Biodiversity and Conservation (2020) 29:933–946
https://doi.org/10.1007/s10531-019-01919-0

ORIGINAL PAPER

Using community knowledge to identify potential hotspots of mammal diversity in southeastern Nepal

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Received: 1 July 2019 / Revised: 10 November 2019 / Accepted: 5 December 2019 /
Published online: 10 December 2019

Abstract

Nepal has been relatively successful in conserving its wildlife by pioneering innovative approaches to conservation, such as benefit sharing in protected area buffer zones and landscape-level conservation approaches. However, compared to other areas of Nepal, the biodiversity of the southeast has received less attention, both in terms of research and conservation. The objective of this study was to use local knowledge as an indicator of wildlife presence and abundance across the forests of southeastern Nepal. Based on 114 focus group discussions with communities in eleven districts between March 2014 and January 2015, we identify potential wildlife hotspots, areas with more prey species to support tiger, areas of species loss, and areas with species of special interest (endangered and data deficient). Our results provide the contours for further study of the presence and distribution of wildlife across the eleven districts. For example, our results suggest that forests in the middle of the study area have higher levels of wildlife diversity, prey species for tiger, and species of interest, while the eastern side of the study area shows more species loss. We do not suggest that these results are an accurate or reliable representation of mammal diversity in southeastern Nepal. However, they can help to prioritize areas for conservation and for further research, as well as build a foundation for working with local communities to conserve wildlife of southeastern Nepal.

Keywords Local ecological knowledge · Mammal conservation · Wildlife management · Nepal · Terai · Churia · Landscape conservation

Communicated by David Hawksworth.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10531-019-01919-0) contains supplementary material, which is available to authorized users.

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Introduction

Nepal has been relatively successful in conserving its wildlife. It has achieved zero poaching of rhinoceros (Aryal et al. 2017) and has an increasing and geographically expanding tiger population (Thapa et al. 2017). Nepal has pioneered innovative co-management approaches to conservation, including creating conservation areas, where communities remain living in protected areas, national park buffer zone revenue-sharing programs, and community forestry programs outside of protected areas (Allendorf and Gurung 2016; Bhattarai et al. 2017). It has also adopted a landscape-level conservation approach, creating five conservation landscapes (e.g., the Terai Arc Landscape in southwestern Nepal and the Sacred Himalayan Landscape in the northeast), which cover more than two-thirds of the country (Ministry of Forests and Soil Conservation 2016).

Compared to other areas of Nepal, the biodiversity of southeastern Nepal has received less attention in terms of research and conservation, and relatively little is known about the wildlife. It has only one protected area, the Koshi Tappu Wildlife Reserve, which is home to the only remaining population of wild water buffalo (*Bubalus arnee*) in Nepal. However, the area has great potential as a corridor because it links three existing conservation landscapes. It overlaps on the eastern side with the transborder Kanchenjunga Landscape that links protected areas in Nepal, India, and Bhutan. On the western side, it links with the Terai Arc Landscape and the Chitwan Annapurna Landscape in central Nepal. Part of this area has been included in a new landscape proposed by the government, the Eastern Chure-Terai Complex (Ministry of Forests and Soil Conservation 2016). More studies are needed to understand the potential of southeastern Nepal for wildlife conservation and to provide a baseline for initiating conservation activities (Ministry of Forests and Soil Conservation 2016).

Conducting traditional wildlife surveys across such a large area can be prohibitive in terms of cost, time, and labor. However, local knowledge can be used to collect data on the presence and status of wildlife relatively quickly and cost-effectively across a large geographic area (Meijaard et al. 2011; Pan et al. 2016; Nash et al. 2016; Miard et al. 2017). Community knowledge has been used to identify and locate mammal species in an area where little is known (Nash et al. 2016) and for mammals that would otherwise be difficult to locate (Miard et al. 2017). Community knowledge can be fairly accurate, even for smaller mammals (Pan et al. 2016; Nash et al. 2016), although communities can underestimate the presence of cryptic and elusive species and overestimate the presence of charismatic and problem species (Caruso et al. 2017). In addition to providing information about wildlife, community surveys serve additional purposes. Soliciting community knowledge can raise people's awareness, contribute to more effective decision-making (Danielsen et al. 2014), and help to engage communities in conservation (Steinmetz et al. 2006).

In Nepal, 30% of forests are managed by local communities (Ojha et al. 2009). Community forests greatly expand the landscape for biodiversity conservation (Dahal et al. 2014), complementing protected areas, which contain 17% of the forests in Nepal (DFRS 2015). However, community forestry emphasizes forest management and wildlife conservation has not been integrated into management strategies and practices, although the potential is great (Shrestha et al. 2010; Thani et al. 2019). For example, although wildlife management is not integrated into community forest operational plans, people do perceive that wildlife presence is an important indicator of sustainable forest management (Pokharel and Tiwari 2018).

The objective of this study was to use local knowledge as an indicator of wildlife presence and abundance across southeastern Nepal in order to provide a landscape-level baseline of wildlife presence, highlight the potential value of the area for biodiversity conservation, and guide the prioritization of areas for research and conservation activities. While community surveys have successfully been used to collect information about individual species (e.g., Pan et al. 2016; Nash et al. 2016), as far as we know, this is the first time community knowledge has been used across a large landscape to understand the diversity and abundance of many species of wildlife.

