak forest (1,800 – 2,600 m), cool broadleaf forest (2,000 – 2,900 m), mixed conifer forest (2,700 – 3,200 m), fir forest (3,300 – 3,800 m), juniper/rhododendron forest (3,700 – 4,200 m) and alpine scrub (4,000 – 4,600 m) to snow covered rocky peaks up to 7,300 m in the north (FRMD, 2016). In addition to its rich biodiversity (Thinley & Tharchen, 2015), the Park protects the catchments of four major rivers: Pa Chu, Wang Chu, Mo Chu and Pho Chu.

5.3.2. Interviews

There is a resident population of c. 5,200 people in Jigme Dorji National Park, distributed across in 13 Geogs (sub-districts) within the five Dzongkhags (districts) of Gasa, Punakha, Wangdiphodrang, Thimphu and Paro (Thinley & Tharchen, 2015; Fig. 5.1). Our study focused on three Geogs (Laya, Khatey and Khamey) in the Gasa Dzongkhag that overlap with the distribution of the Bhutan takin. Laya's residents are nomadic yak herders in the high alpine meadows encompassing the takin's summer habitat. Khatey and Khamey encompass the takin's winter habitat, where residents are primarily agropastoralists. During our study the population of the three Geogs was 2,505 people in 428 households (Thinley & Tharchen, 2015). Semi-structured face-to-face interviews with 169 respondents (Annexure 2) were conducted in March 2015. In addition to obtaining demographic information, interviews also investigated knowledge and perceptions of, and attitudes towards, the takin.

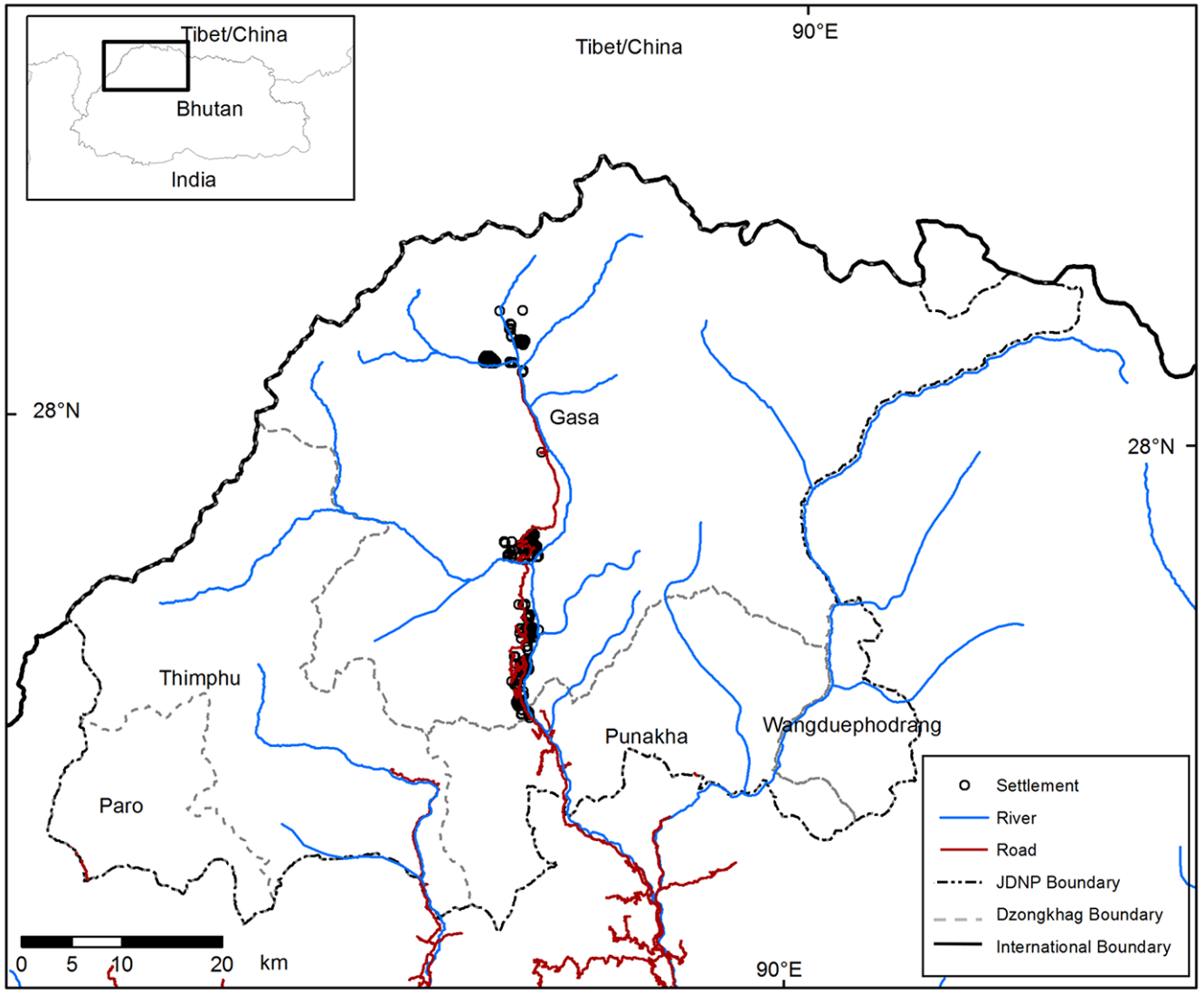

Figure 5.1 The study area and locations of interviewed villages in Jigme Dorji National Park, Bhutan

Interviews were approved by the University of New England's Human Ethics Committee (approval HE14-264). Respondents comprised farmers, yak herders and school children of which 91 (54%) were Laya residents and 78 (46%) were Khatey and Khamey residents. Most respondents were aged between 25 and 50 years (69%, n = 117). Youths (below 25 years of age) comprised 17% (n = 28) of respondents, and respondents >50 years of age comprised 14% (n = 24). Most respondents were subsistence farmers (83%, n = 130).

5.3.3. Data analysis

We analysed response data using *R 3.4.0* (R Development Core Team, 2017) focusing on conditional inference tree analysis using the *cTREE* function in package *party* (Hothorn et al., 2006). We analysed the responses to five questions: (1) Do you know that the takin is Bhutan's national animal? (2) Do you know that the takin is a Vulnerable species? (3) Are you aware that the takin is a protected species? (4) Do you like the takin from four choices as follows: a lot, a little, don't care, not at all? (5) Do you think the takin should be protected?

Responses (dependent variables) to each of the five questions were assessed for association with primary explanatory variables of locality (village and Geog) and demography (gender and age). With the exception of question 3, neither locality nor demography were identified as significant predictors. In these instances, the analyses were re-run using the respondent answers to the other four questions as potential predictor variables (e.g. was respondent's knowledge of takin as a Vulnerable species associated with knowledge of takin as Bhutan's national animal?). This was done to determine significant associations between respondent's knowledge and attitude toward takin.

We used the adjusted Bonferroni test (Hothorn et al., 2006) as the primary indicator of association strength, with $P < 0.05$ indicating significance. A conditional inference tree analysis compares an assigned dependent variable with explanatory variables in an iterative fashion to identify the explanatory variable with the most power (at $P < 0.05$), and a binary split of the data occurs within that variable to maximize explained variation. The process is then repeated for all subgroups by iterating across all potential explanatory variables. The end result is a hierarchical explanatory tree of pattern explained by variables and subgroups of variables (Hothorn et al., 2006). Results are represented graphically to show the hierarchical significance of variables and the final groups of response values following binary splits.

5.4. Results

Respondents comprised farmers, yak herders and school children of which 91 (54%) were Laya residents and 78 (46%) were Khatey and Khamey residents. Most respondents were 25 – 50 years of age (69%, $n = 117$). Youths (< 25 years of age) comprised 17% ($n = 28$) of respondents, and respondents > 50 years of age comprised 14% ($n = 24$). Most respondents were subsistence farmers (83%, $n = 130$).

