Does Wildlife Play a Role in the Epidemiology of Livestock Diseases? Preliminary Results and Management Implications of a Survey of Perceptions and Practices of Farmers Living in a Protected Area of Bhutan

บทบาทของสัตว์ป่าทางระบาดวิทยาของโรคปศุสัตว์ ผลการศึกษาเบื้องต้นและการประยุกต์การจัดการที่ได้จากการสำรวจการรับรู้และการปฏิบัติของเกษตรกรที่อาศัยในพื้นที่คุ้มครองของประเทศภูฏาน

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บทคัดย่อ

การศึกษาวิจัยในชุมชนเพื่อที่จะประเมินความรู้ ทัศนคติ และการรับรู้เกี่ยวกับประเด็นสุขภาพของปศุสัตว์และสัตว์ป่าของประชาชนในพื้นที่ โดยจำแนกตามการอยู่อาศัยในเขตพื้นที่คุ้มครองของประเทศภูฏาน โดยเลือกศึกษาเพื่อทำการเปรียบเทียบในพื้นที่สองตำบล ที่ตั้งอยู่ในเขตและนอกเขตอุทยานแห่งชาติจิกมี ดอร์จี ผู้เข้าร่วมงานวิจัยถูกเลือกโดยวิธีสโนว์บอล ดำเนินการเก็บข้อมูลโดยใช้ทั้งวิธีการเก็บข้อมูลเชิงคุณภาพและปริมาณ ได้แก่ การสัมภาษณ์รายบุคคล การประชุมกลุ่ม การสังเกตและการร่วมทำกิจกรรมกับประชาชนในหมู่บ้าน โดยเน้นศึกษาในหัวข้อความตระหนักและการรับรู้ของบทบาทของสัตว์ป่าในการระบาดของโรคในปศุสัตว์ ผลการศึกษาพบว่าชาวบ้านส่วนใหญ่เป็นเจ้าของปศุสัตว์อย่างน้อยหนึ่งตัว ในด้านการบริการทางสัตวแพทย์ เจ้าของสัตว์รายงานว่าเป็นเรื่องที่ง่ายมากในการเข้าถึงการให้บริการทางสัตวแพทย์ เรื่องเดียวที่เจ้าของสัตว์กังวลคือความต้องการในการเพิ่มจำนวนผู้ปฏิบัติงานด้าน

สัตวแพทย์(20%) มีรายงานว่าปศุสัตว์ที่อาศัยอยู่ในเขตอุทยานแห่งชาติมีการใช้พื้นที่ในการให้สัตว์เลี้ยงกินหญ้าและแหล่งน้ำร่วมกับสัตว์ป่าบ่อยครั้งกว่าที่รายงานพบในพื้นที่นอกเขตอุทยาน ประชาชนส่วนใหญ่มีความตระหนักในการเกิดโรคร่วมกันระหว่างปศุสัตว์และสัตว์ป่า (55.2%) การศึกษานี้แสดงให้เห็นถึงความจำเป็นในการสร้างความตระหนัก การมีส่วนร่วมของชุมชนในการร่วมกันแก้ไขปัญหาด้านสุขภาพของปศุสัตว์และสัตว์ป่า

คำสำคัญ: ระบาดวิทยา, การอยู่ร่วมกันระหว่างมนุษย์และสัตว์ป่า สุขภาพปศุสัตว์

ABSTRACT

A community-based study was conducted to assess the knowledge, attitudes and perceptions regarding livestock and wildlife health issues of local people depending on their proximity to protected areas in Bhutan. Two sub-districts located inside and outside Jigme Dorji National Park were selected for comparison. Participants were selected by applying snowball-sampling method. Data was collected through use of both qualitative and quantitative approaches involving individual interviews, group meetings, personal observations and active participation in villagers' activities. Key areas of enquiry included awareness and perceptions of the role-played by wildlife in the epidemiology of livestock diseases. The study found that most of the respondents reported owning at least one livestock. In terms of veterinary health care services, animal owners found it was very easy to access and the only concern was the need for additional staff (20%). Livestock inside the park were reported to share the same grazing area and water with wildlife more frequently than those of outside the park. People were generally aware of livestock animals and wildlife sharing some diseases (55.2%). The study highlights the need for awareness and for community engagement and participation in dealing with health issues of livestock and wildlife.