Methods

Study area

The study area covers the forested areas from the Baghmati River in central Nepal to the Mechi River on the eastern border of Nepal and includes eleven districts between Sarlahi and Jhapa Districts (Fig. 1). The area is under high human pressure and has relatively high forest loss (Bhuju et al. 2007; Ghimire 2017). Much of the remaining forest in the area is in the Churia Range, which is increasingly being recognized as an area vital to conservation (Singh 2017) because of its role in filtering and providing water for the terai, the southern plains region, of Nepal (Bhuju and Yonzon 2004; Singh 2010).

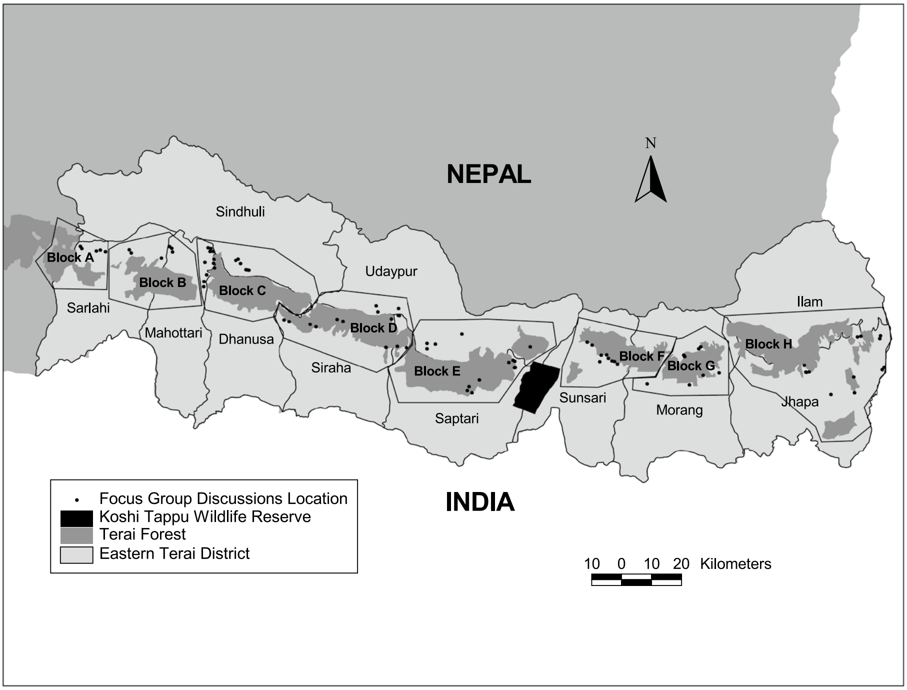

Fig. 1 Map of the study area, showing terai forest blocks and locations of focus group discussions (held in or near villages or in community forests)

While degraded and fragmented (Thapa 2016), these forests contain species of conservation interest, such as elephants *(Elephas maximus*) (Neupane et al. 2017), fishing cats (*Prionailurus viverrinus)* (Taylor et al. 2016), and wild buffalo (*Bubalus arnee*) (Heinen and Kandel 2006).

These forests also have the potential to provide additional habitat for species expansion, such as tigers (Aryal et al. 2016; Thapa and Kelly 2017a). Nepal is a model country for tiger conservation, on track to double the population by 2025, but it is unclear if there is sufficient habitat and prey to achieve this goal (Aryal et al. 2016). While Churia forests were previously ignored as potential tiger habitat, recent studies highlight the existence of tigers in the Churia Range of Chitwan National Park (Thapa and Kelly 2017a, b) and tigers have expanded eastward when conditions are conducive, for example, into Parsa National Park (Lamichhane et al. 2018).

Community forest focus groups

We surveyed the largest community forests from the Bagmati River to the Mechi River on the eastern border in eleven districts between the Sarlahi and Jhapa Districts (Table 1). Community forests were selected based on their size from lists published by District Forest Offices. In total, we conducted 114 focus group discussions with community forest user group (CFUGs) members and other community members in 96 community forests between March 2014 and January 2015. In each district, we conducted between two and eleven focus group discussions (Table 1) and from five to 23 focus groups within each forest block (Table 2 and Fig. 1). The average size of the community forests in the study was 323 hectares and the average age was 14 years. We analyzed data by block, but we also present district summaries because sampling was done at the district level and community forests are registered by district and show patterns in their registration, both in terms of when they registered and the size.