5.4.1. Knowledge of the takin as Bhutan's national animal

Knowing that the takin is Bhutan's national animal was not significantly explained by demography and locality. When secondary explanatory variables were included, awareness was significantly associated with knowledge of the takin's protected status (Fig. 5.2), with 85%of respondents knowing the takin is protected. This group of respondents also included a high

percentage of respondents who knew the takin's status as the national animal. The 16 respondents who did not know the takin is protected did, however, know that it is the national animal.

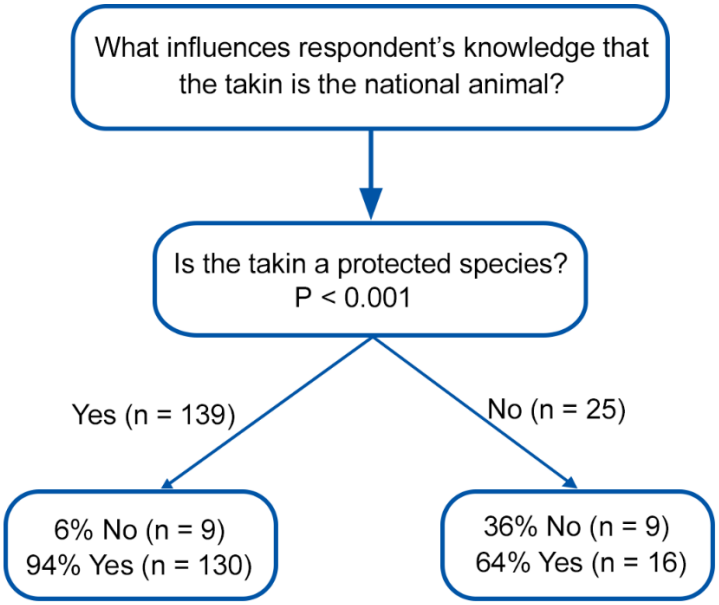

Figure 5.2 Conditional inference tree displaying significant explanatory variables for the questions 'What influences respondent's knowledge that the takin is the national animal?' 164 of 169 possible respondents answered. Respondent's knowledge of takin being a protected species was the only significant predictor.

5.4.2. Knowledge of the takin's vulnerable status

Locality (Geog) within the seasonal range of the takin was the only significant ($P < 0.05$) primary predictor of knowledge of the takin's Vulnerable status (Fig. 5.3). Of the interviewees who responded to this question, 61% from Laya in the takin's summer range knew the species to be Vulnerable compared to 39% from Khatey and Khamey in the takin's winter range.

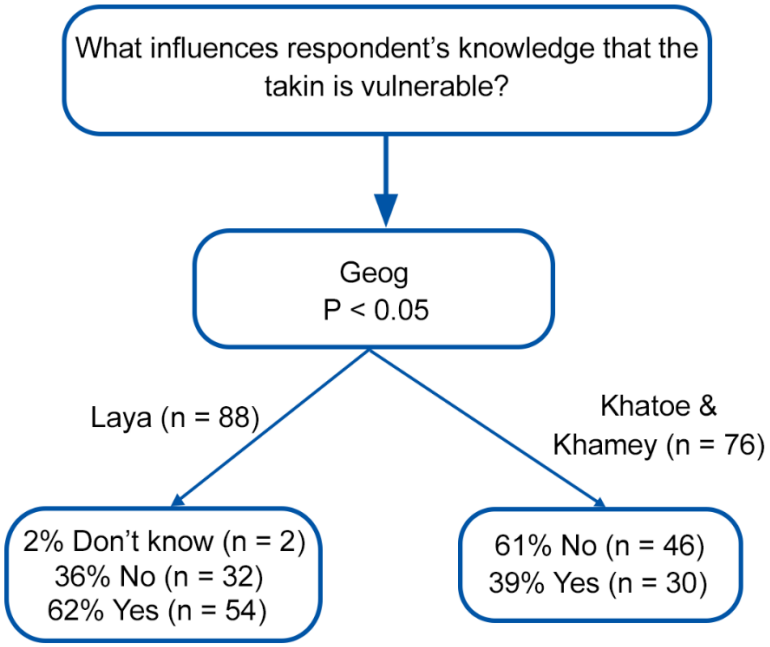

Figure 5.3 Conditional inference tree displaying significant explanatory variables for the question 'What influences respondent's knowledge that the takin is vulnerable?' 164 of 169 possible respondents answered. One of the significant explanatory variable (respondent's locality or 'Geog') and the grouping of responses are displayed.

5.4.3. Knowledge of the takin's protected status

Neither demography nor locality explained whether or not respondents knew the takin is protected. With inclusion of secondary explanatory variables, knowledge of the takin's protected status was significantly associated with awareness of Bhutan's Forest and Nature Conservation Act 1995 (Fig. 5.4). Seventy-six per cent of respondents were aware of this legislation, which corresponded to a high proportion of respondents who also knew the takin was protected (96% or 120 of 125 respondents who were aware of the legislation also knew the takin's protection status). Furthermore, 91% of the respondents who were aware of the legislation, also liked the takin 'a lot'. Of respondents who were unaware of the legislation, 49% nevertheless knew the takin is protected. Amongst those who were aware of the legislation, degree of fondness for the takin was significantly associated with knowledge of its protected status: 97% of respondents

who were aware of the legislation and liked the takin ‘a lot’ also knew of its protected status, compared with 82% of respondents who knew the legislation but liked the takin ‘a little’.

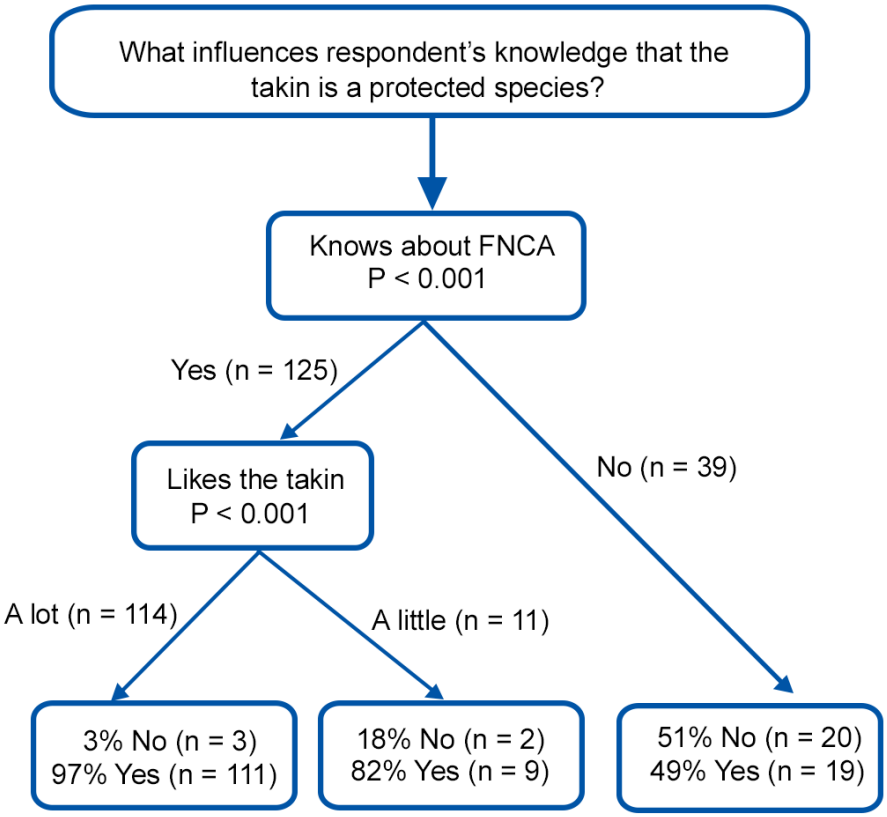

Figure 5.4 Conditional inference tree displaying significant explanatory variables for the question ‘What influences respondent’s knowledge that the takin is a protected species?’ 164 of 169 possible respondents answered. Two explanatory variables were significant (respondent’s knowledge of FNCA, and respondent’s fondness for takin).

5.4.4. Fondness for the takin

Fondness for the takin was not explained by demography or locality. Following inclusion of secondary explanatory variables, fondness was significantly associated with overwhelming support for its protection (95%, Fig. 5.5). However, 50% of respondents who did not support takin protection still liked the takin ‘a lot’. Of respondents who believed the takin should be protected most knew that it is the national animal and also liked the takin ‘a lot’.