Keywords: epidemiology, human-wildlife interface, livestock health.

INTRODUCTION

As a result of increasing human population and encroachment in wildlife habitat, contacts between humans, livestock and wildlife have increased in many parts of the world over the past decades (Mazet *et al.*, 2009). The resulting "human–wildlife conflicts" usually refer to negative impacts of these interactions on local people's livelihoods, such as crop destruction by wild herbivores, killing of livestock by wild predators, or direct threat to humans (Wang *et al.*, 2005). However, other indirect or 'hidden' impacts of human-wildlife

conflict are often under looked and poorly documented, especially health impacts and opportunity or transaction costs (Barua *et al.*, 2013). One of the major negative consequences suffered by people and their livestock, living at the human/wildlife interface, is disease transmission, and many developing countries cannot respond appropriately to the associated risks of emerging zoonotic diseases (de Garine-Wichatitsky *et al.*, 2013).

Diseases associated with wild species might adversely affect local farmers by causing direct mortality or reduced productivity of livestock thus causing economic losses, their socio-cultural importance (de Garine-Wichatitsky *et al.*, 2013) and by directly affecting the health status of livestock owners and their families (Daszak *et al.*, 2000). Wildlife has also been confirmed as a source of major emerging diseases such as highly pathogenic H5N1, SARS and Nipah Virus that have resulted in pandemics during the last decades (Chua *et al.*, 2002; Epstein *et al.*, 2006, Hughes *et al.*, 2009; Yang *et al.*, 2007).

The increasing role of wildlife in the emergence of livestock and human diseases is due to numerous anthropogenic changes taking place at the livestock–wildlife interface, as well as within wildlife, livestock, and human populations (Rhyan and Spraker, 2010). In the last half-century, despite substantial attention given to animal diseases, the understanding of disease processes, and how to manage them at the livestock–wildlife interface, remains inadequate. Globally, the role of wildlife in livestock diseases is expected to increase and will require an improved understanding of the ecology of pathogens at the livestock–wildlife interface along with development of tools and mitigations to manage these pathogens (Miller *et al.*, 2013). The role of wildlife in human and domestic animal disease emergence is a factor which can no longer be ignored (Ryser-Degiorgis, 2013), but little is known regarding the role of wildlife in the epidemiology of zoonotic and livestock diseases in Bhutan. Rather than a top-down approach, we adopted a community-based approach inviting participation of locals in the survey and drawing on their capacities and resources for proposed solutions. A critical step in community health research and planning is triangulating knowledge, attitudes, and practices with self-reported health and disease history (Berrian *et al.*, 2016). The objective of this study was to determine the knowledge, perceptions and attitudes of local stakeholders regarding health issues affecting their livestock in human-wildlife interface areas through participatory approach. The study aimed at evaluating the impacts of wildlife on health of livestock.

MATERIALS AND METHODS

Study site

Two study sites were selected, Khamaed, located inside Jigme Dorji National Park (JDNP) and Kabjisa which is located outside the park for comparison (Figure 1 and 2). The characteristics of both study sites are shown in Table 1. The park is located in the northwestern part of Bhutan. Its border coincides with the international border between Bhutan and China. There are around 5,036 people and about 651 households within the park (JDNP draft plan, 2005-2007). These local communities directly or indirectly depend on the natural resources in the park for their livelihood. The park is a repository of several mammal and bird species, which are globally and regionally threatened.

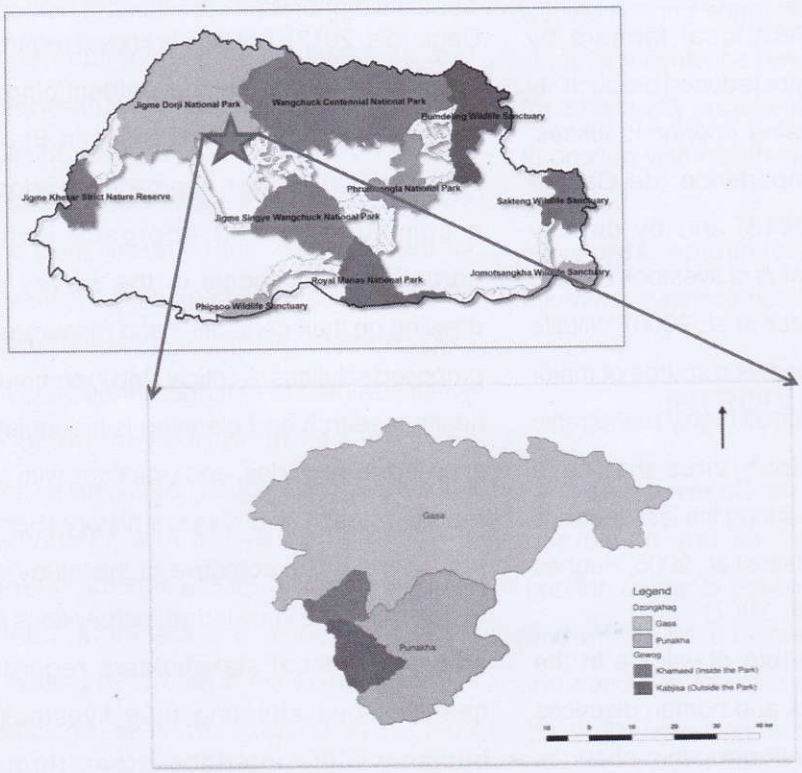


Figure 1 Map illustrating the study sites : Khamaed *gewog*, Gasa *Dzongkhags* located inside Jigme Dorji National park, and Kabjisa *gewog*, Punakha *Dzongkhags* located outside Jigme Dorji National park.

(A)

(B)

Figure 2 Damji village, located within Khamaed *gewog* inside Jigme Dorji National Park (A) and Damche village, located within Kabjisa *gewog*, outside Jigme Dorji National Park (B).

Data Collection

The fieldwork was conducted from February to April 2017. Data collection methods employed were administration of questionnaires through in-depth individual interviews, participatory mapping and feedback meetings, personal observations and conversations. Key resource persons were selected as representatives from each sector: livestock, human health, wildlife, chief and other representatives of the village. Participants were then selected based on the snowball sampling method (Sadler *et al.*, 2010). We integrated ourselves as much as possible with the daily activities in the village and made sure participants knew we had no direct affiliation with the government. Informed consent was requested from each potential participant after being given an oral description of the purpose of the study and the estimated time of each interview. Their participation was confidential and voluntary and participants could withdraw from the interview at their own will. The Graduate School of Kasetsart University and the Forest Department of the Royal Government of Bhutan reviewed the proposal and granted permission for the study.

The questions underwent subject validation by experts followed by a pilot testing in the field and were adjusted to maximize participants' comprehension. The final questionnaire consisted of both qualitative and quantitative data collection, including successive "Free-listing" exercises (Borgatti, 1999) during which the informants were asked to cite all the names of livestock diseases (and wildlife species in a subsequent exercise) known to them, in the order with which the names came to their mind and in any language they preferred (including local vernacular

Table 1 Characteristics of the study sites, Khamaed *gewog* (inside Jigme Dorji National park) and Kabjisa *gewog* (outside Jigme Dorji National).

	Khamaed *gewog* (inside the park), Gasa *dzongkhag*	Kabjisa *gewog* (outside the park), Punakha *dzongkhag*
Location	Southern part of Gasa *dzongkhag* (district) bordering with Punakha District	Northern part of Punakha *dzongkhag* (district) bordering with Gasa District
Altitude	1,800-2,300 masl	1,570 masl
Temperature	8°C to 26°C	12°C to 32°C
Land coverage	69.23km^2 of registered land out of which 299.13 acre are arable land and the remaining 230 acre are classified as *tsamdro* (grazing land)	1,372 acres of which 1,252 acres are wet land (paddy fields) and 670 acres are dry land
Number of households (interview with head of the *gewog*)	125 households	498 households
Number of population and proportion of males and females	713 comprising of equal proportion of males and females	4,525 of which 2,173 (48%) are male and 2,352 (52%) are female
Source of income	People grow paddy, wheat, peas, barley, maize and various vegetables. Livestock rearing mainly; collection and sale of *Cordyceps* and non-timber forest products	People grow paddy, wheat, buckwheat and barley. Sale of vegetables is an important source of income to the people of Kabjisa and people grow chillies, brinjal, cabbage, beans and broccoli
Road connection	The *gewog* is connected to the rest of the *gewogs* of Goenkhatoe by motor road and Lunana and Laya by mule track.	The *gewog* is well connected by motor road, telecommunication and internet facilities
Facilities	Headquarter JDNP, one Central school (up to 12th grade), Basic Health Unit (BHU), Renewable Natural Resources Centre (RNR centre), ECCD and Sub-division Department of Road (PWD)	Primary school and a higher secondary school (up to 12th grade), Basic Health Unit (BHU), Renewable Natural Resources Centre (RNR centre), ECCD and two international chain of resorts (>4 star)