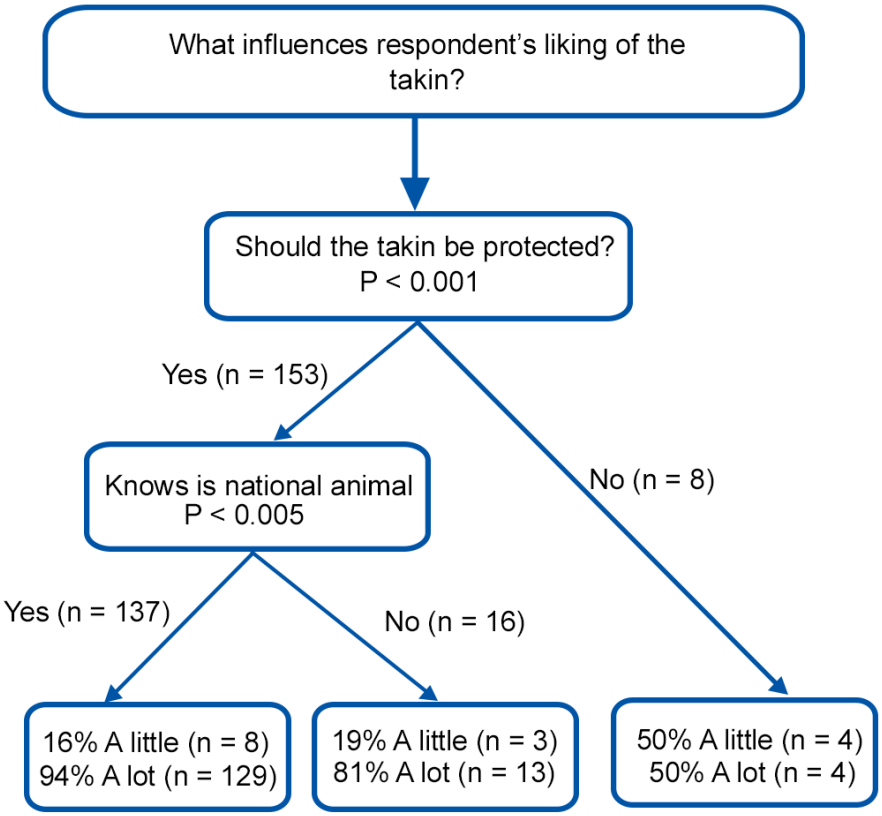

Figure 5.5 Conditional Inference tree displaying significant explanatory variables for the question 'What influences respondent's liking of the takin?' 161 of 169 possible respondents answered. Two explanatory variables were significant (respondent's attitude towards takin protection, and knowledge of takin as Bhutan's national animal).

5.4.5. Protection for the takin

Demography and locality did not have any significant association with whether respondents thought the takin should be protected. Following inclusion of secondary explanatory variables, support for takin protection was significantly associated with fondness for the species; 91% of respondents liked the takin 'a lot', of which most supported takin conservation (Fig. 5.6). However, of the few of respondents who liked the takin 'a little', only 73% supported protection. Ninety-six percent of respondents addressed the question of whether the takin should be protected. This cohort comprised residents who were willing to support takin conservation by

protecting takin and its habitat (16%; *n* = 27); being an informant on illegal activities (14%; *n* = 24); not harming and disturbing the takin (14%; *n* = 23); providing required assistance (9%; *n* = 16); contributing labour for takin conservation (8%; *n* = 13); and spreading awareness of the takin (7%; *n* = 12).

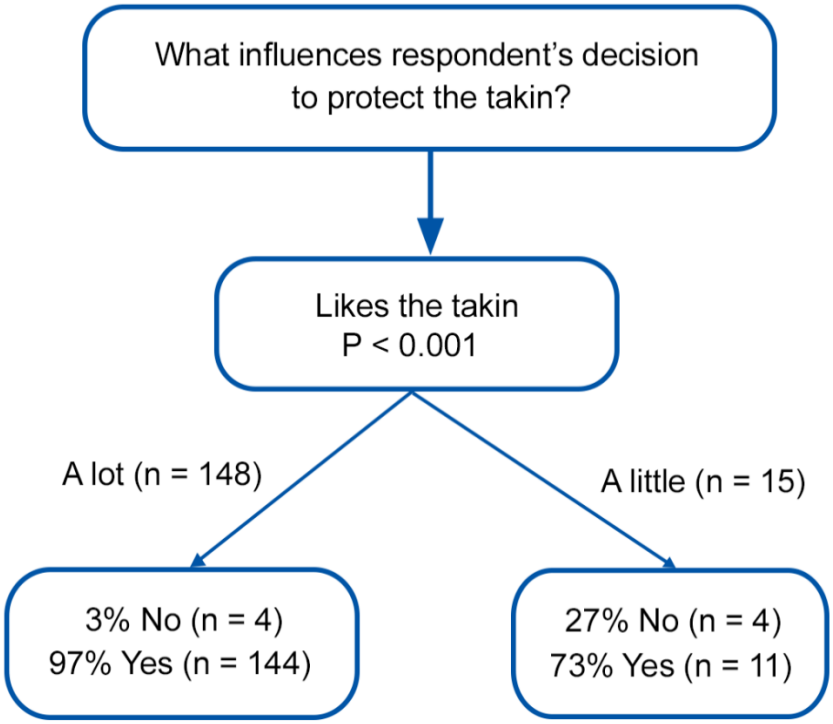

Figure 5.6 Conditional inference tree displaying significant explanatory variable for the question 'What influences respondent's decision to protect the takin?' 163 of 169 possible respondents answered. Respondent's fondness for the takin was the only significant predictor.

5.5. Discussion

The overall positive perception of the takin by residents of Jigme Dorji National Park could be attributed to the Buddhist religious ethos of respect for life and harmonious coexistence with nature (Brooks, 2010). Similarly, Hindus in India and Nepal share similar views by practicing

ahimsa, which equates to respecting all life forms (Sahni, 2008). Positive attitudes to snow leopards have been reported in other Himalayan Buddhist regions in Ladakh (Fox & Chundawat, 1988) and Spiti in Himachal Pradesh, India (Bagchi & Mishra, 2006). The Bhutan takin also has local religious and mythological significance that may enhance positive perceptions. Legend has it that the so-called Divine Madman Lam Drukpa Kuenley, a significant religious figure in Bhutan, combined the head of a goat with the body of a cow to create the takin (Downes, 2011), which led to the takin being chosen as Bhutan's national animal.

Awareness of the takin as the national animal was significantly linked to knowledge of its protected status, irrespective of where respondents lived. This can be attributed to conservation education awareness programmes and an agreement with the takin's summer habitat residents to not graze their domestic livestock one month prior to the arrival of migrating takin. Bhatia et al. (2017) suggested that conservation education and awareness can be best delivered by reference to the karmic cycle in predominantly Buddhist nations, as exemplified by the annual Takin Festival in Jigme Dorji National Park, at which residents are informed of the benefits of protecting takin habitat in its summer grazing alpine meadows at Tsharijathang. This also helps to facilitate sustainable collection of the highly prized cordyceps *Ophiocordyceps sinensis* fungus and other non-timber forest products (Mukhai et al., 2013; Wangchuk et al., 2013; Wangchuk & Wangdi, 2015). This additional socioeconomic benefit could possibly explain the overwhelming support for takin conservation amongst Park residents, in addition to the species' national status and religious significance. Positive perception of the takin by residents in the takin's winter range could be attributed to the fact that this species does not consume crops. The takin prefers forest for shelter (Sangay et al., 2016) and, moreover, agricultural fields are left fallow during winter.

Significantly higher awareness among residents in the takin's summer habitat compared to residents in the winter habitat could be attributed to socioeconomic activity that increases contact with congregating takin herds in the open alpine meadows. The lucrative cordyceps in these meadows are collected in the summer by Laya residents, who have become affluent from the associated trade (Wangchuk et al., 2013; Shrestha et al., 2017) and are able to afford televisions and smartphones (Lhamo & Oyama, 2015; MoIC, 2016; NSB, 2016), thus increasing exposure to conservation messages about the takin. Despite also having access to media, Khatey and Khamey residents are less exposed to takin in the dense broadleaved forested winter habitat, where takin herds fission into small groups that reduce chance encounters with residents collecting non-timber forest produce.