language). The questionnaire consisted of five sections: i) Demographic section entailing informant details and socio-economic status; ii) Livestock Health section with "free-listing" of names of livestock diseases known to the informant, accessibility of veterinary services and grazing practices; iii) Wildlife section with "free-listing" of wildlife species known and perceptions of wildlife species named by the informant. After the individual interviews, collective participatory mapping and feedback meetings were conducted with the participants. The objective of the meetings was to present the preliminary findings pertaining to the ranking and frequency of the listed diseases, and find the group consensus for the results.

Data analysis

Data gathered from the field were entered into the database in Epi Info 7 (CDC, Atlanta) and were analyzed using R Software version 1.0.136 (R Core Team, 2015). Descriptive statistics were used to summarize the main features of the data collected. Summary statistics including mean, median, standard deviation (SD), range, and maximum values for continuous variables and frequency and proportions for categorical variables were calculated. Free-list analysis using Flame Software in Microsoft excel (Pennec *et al.*, 2012). Sutrop index (a composite index combining both frequency and order of mention) was calculated for all items in both livestock and wildlife species free-list. We used Chi-square (χ^2) tests to determine the association between categorical variables according to information collected from the villagers lived inside and outside the park.

RESULTS

Characteristics of respondents

A total of 61 questionnaires were administered with equal proportion of respondents who lived inside (n=30) and outside the park (n=31). Each interview lasted for 1.5 to 2 hours and was conducted in *Dzongkha* (National language of Bhutan). Participant characteristics are summarized in Table 2.

Respondents consisted of 27 males and 34 females, out of which 67.2% were heads of households. The majority of the people (90%) living inside the park in Khamoed *gewog* are native and have ancestors from the same area, while 74.1% of people living outside the park in Kabjisa *gewog* originate from the same area. The majority of the respondents (n=37, 60%) are illiterate, while 13 of the respondents (21.3%) received primary schooling. Eight respondents received various levels of *Dzongkha* and Buddhist studies of which one underwent astrology and metaphysics training. Two respondents received non-formal education while the highest education level of education was bachelor's degree (n=1) from

outside the park. Most of the respondents (41 of 61, 67.2%) were farmers and held no position in the village, while one third of the respondents held various positions including head of village, representatives of the local government, former head of village, voluntary health worker, volunteer for community forests, focal person for water supply, messenger, president of dairy farmers group and temple caretaker. Respondents owned an average of 2.9 acres of land, ranging from 1 to 8 acres. Overall, contributions to the income of respondents from agriculture were dependent on land holding. The overall average yearly income, in Bhutanese currency (*Ngultrum*, Nu.), was Nu. 77,400 (range: Nu. 4,800 to Nu. 390,000). For the participants who lived inside the park, only one of them owned a vehicle, whereas those who lived outside the park, 11 respondents owned one vehicle and 6 respondents even owned two types of vehicles (14 respondents did not own any vehicle).

Livestock demographics

All respondents who lived inside the park owned at least one domestic animal (usually cattle) while only 15 respondents owned poultry. People rarely owned dogs, while most had cats as companion animals. For the participants who lived outside the park, 29 respondents owned cattle and only 7 owned poultry, out of which 2 respondents had farm with more than 100 birds. There, people had more companion animals, with 80% of respondents owning at least one cat.

Table 2 Demographic characteristics of respondents in both study sites

Characteristics	Khamaed *gewog* (Inside JDN Park) N=30	Kabjisa *gewog* (Outside JDN park) N=31	Total N=61
Male (%)	12(40%)	15 (48.4%)	27(44.3%)
Female (%)	18 (60%)	16 (51.6%)	34(55.7%)
Median of age in year (range)	46 (21-78)	45 (27-64)	46 (21-78)
Household size (mean ± SD)	4.6 ±2.7	6.2 ±3.1	5.4 ±3.02
Median of yearly income in *Ngultrum* (range)	60,000 (4,800-390,000)	90,000 (20,000-360,000)	77,400 (4,800-390,000)

Livestock health

Inside the park, 80% of the respondents (24 of 31) found it was very easy to access veterinary services, while 13.3% (4 of 31) found it was easy, and only 6% (2 of 31) found it was difficult. The majority of the respondents (30 of 31, 96.7%) outside the park found it was very easy to access veterinary services and only one participant said it was easy to access.

With the easy accessibility of modern healthcare system in the villages, the livestock extension agents were regularly consulted for the health and production needs of animals. At the same time, the deep-rooted worship for spiritual beings and elements induces most people (53.3%) to consult an astrologer in many ailments of their livestock. Abortions in cattle are fairly common in both the study sites (mentioned by 48.3% respondents). If abortion does occur, livestock extension agents are consulted for management and treatment of sick animals. Aborted fetuses are discarded.

"*We call livestock extension for treatment and give good feed to the dam and bury the aborted fetus*" [adult woman; Zomina village]

In an event of death of livestock, extension agents are consulted to advise on the causes of the death and on the safety of meat consumption. If the meat is not deemed safe for consumption, the carcass is buried.

People are mostly satisfied with the veterinary services available to them. The only difficulty they face is when the single extension agent is called away for official or personal reasons and service delivery is hindered, especially timely amenity like artificial insemination.

Grazing practices

Access to common grazing land is a traditional right for the local people in both areas. The traditional lands are managed as Community Forests. They provide wood for fuel and for construction purposes, and grazing for livestock. It is in these lands that livestock frequently comes into contact with wildlife while grazing, and also shares the same water source.

Most of the respondents in Khamaed *gewog* indicated that they sent their animals to the forest for grazing. Various reasons were stated for choosing particular areas as grazing lands, including the quality and quantity of forage accessible in winter, fewer leeches, less risk of wildlife encounter and fewer deaths to livestock by falling off cliffs. Common wildlife species mentioned to be found at these grazing areas were: *Show* (sambar deer-*Cervus unicolor*), *Kasha* (barking deer – *Muntiacus muntjak*), *Drong-Gyemtse* (Takin – *Burdorcus taxicolor whitei*), *Bjara* (Goral – *Nemorhaedus goral*), *Ripah* (Wild boar – *Sus scrofa*), *Dom* (Himalayan black bear – *Ursus thiberanus*), *Phaw* (Dhole – *Cuon alpinus*), *Zee* (Leopard – *Panthera pardus*), *Taa* (Tiger – *Panthera tigris*), *Leko* (Kalij pheasant – *Lopura leucomelanos*).

People in Kabjisa *gewog* send their animals for grazing in the forest since fields are cultivated in summer, and also because they consider that there is good fodder in the forests for their livestock. Other reasons mentioned by the respondents include cooler climate, no leeches and biting insects. In both villages, local cattle breed *(Yue-nor)* are considered sturdy and can find their own food in the forest, so they are sent away for grazing. Introduced breeds, mostly Jersey crosses which produce more milk, are kept near the houses or tethered in their own fields and stall-fed.

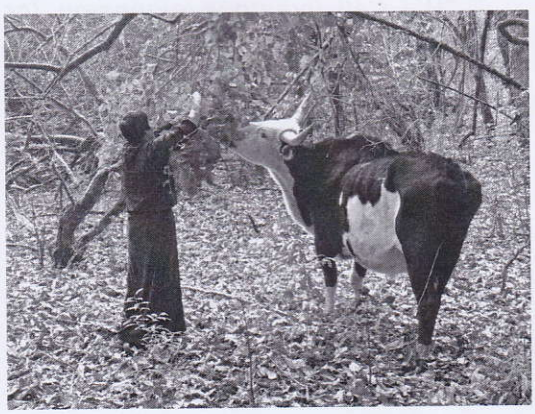
Respondents were asked how frequently their livestock shared grazing area and water with wildlife. Livestock inside the park area are observed to share more frequently the same grazing areas (χ^2, $p < 0.01$) and also water source with wildlife (χ^2, $p < 0.01$).