Regionally, the takin is threatened by deforestation, habitat fragmentation and hunting (Song et al., 2008; Dasgupta et al, 2010; Sangay et al., 2016). Despite positive perceptions towards the species, it remains Vulnerable (Song et al., 2008), facing threats from resource competition with domestic yaks, disturbance by free ranging dogs, habitat fragmentation, and indirect effects from cordyceps collection through the influx of people and animals (e.g. pack horses) that impact the fragile alpine meadow ecosystem and disrupting takin migration (Sangay et al., 2016). Yaks, horses and dogs further threaten the takin by potentially spreading zoonotic diseases in the summer habitat (Wangchuk et al., 2015).

Protected areas in developing countries are crucial for the provision of ecosystem services and also contribute to sustaining rural livelihoods by allowing activities such as livestock grazing and collection of forest products (Rajaratnam et al., 2016). The positive perception of the takin and its conservation by residents of Jigme Dorji National Park affirms acceptance of the species in an environment shared by people and wildlife. The park's periodic education and awareness

campaigns are key to consolidating this harmonious relationship and should be prioritized and supported in the current conservation management plan (Thinley & Tharchen, 2015).

The Bhutan takin could be a suitable montane flagship species for conservation, as it fulfils the 10 criteria for such species proposed by Bowen-Jones & Entwistle (2002).

(1) *Geographical distribution:* It is endemic to Bhutan and restricted to major river valleys and mineral hot springs in the north, with the main population centred in Jigme Dorji National Park (Sangay et al., 2016).

(2) *Conservation status:* It is categorized as Vulnerable (Song et al., 2008) and is threatened by development activities, road construction, grazing competition with domestic livestock, and disturbance by free ranging domestic dogs (Sangay et al., 2016).

(3) *Ecological role:* Its browsing and grazing behaviour influences vegetation structure in both low altitude subtropical forests and high altitude alpine meadows (T. Sangay, unpubl. data).

(4) *Recognition:* It is officially recognized as the national animal.

(5) *Existing usage:* Its uniquely shaped head is officially used as the insignia for two national conservation agencies (the Wildlife Conservation Division and the Bhutan Trust Fund for Environmental Conservation).

(6) *Charisma:* It has charismatic appeal because of its unique and readily recognizable morphology that resembles the head of a goat on the body of a cow, and this study has demonstrated that the Bhutanese have a strong positive perception of the species.

(7) *Cultural significance:* It has entrenched cultural significance through religious and mythological folklore (Downes, 2011).

(8) *Positive associations:* It embodies significant pride as the national animal and draws positive attention from foreign tourists through replication on memorabilia such as stickers, fridge magnets and figurines.

(9) *Traditional knowledge:* It is readily recognized by rural residents in both its winter and summer ranges, with significant knowledge enhancement through the periodic takin festival in Jigme Dorji National Park, and promotion of local knowledge of takin in urban areas through regular features on television and in newspapers.

(10) *Common names:* Known as *Drong Gyem Tse* in Dzongkha, the language of Bhutan.

In summary, the endemic Bhutan takin is endorsed as the national animal and locally recognized. It is Vulnerable, morphologically charismatic, and influences forest structure through its feeding behaviour. Prominent national conservation agencies utilize this species as a logo and its strong cultural significance enhances positive perceptions by rural residents within its narrow geographical range. We propose that the Bhutan takin be used as a flagship species to promote montane conservation in Bhutan, with stewardship provided by residents of protected areas.

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Chapter 6 Synthesis and Conclusion

6.1. Introduction

Large herbivores in most developing countries are threatened with population decline and range contractions through land use change such as habitat degradation, human encroachment, and resource competition from domestic livestock (Ripple et al., 2015). Human population growth and road construction have also added environmental pressure on forests during rapid economic development (Dukpa et al., 2018) and the Bhutan takin's *Budorcas whitei* habitat is no exception. Jigme Dorji National Park in Bhutan has the largest takin population in the country (Thinley & Tharchen, 2015) and is well protected. However, infrastructure development called for by communities in the Park is fragmenting the resident takin population into smaller herds, leading to their scattered distribution. For instance, progressive road access has increased the extraction of both timber and non-timber forest products and disrupted potential takin habitat and migration routes at several sites.

Movement and Habitat Use

As outlined earlier, there has been only one study by Wangchuk et al. (2015) that documented the diet selection of the Bhutan takin at its summer habitat in Jigme Dorji National Park. As such, any information on the Bhutan takin is new knowledge about this unknown species, which will assist its management and conservation.

Takin movements were assessed using fine resolution movement data and analysed at multiple spatial and temporal scales which showed a strong site fidelity and habitat overlap in the summer habitat (Guan et al., 2015). Such site fidelity and habitat overlap resulted in relatively small home ranges within 3.35 – 14.21 km^2 in the summer habitat. These indices are critical for better management of the Bhutan takin's summer habitat.

Bhutan takins have benefited from their wide altitudinal range and the associated large vertical movement (annual migration) encountered across differing forest types. Such vertical movements have facilitated the success in finding adequate foraging resources due to increased food availability (Zeng et al., 2001). Contrastingly, takins in China are reported to have starved and appeared weak during winter months when most habitats are covered with snow (Schaller et al., 1986; Yuan et al., 1990) with limited vertical movement for them.

My research has also discovered new takin wintering habitat areas (Zomling, Barshong and Naro) around the Thimphu and Paro areas. Another discovery is of a male's winter migration route which initially took it higher along ridgelines at about 5000 to 5374 m in the late evening through to midnight, before progressing to lower winter altitudes. This is a unique behavior which needs more investigation spanning over multiple seasons and years to ascertain the possible reasons behind this behavior.

The floristic composition in the takin's summer and winter habitat was assessed and examined in used and unused plots which revealed significant differences in terms of vegetation composition. In the summer habitat, plots used by takin had more trees which the animals used as cover to rest during the hot midday. While there were fewer herbs relative to unused plots, shrubs were however, more diverse in used plots which possibly offer greater food availability as takin are

primarily browsers (Schaller et al., 1986; Wangchuk et al., 2015). Overall floristic characteristics are also influenced by abiotic factors such as aspect, altitude, latitude, precipitation, terrain and temperature (Xu et al., 2017), which contributed to differences in tree, shrub and herb composition in the summer and winter habitats.

Local peoples' perception and knowledge on takin was assessed and found to be very promising due to a long-term education and awareness program implemented by Jigme Dorji National Park authorities. Furthermore, most park residents were aware of the benefits of conservation efforts namely through the sustainable harvesting of Cordyceps, the most valuable and lucrative natural resource in the Park (Wangchuk & Wangdi, 2015; Shrestha et al., 2017). Local people were willing to contribute to a takin conservation program which is a positive indication of their stewardship.

Spatially, the takin has a strong inclination and preference for minerals and salt licks. Animals are mostly distributed in areas where there are either hot springs or salt licks in the river valleys (Ali & Santapau, 1959; Neas & Hoffmann, 1987; Zeng & Song, 1998; Smith & Xie, 2008; Sharma et al., 2015) which have been verified by locality records from this study that confirm takin concentrations around the Tsharijathang hot springs and salt licks of the Shingju area in Jigme Dorji National Park.

Current takin sightings across the country indicate a scattered distribution (Wangchuk, 2011; Dhendup & Tempa, 2016). This suggests that takin are seeking new potential habitat when threatened by infrastructure development such as road construction and the erection of power transmission infrastructure in established habitats. Local people in Jigme Dorji National Park

have also intensified their harvest of both timber and non-timber forest products, especially the collection of the lucrative Cordyceps fungus and juniper for incense.

Management and policy recommendations

The takin is the national animal of Bhutan thereby warranting the utmost priority for its management and conservation. For this purpose, the Jigme Dorji National Park management should reinforce the implementation of the tripartite Tsharijathang Agreement (Wangchuk et al., 2015; Sangay et al., 2016) whereby domestic livestock are not grazed at Tsharijathang one month prior to the arrival of migrating takin. Currently one of the main disturbances in the area that impacts migrating takin are domestic livestock such as yaks and horses which compete for foraging resources with occasional disturbance from dogs and people. Additionally, an establishment of a satellite office at Tsharijathang would facilitate monitoring of anthropogenic disturbance during the takin's occupation in the summer (Sangay et al., 2016).

The Bhutan takin and domestic livestock share the landscape both at the summer and winter habitats and there is an added risk of disease cross transmission between the species (Shackleton, 1997; Wangchuk et al., 2015). There is, therefore, a need to establish a surveillance team equipped and trained to mitigate any outbreaks of zoonoses disease. Furthermore, an education initiative to local grazers on better animal husbandry practices to prevent such outbreaks is also needed (Sangay & Vernes, 2008; Sangay et al., 2016).

Chapter 5 outlined the importance of education and awareness programs for the Park residents, supplemented by the traditional religious ethos which promotes harmonious co-existence to garner greater community support towards conservation efforts. Conservation education and

awareness programs should also promote sustainable utilization of natural resources (e.g. sustainable Cordyceps harvesting) which offer socioeconomic benefits for park residents. These education and awareness programs should be implemented every year to raise and maintain community awareness and community support (Thinley & Tharchen, 2015).

6.2. Future directions

Based on a historically limited knowledge on takin migration and associated movement ecology combined with limited rigorous data from my research, I suggest the following future research initiatives which will potentially further the work presented in this thesis. These future directions fall within three areas: (1) Movement Ecology, (2) Disease Ecology, and (3) Population Ecology.

Movement Ecology

My study's potential was compromised by damage to GPS collars because tagged animals tended to rub their neck region and head butt during fighting, to establish conspecific dominance which then led to the breakage of external antennae. Such breakage compromised the collars' potential capability to communicate with the downloading base station from 500 to 1000 m away, to less than a meter away. Locating collared animals was also very difficult without ascertaining their exact winter migration routes. These constraints hindered the main study objective to reliably document the movement of takin. As such, future research into takin movement ecology must be maintained over a long-term timeframe to acquire multi seasonal data. Such research efforts must employ the use of sturdier GPS and/or satellite collars which can withstand the impact from the rubbing and head-butting behavior of takin.

Disease Ecology

A serious threat to the long-term viability of takin populations in JDNP is the zoonotic disease such as *Brucellosis* sp. (Luo et al., 2012), *Cryptosporidium spp., Giardia intestinalis* and *Enterocytozoon bieneusi* (Zhao et al., 2015) which usually infect a range of domestic ungulate livestock such as cows *Bos indicus*, yaks *Bos grunniens*, sheep *Ovis aries*, goats *Capra hircus*, and horses *Equus caballus* which share the Tsharijathang landscape with takin. Livestock can act as reservoirs of these diseases and represent viable transmitters of diseases to wild takin (NBC, 2008; Tenzin et al., 2013; Dahal et al., 2013, DoL, 2017). The prevalence of such diseases in the area further endangers other wild sympatric ungulates such as blue sheep *Pseudois nayaur*, goral *Naemorhedus goral*, barking deer *Muntiacus muntjak*, sambar *Rusa unicolor*, and wild boars *Sus scrofa* (Wiethoelter et al., 2015; Cunningham et al., 2017). Additionally, the takin as a migratory species has a greater probability of exposure to the zoonoses diseases while migrating between summer and winter habitats through a landscape prevalent with domestic livestock. Therefore, the spatio-temporal mapping of zoonoses disease hotspots is recommended as a critical measure to better prepare for a possible disease outbreak through pre-intervention strategies (Sangay et al., 2016).

Population Ecology

A genetically based demographic study on the takin population in its stronghold of Jigme Dorji National Park is also needed, given potential inbreeding pressure from fragmented sub-populations. Such information would significantly contribute towards the preparation of a holistic species conservation and management action plan for the takin population in the park and ultimately secure the long-term survival of this iconic national animal.

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Annexure 1: Vegetation Survey Formats

Date:

GPS Reading:

Strata (Eco-type):

Plot No:

Altitude:

Slope (in °):

Aspect:

Soil Type:

Estimated Canopy Cover %:

Mid-storey Cover %

Ground Vegetation Cover %:

Bare Soil Cover %:

Litter Cover %:

Fallen/Dead Trees Cover %:

Moss Cover %

Tree Layer: (>10cm dbh)

Location/ Nearest village

Geog Name

Species	Dbh	Height	Condition	No. of Epiphytes	Remarks

Tree Layer: (>1metre Height & < 10cm dbh)

Species	Dbh	Height	Condition	No. of Epiphytes	Remarks

Regeneration:

Recruit (<5cm height)

Species	Number	Remarks

Seedlings (>5cm and <=1m height)

Species	Number	Remarks

Shrubs:

Species	Height	Cover %	Remarks

Understorey:

Species	Type	% Cover	Distribution	Age Composition	Height (cm)	Remarks

Type:
M: Moss; L: Lichen; H: Herbs; O: Others

Age Composition:
1: Only first year recruitments (seedlings)
2: Mixed - old and young plants

Height:
Note average height considering small, medium and tall plants

Epiphytes & Others:

Species	Host Species	% Cover	Remarks

Species of Concern:

Species:

% Cover:

Distribution Pattern:

% Age Structure:
Seedlings:
Juvenile:
Mature:

Phenology:

Species:

% Cover:

Distribution Pattern:

% Age Structure:
Seedlings:
Juvenile:
Mature:

Phenology:

Species:

% Cover:

Distribution Pattern:

% Age Structure:
Seedlings:
Juvenile:
Mature:

Phenology:

Species:

% Cover:

Distribution Pattern:

% Age Structure:
Seedlings:
Juvenile:
Mature:

Phenology:

Distribution Pattern:

 Unifrom  Patchy Sporadic

Disturbance Indicators:

Grazing: ☐ Fire: ☐ Human Influence: ☐

Dung: ☐

Cows sighting: ☐

Thinning: ☐ Lopping: ☐

Harvesting: ☐ Pruning: ☐

Cut Grass: ☐ Footprints: ☐

Ecosystem Health:

Pests and Diseases: ☐ Soil Erosion: ☐ Land Slides: ☐

General Remarks on the Plot:

Notes:
1) Grazing, fire and Human Influence to be noted as ‘1’ for presence and ‘0’ for absence
2) Other indicators to be noted as ‘1’ for presence and ‘0’ for absence
3) In the ecosystem health; note only presence and absence (code as ‘1’ and ‘0’)

Annexure 2: Takin Questionnaire Survey

		Date	
Name of Interviewer		Name of Interviewee	
Range		Village	
Division/Park		Geog/Dzongkhag	
Altitude		Education (Year)	

1. PEOPLE'S PERCEPTIONS

1.1. Do you know that the takin is the national animal of Bhutan? *(Tick)*
Yes No

1.2. Do you like the takin? *(Tick)*
A lot A Little Don't Care Not Much Not at all

1.3. Should the takin be protected? *(Tick)*
Yes No

1.4. Do you know about the Forest and Nature Conservation Act 1995? *(Tick)*
Yes No

1.5. Are you aware that takin is a protected species by the 1995Act? (*Tick*)
Yes No

1.6. Will you be able to support a takin conservation program in your area in future? *(Tick)*
Yes No

1.7. If so, how would you support this program? (Please state your action)

1.8. Are takin endangered in their habitat? *(Tick)*
Yes No

1.9. If yes, how are they endangered (reason)?

1.10. Are you aware of the agreement that was drawn up to not allow any disturbance (be it livestock or human) in the takin habitat during summer? *(Tick)*

Yes No

1.11. If yes, who told you about it?

2. SOCIO-ECONOMIC STATUS

2.1. In your community, has the living standard increased compared to 10 years ago? *(Tick)*

Yes No Not Sure Don't Know

2.2. If yes, has that translated into procurement of the following: *(Tick)*

Vehicle	Power Chainsaw	More yak/cattle	Build a better home

Others (specify in column below)