Livestock disease free-list analysis

The majority of respondents cited the same vernacular name for most of the diseases mentioned both inside and outside the park. *'Khatsha kangney'* in *Dzongkha* or 'Foot and Mouth Disease (FMD) was the most frequently and first mentioned disease by all respondents (highest Sutrop index score,0.378).

Respondents were also asked whether the livestock diseases/syndromes cited were related to wildlife or not (Table 3). The majority of respondents inside the park (55.2%) perceived wildlife as being involved in livestock diseases, while 20.7% stated that wildlife was not involved at all and 24.1% did not know. A similar proportion of respondents outside the park perceived wildlife as playing a role in livestock diseases (50%), which was not significantly different from the proportion inside the park (Fischer's test, $p = 0.778$), while 16.7% considered that wildlife played no role at all, and 33.3% did not know.

(A)



(B)

Figure 3 Grazing areas of livestock in farmer's own fields (A) and in grazing land (B).

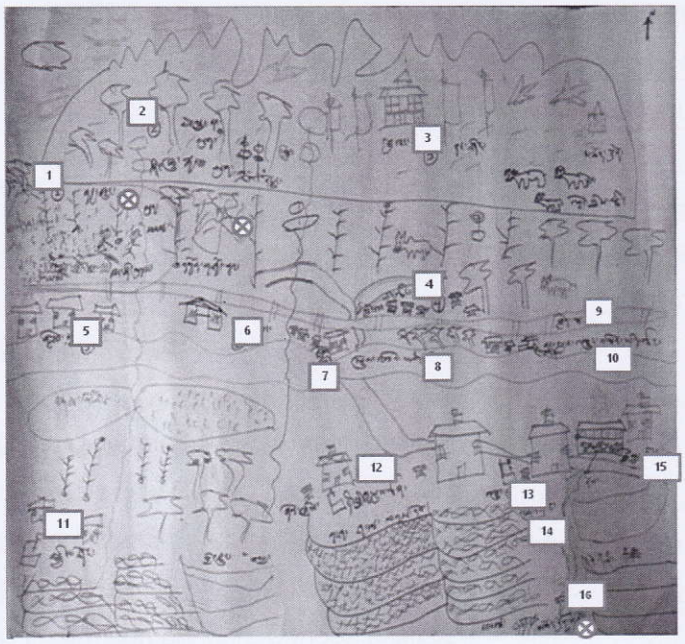


Figure 4 Participatory map of the villages located inside JDN park, natural resources and human-wildlife conflicts drawn during the focus group discussion in Khamaed *gewog*.

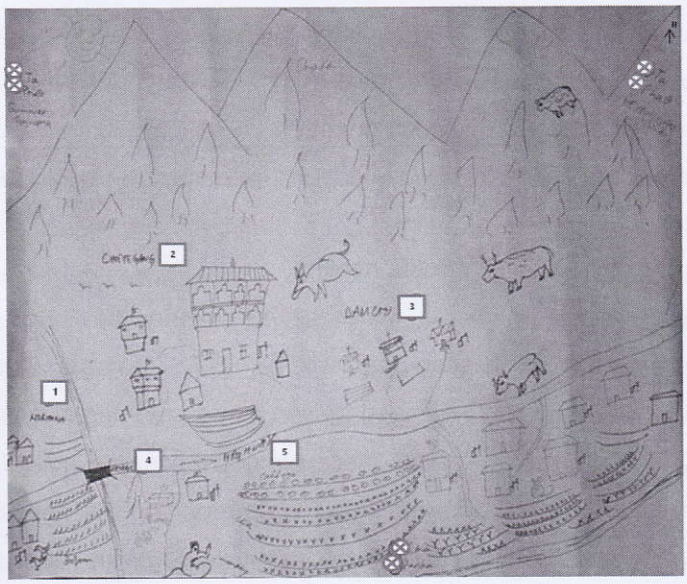


Figure 5 Participatory map of the villages located outside JDN park, natural resources and human-wildlife conflicts drawn during the focus group discussion in Kabjisa *gewog*.

Table 3 List of livestock diseases cited by respondents as being related to wildlife, frequency of citation, perceived involvement of wildlife.

Diseases	Frequency				Main Wildlife species cited (Frequency)	Second most cited wildlife species (Frequency)
	Cited	Yes	No	Don't know		
Khamaed *gewog* (Inside JDN park)						
FMD	16	13	2	1	Sambar deer (7)	Barking deer (4)
Bird flu	8	5	1	2	Kalij pheasant (2)	
Black Quarter	6	3	1	2	Barking deer (1)	Sambar deer (1)
Liver fluke	6	1	4	1	Sambar deer (1)	Barking deer (1)
Ephemeral fever	3	1	1	1	Barking deer (1)	Sambar deer (1)
NID_Ectoparasite	2	1	1	0	Sambar deer (1)	Barking deer (1)
NID_Endoparasite	1	1	0	0	Barking deer (1)	Sambar deer (1)
Gid	1	1	0	0	Barking deer (1)	Sambar deer (1)
Kabjisa Gewog (Outside JDN park)						
FMD	19	11	1	7	Sambar deer (3)	Barking deer (4)
Tick infestation	8	2	5	1	All wildlife (2)	
NID_Diarrhoea	1	1	0	0	All wildlife (1)	
NID_Cough	4	1	2	1	Barking deer (1)	Sambar deer (1)
Epilepsy	1	1	0	0	Barking deer (1)	

Note: "Yes", "No" and "Don't know" refers to respondents reply to the question "Is this disease related to wildlife?".

For FMD, the most frequently cited modes of transmission from wildlife to livestock were grazing in the same area and through transfer of saliva (n=10, 76.9%), while the rest of the respondents (n=3, 23.1%) cited unhygienic practices of defecation after consumption of infected meat. The mode of transmission cited for other diseases were also generally mixing and sharing of grazing area and water sources with wildlife.

Wildlife health

When asked whether they have ever seen dead wildlife, 66.7% of respondents in Khamaed *gewog* responded negatively. The results were almost the same in Kabjisa *gewog*, with 61.3% reporting that they have never seen dead wildlife. With regards to seeing sick wildlife, the great majority of the participants responded negatively (n=52), and only 9 respondents had ever seen sick wildlife,

such as blind or limping takin, sambar, wild boar, bear, barking deer, pheasant, monkey and wild birds.

Although people reported that they often go to the forest for various purposes (e.g. collect natural resources, cattle herding), they rarely see dead wildlife carcasses. The reasons invoked are that carcasses are eaten by carnivores and most wildlife dwells deep in the forest where people do not go usually.

"We do not see dead wildlife often or we just see remains eaten by carnivores" [adult man; Jabesa village]

Most people ignore and do nothing if they see a carcass, while some (19.7%) take it home for consumption it if it looks fresh or edible. It is considered a bad omen to see intact carcass of wild animals without any apparent wound or cause of death.

"I believe that it is bad luck to see carcass without any sign of injury, so leave it" [adult man; Damji village].

It is also believed that eating the meat of barking deer will cause abscess.

"If you eat meat of Barking deer, it causes abscess due to the impurities ("dreep") in the meat" [adult woman; Damji village]

Some would carry the antlers of deer as trophy or for aesthetic purposes to decorate doors or altar rooms.

"Brought the antlers home to keep as it is a treasure ("nob") and it is beautiful" [adult man; Jabesa village]

If sick wildlife is seen, people do not interfere, especially if it is a carnivore. They try to help or relocate if it is harmless. People in the park are more aware of who and where to inform or report in the event that dead or sick wild animals are sighted.

"Inform park and livestock. Don't think the foresters can cure if they are sick" [adult woman; Damji village]

Despite their killing of livestock, dangerous predators are perceived by most farmers as beautiful and worth protecting.

"Wild dogs are beautiful with their muzzle covered with the blood of the cattle they have killed: they look like people chewing betel nut!" [an old woman; Damji village]

Wildlife species free list analysis

There was no significant difference in the length of list cited by respondents inside vs outside the park (χ^2, p = 0.224). *'Kasha'* (barking deer) was the most frequently cited and *'shaw'* (sambar deer) was the second most frequently cited overall and individually in both the areas, but sambar deer was higher in saliency (Sutrop Index= 0.450).