2.3. What kinds of fuel do your household use for cooking purposes? *(Tick)*

Firewood	LPG	Pressurized Stove	Dung

Others (specify in column below)

2.4. Any comments that are not covered in earlier questions?

THANK YOU FOR YOUR KIND COOPERATION

Annexure 3: Research Team Members

Sl.No.	Name	Role	Institution	2012	2013	2014	2015
1	Sangay	Principal Investigator	UWICE	✓	✓	✓	✓
2	Ugyen	Research Assistant	UWICE	✓			
3	Ugyen Tenzin	Research Assistant	UWICE	✓			
4	Sonam Penjor	Research Assistant	UWICE	✓			
5	Kuenzang Gyeltshen	Veterinarian	WCD	✓	✓	✓	✓
6	Chimi Dorji	Assistant Veterinarian	WCD	✓			
7	Tshewang Wangchuk	Consultant	Bhutan Foundation	✓			
8	Prof. Joel Berger	Consultant	University of Montana, US	✓	✓		
9	Dr. Nancy Boedeker	Veterinarian Consultant	Smithsonian Institution, US	✓	✓		
10	Tashi Dendup	Research Assistant	UWICE		✓		
11	Tshethup Tshering	Research Assistant	UWICE		✓		
12	Dorji Gyeltshen	Research Assistant	JDNP		✓		
13	Dr. Kinley Choden	Assistant Veterinarian	NAH		✓		
14	Kinzang Pelden	Lab Technician	NAH		✓		
15	Gyeltshen	Field Assistant	JDNP		✓		
16	Dorji Singye	Field Assistant	Freelance Guide		✓		

17	Rinchen Drakpa	Research Assistant	UWICE	✓	✓
18	Kinga Thinley	Research Assistant	UWICE	✓	
19	Karma Wangdi	Research Assistant	UWICE	✓	
20	Tshewang Norbu	Research Assistant	UWICE	✓	✓
21	Tenzin	Research Assistant	UWICE	✓	
22	Kul Bahadur Gurung	Research Assistant	UWICE	✓	
23	Tshencho Tshering	Assistant veterinarian	WCD	✓	✓
24	Phurba Wangchuk	Research Assistant	UWICE		✓
25	Jangchuk	Research Assistant	JDNP		✓
26	Tenzin Namgay	Field Assistant	Local		✓
27	Sena	Field Assistant	Local		✓

Note: Study duration at summer habitat were: (June 9 to July 15, 2012; June 26 to August 3, 2013; July 1 to August 3, 2014; and June 21 to August 3, 2015).

Annexure 4: Profile of Collared Animals

2012 Collared Animals

The first takin collared was a prime adult male, weighed about 384 kg and named as Drukpa Kuenley after Chogyal Lama Drukpa Kuenley's magical divine clone to give life to the goat's head struck on to cow's body. It was collared on 26 June 2012 and has a GPS accelerometer collar with a tag id. (TM2059). The animal was seen on 1 July 2013 but failed to communicate to the base station while trying to download the data.

The second animal was another adult male, named Ngi Dasho and weighed 314 kg. The animal was darted on 30 June 2012 and had two types of telemetry units: a UHF and GPS accelerometer collar; the UHF collar frequency was 151.395 Mhz. He was seen at the mudflat on 6 July 2013 and later captured on a camera trap north of mudflat on 10 July 2013.During the 2014 field work, his signal was received at Shingju on 25 July and seen atthe mudflat from 28 to 31 July 2015.

A sub-adult female was captured on 2 July 2012 at 0630 hrs and named Zhiwa Zeyma. She had UHF collar with a frequency 151.333 Mhz. She was seen at the mudflat on the 6 July 2013. In 2015, she was seen with her calf on 5 July 2015. Her signal was received at Drushi and Tabdrushi on 21 and 22 July 2015 andcame to the mudflat on 19 and 23 July 2015.

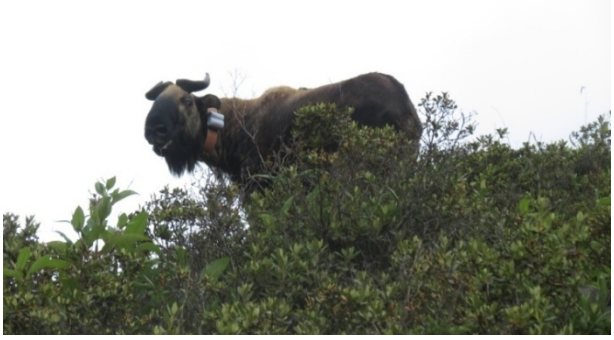
A second female takin was caught on 2nd July 2012 at 1530 hrs, named Yeewong Buthi. She weighed about 243 kg, her chest girth (142 cm) and neck girth (57 cm). We mounted a UHF collar with 151.374 Mhz frequency. After collaring, she was not seen or visited mudflat.

2013 Collared Animals:

On the 8 July 2013 was a successful day as the team managed to collar three adult male takins. First collared animal carried a tag id. (TM 2895) at 1111 hrs. He weighed approximately 330 kg with a chest girth (160 cm) and his neck girth (67.5 cm). Physically, he looked healthy and had all his teeth intact. We managed to download his data on 29 July 2013.

The second takin was collared with a tag id. (TM 2894) at 1544 hrs and weighed about 264 kg. His physical health was not at its best. May be stressed due to the breeding season. He lost two teeth missing and sustained a gore wound at the abdomen region and had left horn tip broken. His data was downloaded on 27 and 29 July 2013.

The third animal was collared at 1652 herewith a tag id. (TM 2724). He weighed 249 kg with chest girth (146 cm) and neck girth (78.7 cm). The data was downloaded on 29 July 2013. He was again darted on 21 July 2014 and fitted with a new-collar tag id. (TM 2893).



After a gap of 18 days (on 26 July), we got another male with a collar tag id. (TM 2892). He was darted at 1627 hrs and went down by 1632 hrs. He weight was about 246 kg with chest girth (143 cm) and neck girth (68.5 cm). The data was downloaded on 27 July 2013.

2014 Collared Animals.

To intensify efforts, we tried to capture animals in the winter habitat. Unlike the summer habitat, the winter habitat is very dense with thick undergrowth of shrubs and herbs. On 8 April 2014, we captured a male takin at Kabina, Gasa at 1243 hrs and attached with collar ID TM2898. The tag's functionality was tested and was able to download data until 14 April 2014 at 0516 hrs.

At the summer field work in 2014, efforts were made to recapture collared animals and on 21 July 2014, we managed to recapture collared takin with a tag id. (TM 2724) which was collared on 8 July 2013. The old collar was replaced with a new collar with a tag id. (TM2893). We were delighted to learn that the battery on the unit has not exhausted but was on low voltage. The data started to download from

the previous tag to the base-station, when the units (collar and base station) were a meter apart. Upon close examination, we found that the tag's external antenna was broken and learnt the need to reinforce the antenna for better communication. We were delighted, as it would reveal the individual's movement and activities.

2015 Collared Animals

Upon thoroughly monitoring takin movement for two months and strategizing the collaring exercise at the winter habitat in Kabina, Gasa. On 12 April 2015, we managed to collar one adult female at 1015 hrs at Khawza at an altitude of 1811 m. She was fitted with a tag id. (TF2887).

During summer field work of 2015, we managed to collar five females and a male at the summer habitat. The first adult female was collared on 28 June 2015 at 1021 hrs with a tag id. (TF2897). The animal was back in the mudflat on 9 July and after the animal was not seen at the summer habitat.

Another adult female was collared on 5 July 2015 at 0813 hrs and fitted with a tag id. (TF2889). Her data was downloaded when she came to the mudflat in the evening at 2030 hrs and again visited mudflat on 27 July 2015.

Third adult female was collared on 6 July 2015 and fitted with a tag id. (TF2899). The animal was in the mudflat area on 9, 21, 22 and 23 July 2015. On those visit at mudflat data were downloaded.