DISCUSSION

The majority of respondents in both study areas found that it was very easy to access veterinary health service as people have access to free government run veterinary services in the area. Livestock rearing is an

integral part of the agricultural system in Bhutan and the livestock development program is given a high priority in the development plan of Bhutan (Gross National Happiness Commission, 2013). The good perception of the efficiency of veterinary services by the local farmers that we interviewed reflects these efforts made at national, district and local level to sustain this activity. However, the respondents revealed a need for additional staff, especially for timely amenity like artificial insemination.

Self-reported livestock health issues during interviews may introduce biases such as recall bias (Berrian *et al.*, 2016) and possible language bias (de Garine-Wichatitsky *et al.*, 2013). This was regulated by cross checking information given by different respondents, and including local health assistants and veterinarians in the study. Also, conducting the group meetings after the individual interviews helped confirm the data. Snowball sampling was also appropriate for this type of research as it enabled us to draw an inclusive list of participants for the study (Sadler *et al.*, 2010).

Based on the diseases free listing exercises carried out, the knowledge base was relatively similar in both areas. The role played by wildlife in transmitting diseases to livestock disease is well mentioned, especially in the case of FMD but no other clear diseases were mentioned. This result may be due to the fact that no outbreak of zoonotic diseases (such as rabies or anthrax) has been reported in the areas in the past 10 years, although these diseases do occur in Bhutan (Dorjee *et al.*, 2016; Tenzin *et al.*, 2011). Also no report of wildlife diseases outbreaks, such as avian influenza has been reported in the area (National Center for Animal Health, 2012). At the interface between domestic and wild animals, ecosystems and human populations, many countries have adopted formal approaches for cooperation between veterinary services, human health services and other key public services (Landford and Nunn, 2012) to control and prevent zoonotic diseases, which could be adopted especially in interface areas in Bhutan. An awareness campaign focusing on zoonotic diseases risks would be beneficial for the local communities and for the efficiency of such prevention programme.

We found a significant difference in livestock sharing of grazing area and water with wildlife inside and outside the park. Respondents inside the park send their livestock for grazing in the forests more often than respondents outside the park. Due to short supply of fodder and smaller land holding, people release their livestock in the nearby forests for grazing, thus increasing the risk of livestock depredation by wild carnivores (Wangchuk *et al.*, 2014). Herd management has been identified as a factor strongly influencing predation rate (Tshering & Thinley, 2017), with herded livestock being less

vulnerable to predation irrespective of breed and type, highlighting the importance of proper tending of livestock to prevent wildlife predation. Also, maintaining small and manageable cattle herds and either stall-feeding them or keeping them in nearby grazing areas could minimize depredation losses (Tshering and Thinley, 2017). In both areas surveyed, cattle herding was not systematic and appeared to be often limited to the action of driving the cattle to the desired grazing range, often in the forest, and back home at night, without careful monitoring of the movements of the herd or ensuring its protection during the day time. Therefore, a comprehensive management strategy customized for each area with the involvement of government managers and farmers should be devised to decrease the risks of livestock predation, thus also contributing to wildlife conservation by reducing conflicts.

Wildlife health surveillance produces knowledge that benefits at least three different sectors, including animal health, public health and conservation (Ryser-Degiorgis, 2013). Awareness and knowledge sharing in this regard is crucial. Discrepancies were seen among the response of the participants regarding the actions they will take if they see dead or sick wildlife. Awareness about reporting and actions to be taken after sighting dead or sick wildlife is highly desirable especially since few respondents in both the areas described encounters with dead and sick wildlife. Reports of unusual wildlife die-offs and sightings of carcasses largely depend on disease awareness, personal interests and the goodwill of the public and of field professionals (Ryser-Degiorgis, 2013), but people basically have no awareness in regards to actions to be taken in case of seeing dead or sick wildlife. Participatory approach, cross-sectorial networking and communication are vital for efficient wildlife health surveillance. A participatory co-managed wildlife surveillance project could be initiated in our study area, and we believe that it would be welcomed and useful in the majority of areas of Bhutan where wildlife and livestock interact.

These findings highlight the overall complexity of disease epidemiology at wildlife-livestock interface, as perceived by local farmers, and the importance of local involvement in conservation management for a broad, social-ecological approach to health.

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