An adult male was collared on 9 July 2015 at 1425 hrs and fitted with a tag id. (TM2886). The animal was located again at the mudflat on 14, 15, 21, 22 and 23 July 2015 and successfully downloaded data. Further, Ap Tshewang, a local yak herder, and his family saw the process of collaring. He came voluntarily to help in positioning the animal. He was excited to have patted and kissed the drugged animal. It was heartening to see genuine gestures from the local people. We felt happy as he appreciated our work and a sense of the importanceof takin conservation.

Fourth adult female was collared on 12 July 2015. She was darted at 1352 hrs and it took some time for the drug to take effect. She went down at 1421 hrs.We administered the antidote and the animal left the scene at 1450 hrs and she carries a tag id. (TF2891).

A fifth adult female was collared on 13 July 2015 at 1815 hrs and fitted with a tag id. (TF2940). We could not take a picture as it was late. The signal from the animal was received at Tabdrushi on 21 and 22 July 2015 and downloaded data successful. On 23 July 2015, a faint signal was received from nearby the mudflat.

Annexure 5: Some Basic Morphological Measurements of Collared Animals

Year	Name	Date	Sex	Approx. Weight. kg	Body Length (cm)	Chest Girth(cm)	Neck Girth(cm)	Shoulder Height(cm)	Hind Height (cm)
2012	Drukpa Kuenley	26-6-12	Male	384	168	170	76.5	-	-
2012	Ngi Dasho	30-6-12	Male	314	-	157	67	-	-
2012	Zeyma Zhiwa	2-7-2012	Female	110	155	107	-	-	-
2012	Yiwong Buthi	2-7-12	Female	243	174	142	57	-	-
2012	Calf (3mth)	25-6-12	Calf	-	-	66	-	-	-
2013	TM2895	8-7-13	Male	330	152	160	68.58	-	-
2013	TM2894	8-7-13	Male	264	-	149	77.4	-	-
2013	TM2724	8-7-13	Male	249	-	146	78.7	-	-
2013	TM2892	26-7-13	Male	246	-	143	68.5	-	-
2014	TM2898	8-4-14	Male	-	-	-	-	-	-
2014	TM2893	21-7-14	Male	-	-	-	-	-	-
2015	TF2887	12-4-15	Female	225	152	-	62	110	92
2015	TF2897	28-6-15	Female	202	166	-	72	105	102
2015	TF2889	5-7-15	Female	-	195.5	-	63.5	112	107
2015	TF2899	6-7-15	Female	220	195.5	137	76	114	122
2015	TM2886	9-7-15	Male	198	208	132	61	114	107
2015	TF2891	12-7-15	Female	206	155	134	59.5	115	109
2015	TF2940	13-7-15	Female	272	197	-	79	109	104

Annexure 6: Challenges in the Field

The challenges in the field are innumerable and were daunting. Such challenges are imposing and intimidating both from the natural environment as well as on a person's physical fitness, after a lengthy preparatory phase. Natural challenges are ones associated with the landscape such as rugged topography, dense vegetation, fast flowing rivers, etc. whereas physical challenges are those experienced by the research team which were demanding both physically and mentally.

Logistic Arrangements

The logistic arrangement is the most time-consuming activity; it demands meticulous planning with a checklist of 'things to do' about a month before the actual execution. It constantly requires updating with network analysis so that things do not conflict with time. The logistic arrangement starts with basic things like shopping for foods and crockery (including gas reserves and stoves) to last the whole duration of the field season. All the foods are packed into a load of approximately 20 - 25 kg (side pony load) but keeping the provision to add on extra supplies during an emergency.

Similarly, the long list of field equipment had to be meticulously checked and neatly packed to prevent damage during the handling and transportation. This was a very demanding task. Equipment such as camera traps, time-lapse cameras, weather loggers, tracking equipment (collars), observation equipment, immobilization drugs, sample collection kits, measurement tools, communication sets and peripherals (batteries and charging units), solar panels, petrol generator and fuel, plant press for vegetation samples, datasheets and reference books were common and had to be organised. All these equipment were packed into different boxes and inventoried to different pony load packs. In addition, the camping gear consisted of all

personnel's living tents, a kitchen tent, a dining tent, a lab tent and a store tent. Moreover, an inventory of all the team members' personal belongings and their estimated weight was required and fitted to a standard pack pony load. Finally, the pony contractors were contacted, and a request made on the total number of ponies required to transport gear and food supplies.

The Long, Arduous and Perilous Trek

The takin summer habitat study site is four days trekking distance from the nearest motorable road i.e. from the Gasa Dzongkhag headquarters. The field research trip was implemented in June which happens to be monsoon season and is characterised by the incessant rain. With the sheer number of gear and having to repack after unpacking for night halts, the trek started slowly but walking behind the packed ponies was interesting. There were instances where the sight sent a chill through the spine when the ponies negotiated the narrow trail on the cliff face

Picture: 1 A section of trail showing pack horses transporting field gears and food to summer habitat, Jigme Dorji National Park, Bhutan.

without much room to move. It was worse on our return journey after much rain for almost six weeks, where most of the trails were washed off on several locations and walking on an unstable trail was treacherous. Instability of trails often led to some pack ponies stumbling and falling and we had to console the pony owner during such situations.

Camping at the foot of the towering mountain peak provided spectacular views but sometimes having to camp on the wet ground was the most undesirable thing endured by the research team. It becomes unpleasant when it rains at that height as the rain characteristically drops horizontally and we were not confident in the quality of the rain gear that we packed. We endured these conditions while trekking over eight to nine hours per day.

Appeasement Prayers to Local Deities.

Whenever the field reserch trip to Tsharijathang was undertaken, prayer flags were hoisted on the Shingchela top (5200 m) overlooking the Tsharijathang Valley for good luck and success of the venture. A day was also spent on the appeasement of local deities with the help of Gomchen (lay monks) in the area. This appeasement prayer was conducted to seek assistance from the local deities and to allow the area to be used for the research. It also boosted the morale of the research team.

Field work and schedule

The planning and scheduling of the next day's field work were discussed over dinner when all the team members joined in a communal meal. Usually when takins were foraging through the night at the hot springs and the nearby woodland, field work started early before dawn at 0330 hrs (while the cook gets up at 0300 hrs to prepare tea for the group) and after a cup of hot tea.

The team left in absolute silence and with torchlights to their assigned position. The idea of going early was to take a vantage position before dawn at 0430 hrs when takin come to the hot spring for a drink. Upon arriving at the position, the waiting began while team members are updated on takin activity and movement by the person on the vintage point. The waiting in absolute silence was a pure test of patience and endurance. It sometimes continued until the cook announced breakfast over the walkie-talkie or even past lunch time if the animals are still in the Juniper woodland. But for the veterinarians, once positioned in their designated hide-out, their meals were served at the hide-out. This strategy was to minimise commotion and leaving behind human scent in the area. The veterinarians stayed immobile in the position for whole day to watch for approaching takin. Sometimes this waiting ran for the whole day until 1800 hrs - 1900 hrs.

Choice of dart gun

The team's primary goal was to collar as many animals as possible, and the choice of dart gun is an important decision, because the group's success and morale depended on a good shot by the veterinarian and successful delivery of the anaesthetic.

The choice of the dart gun on several occasions also failed to deliver a successful shot. For instance, there was an occasion when I was with the veterinarian and he couldn't take a shot as the animal was 45 yards away as per the rangefinder, while the capture gun Dan-Inject could only deliver a shot at a maximum range of 40 yards. There was no chance of inching towards the animal due to lack of cover and so we had to watch the animal forage to its content and leave the area. A similar situation was experienced with the Palmer Cap-Chur Gun but this time the target was missed due to a damp cartridge which did not power at the expected range. Such misses

were costly as it affected the group morale, confidence, integrity and vigour. Once the herd was disturbed, it took a fortnight for the same herd to visit the hot spring again. If the veterinarian missed a shot, group members got extremely dissapointed and even the cook reciprocated by intentionally preparing inferior quality meals with lots of soup and salt in the curry to show his frustration. Therefore, it was an important decision to wisely choose and handle the capture equipment.

Short Field Season

Tsharijathang is a place where many takin herds come together from the nearby valleys and forests during summer. The valley's takin population comprised the fusion of many takin herds. Such fusion of many herds offered the best opportunity for the research team to implement the collaring exercise. The unique landscape features in the valley is the hot spring where takin congregate in big herds to drink, particularly during early morning and late evening. However, the animals are present in the valley for a short season, thereby giving a short window of fieldwork from mid-June when takin arrive to early August when they leave. The team had only six weeks to implement the collaring exercise in a year. The takin presence was a great opportunity but approached cautiously after thorough planning, discussion and strategizing the implementation plan because of the consequences of missed opportunities to successfully dart an animal. This relatively short window of opportunity greatly reduced the chance of achieving the goal of collaring more animals.

Vegetation and Landscape features (topography)

Tsharijathang is a valley which has a mosaic of habitats interspersed with alpine meadow and alpine forest of fir mixed with birch and maple trees. Shrub communities are dominated by mixed rhododendron and willow trees, and most herbs are either medicinal or aromatic plant species found in the alpine region. Thus, yak herders enjoy the readily available herbal medicines and incense plants in abundance at their door step. But when venturing out with the collaring exercise as the primary goal, intertwined and impenetrable shrub forest in rugged topography is the biggest obstruction to travel and sight. There was an instance when the team was following takin in the thick rhododendron shrub, but after dodging several branches, there was no chance of advancing further through the forest. The team decided to go back and use a longer route from the alpine meadow. Besides, the topographical feature was extremely rugged where, on occasion, it entailed climbing vertically. Climbing vertically burdened with field gear was hard. I once missed a step and nearly had a vertical fall of 100 meters. Fortunately, a small rhododendron shrub of less than a centimetre diameter which I grabbed on saved me from very serious and/or fatal injury.

Rain and River

The field season was during the peak monsoon season in June and July. The monsoon is characterised by incessant rain which is usually accompanied with high winds in the high-altitude valley at 4000+ m. The incessant downpour of rain at that altitudinal range makes the Tsharijathang River to swell and rise. This swell and surge of rain water would sometimes wash off the only accessible log bridge. Crossing the freezing river to start the morning work was undeniable very uncomfortable and having to work rest of the day with your wet pants wet was

very discouraging. One day it rained almost the whole morning, but the veterinarian managed a successful tranquilizer shot but the drugged animal went down on a small island in the Tsharijathang River. Realizing how difficult and important the animal was, I jumped into the river without a second thought to safely position the dropped animal. Later I learnt that the veterinarian was washed off about a meter before he caught a twig to fish out himself from the river. Then, I realized how incapacitated I was without a swimming skill.

Bridge building

During the collaring exercise, building log bridges was a requirement over the Tsharijathang River at the summer habitat and Mochu River at the winter habitat, to improve access totakin habitat. Building a log bridge was a rather painful and time-consuming job as none of the teammembers had experience but intuitiveness and perseverance prevailed to eventually fashion a log bridge. Usually, preliminary surveys were carried out to locate a spot for the shortest length of bridge. At Tsharijathang River which is one of the tributaries of the Mochu River, it took six men about six hours without success to position both ends of a log across the river.

Picture: 2 A bridge constructed to access takin winter habitat at Kabina, Jigme Dorji National Park, Bhutan.

Later, it took eight men over 8 hours to build a 7 m log bridge over Tsharijathang River, but all

were completely drenched from heavy rain. At the Mochu River, a log bridge was built with the help of 20+ men, but it was washed off in the evening from the swollen river. After rebuilding efforts, the bridge still washed off a couple of times at the location. But with great persistence and perseverance, we managed to have at least two functioning log bridges to access takin habitat.

Altitude and Climatic Condition

Tsharijathang Valley is situated at an altitude of 4000 m at the lowest point. Our field camp was set at 4160 m. In the peak of summer, the temperature dropped drastically in the evening and made it very unhospitable. The team was also physically tested by having to climb over Shingchela Pass at 5200 m to reach Tsharijathang Valley. The morning chill was quite unwelcoming to come out of the comfort of your sleeping bad and bedding. Particularly in the early morning, the valley would be covered with thick fog and low cloud and that made visibility rather difficult at even 10 m away. Rain was almost perfectly horizontal to make your umbrella useless.

Climbing either up or down.

Climbing up or down was the principal physical activity engaged twice daily during our field stay. It took time to acclimatise our heart and lungs in the thin oxygen-poor environment. It usually took 45 minutes to an hour to climb up to the camp from valley, but we could later make it in half an hour. The thin and cold air did not help in our uphill climb. It was highly challenging to run after the drugged takin because they ran ten times faster than any of us. For a distance which took us about an hour, takin covered it in less than ten minutes. Dogs were faster and covered the distance in less than five minutes. One day while we were monitoring takin

movement from the top ledge, we saw a group of four dogs running across the valley towards the ridge south of Jarila. They covered this route in 15 minutes which would have taken us more than 2 hours of strenuous trekking. Dogs are agile and fast in the dense environment of shrubs and undergrowth vegetation.

Unsuccessful re-tracking the collared animals

Once collared takin recovered and moved off, it was imperative to re-track these animals especially in the winter habitat to initiate data download. Despite several attempts to scan established routes and known habitat, we failed to locate most collared animals. It could therefore be interpreted as: 1. Collared animals are using new areas previously unknown because, for example, scanning for collared animals in the established and well-known habitat around Damji area was unsuccessful. 2. Collared animal movements were disrupted by disturbance from infrastructure development such as road construction and road widening. 3. There could have been technical issues with the collars and/or antennae breakage from takin behavior resulting in a greatly reduced range for data communication with a download base station. Unsuccessful re-tracking of collared takin was the biggest drawback of the study.

Sensitive animal

Constant disturbance in the Tsharijathang Valley from yak, horse, dog and human has affected the takin. Like any wild animal, takin are sensitive and cautious in their movements with the acute sense to notice a slight change in the environment. Such a response to the disturbance proved very demanding for the team to approach sensitive and wary takin to initiate a collaring

exercise. The sensivity of takin made the collaring exercise complex and our target hard to achieve. We needed the takin to visit the valley as usual despite the anthropogenic disturbance for two reasons: 1. Takin are then available for collaring and the open valley enabled the monitoring of drugged animals' escape routes, 2. Data download from those collared animals was enabled because the collars automatically triggered the base-station to download data. Therefore, it was imperative that the research team was as stealthy as possible to be able to effectively collar sensitive and flighty takin in the valley.

Human Resource

My research had the highest human resource turnover (see Annexure 3 on study team members). Except for a few officials, no research assistants came twice on the trip to Tsharijathang to assist the study. It was very demanding with strenuous physical trekking and an equally stressful mental exercise from early on as 0300 hrs in the morning through to 1900 hrs in the evening. For instance, I heard from someone that one of the field assistants had warned his colleague (who volunteered to join in the field) to leave a will behind before venturing to the field. It was subsequently hard to convince the field assistant (who had volunteered) to join the study as it was a test of both physical and mental health.

Picture: 3 A team posing at the highest summit (Shingchela) 5200 m asl, Jigme Dorji National Park, Bhutan.

However, my recount of the field work is not only about all these hardships and challenges. Once in the valley, you were greeted with a vast landscape of alpine flowers, creating a scenic view of unmatched beauty in the world. In the distant, one observed the towering mountain which feeds the valley with the Tsharijathang River that meandered right through the middle of the valley. Additionally, all the shrubs and colourful rhododendron provided a hue to this beautiful valley. For instance, one fine day there was not much takin activity in the valley, whereby I decided to take my camera and go on a photo shoot of alpine flowers. On that single day, I was greeted with 86 different species of alpine flowers. It increased my awe of the valley. The other notable component is the wildlife fauna in addition to the takin. Occasionally, one witnessed a snow leopard trying to stalk unwary takin calves, and when alerted, takin herds bunched together to threaten the cat as an anti-predatory defense. One also observed a huge black bear on the prowl looking for a mate or a big herd of blue sheep of 200 and more. Snow-clad mountains reflected the first light of the morning sun and the different hues to create a mesmerizing scene, which made a worthy greeting to a typical morning. I was awestruck with the beautiful scenery and aroma from aromatic and incense plants growing in abundance across the magnificent landscape of the Tsharijathang Valley and will always carry this in living memory.