We showed the focus groups laminated pictures of 56 species copied from Baral and Shah (2008). We asked groups to discuss and decide how often they saw each species based on these response categories: “never,” “only in the past,” “rarely (< 1 time per

Table 1 Description of community forests in study by district

District	Community forests in study	Size (hectares)		Age of CFUG in 2015 (years)	
	N	Mean	SD	Mean	SD
Dhanusa	4	470	213.3	17.0	0.00
Ilam	2	385	21.2	19.5	0.71
Jhapa	10	432	140.1	14.1	8.14
Mahottari	8	249	112.3	15.0	3.59
Morang	10	250	214.4	8.7	5.52
Saptari	10	210	89.3	18.4	3.66
Sarlahi	11	340	187.5	12.2	3.89
Sindhuli	11	266	122.2	11.3	6.31
Siraha	10	398	218.6	12.6	3.13
Sunsari	10	363	279.1	16.1	1.20
Udayapur	10	314	123.7	17.9	3.31
Total	96	323	183.7	14.2	5.37

Table 2 Description of community forests in study by forest block

Block	Districts in block	Community forests in study	Size (hectares)		Age in 2015 (years)	
		N	Mean	SD	Mean	SD
A	Sarlahi	5	343	232.8	15.8	2.77
B	Sarlahi, Sindhuli, Mahottari	6	337	164.0	9.2	0.41
C	Sindhuli, Mahottari, Dhanusa	23	295	154.0	13.6	5.26
D	Siraha, Udayapur	15	354	188.2	14.8	4.09
E	Saptari, Udayapur	15	261	135.3	17.8	3.90
F	Sunsari, Morang	11	357	265.6	15.5	2.42
G	Morang	9	245	226.7	8.7	5.85
H	Jhapa, Ilam	12	424	128.2	15.0	7.66
Total		96	323	183.7	14.2	5.37

year)", "regularly (many times in 1 year)," and "commonly (all the time)." Each response was coded: never = 0, only in the past = 0.5, rarely = 1, regularly = 2, commonly = 3.

In some community forests, multiple discussions with different groups were held (i.e., CFUG committee members forest guards, and women forest users). In those cases, we combined the data from the different groups in one community forest by using the highest abundance for each species that was given in a discussion. By doing this we chose to err on the side of overestimated wildlife presence and we avoided the issue of a group not seeing a species or not seeing as often as another because they entered the forest less frequently.

Analysis

We organized the analysis around the following four questions:

1) Where do people report having the greatest number and abundance of species?
2) Where do people report the greatest number and abundance of tiger prey species?
3) Where do people report species occurring in the past but not at the present time?
4) Where do people report the presence of species of special interest (endangered and data deficient)?

To answer the first study question, we summarize the data by forest blocks (Fig. 1). Across the community forests in each block, we calculate the mean number of species present and the mean abundance score (how frequently species were seen). The number of species is the total number of species that a group said was present in their community forest. The abundance score is the sum of the responses for how often species were seen. We recognize that our use of the term "abundance" to summarize how often species were seen is not strictly the correct use of abundance in the ecological sense, but we use it as a proxy for how common species are. Species were not included if they were seen in only the past.

The mean total number of species in a block is the mean of the total number of species across the community forests in each block. The mean total abundance of species in a block is the mean of the total abundances across the community forests in each block.

For the second question, we perform similar calculations to obtain the mean number of tiger prey species and the mean tiger prey abundance score by combining the scores for the following prey species: gaur, wild water buffalo, nilgai, four-horned antelope, Himalayan serow, goral, sambar, chital, hog deer, barking deer, wild boar, and pygmy hog. Again, species were not included if they were seen in only the past (0.5).

For the third question, to describe possible species loss, we describe how many species and which species in each block were seen only in the past and the number of community forests within each block that reported seeing at least one species only in the past.

For the fourth question, we summarize the data on endangered species and data deficient species and present information for species of particular interest. For each block, similar to total species and prey species, we describe the mean abundance and mean number of endangered species and the mean abundance and mean number of data deficient species across the community forests. We also present data for individual endangered and data deficient species in Online Appendix S1 showing the percentage of community forests reporting each species' presence within each block.

Endangered and data deficient species are defined according to their listing in Nepal's National Red List (Jnawali et al. 2011). Endangered species include Asian elephant, hog deer, gaur, sambar, large-toothed ferret badger, Indian and Chinese pangolins, sloth bear, Asian black bear, dhole, striped hyena, honey badger, fishing cat, clouded leopard, smooth coated otter, hispid hare, black giant squirrel, and spotted linsang. Data deficient species include Indian crested porcupine, Malayan porcupine, four-horned antelope, marbled cat, golden cat, Burmese ferret badger, Himalayan serow, and Asian small-clawed otter. We also included one species considered extinct in the wild, the pygmy hog.

Results

Species richness and abundance

Across the forest blocks, the mean number of species present was 21 (SD = 6.3) and the mean abundance was 43 (SD = 13.6) (Fig. 2). Blocks C and G contained the highest number of species and abundance of species.

Tiger prey species

For tiger prey species, the mean number of species present was 3.2 (SD = 1.11) and the mean abundance was 6.3 (SD = 2.52). The mean prey abundance and total number of prey species was higher toward the eastern side in blocks D through G.

Species seen in the past

Blocks C, G, and H had the largest percentage of community forests reporting having seen at least one species in the past but not at the present time and the greatest total number of species in the past but not at the present time (Table 3). For example, seven of the nine community forests (78%) in block G reported that they do not see at least one species at the present time and those seven community forests reported thirteen species not currently seen.

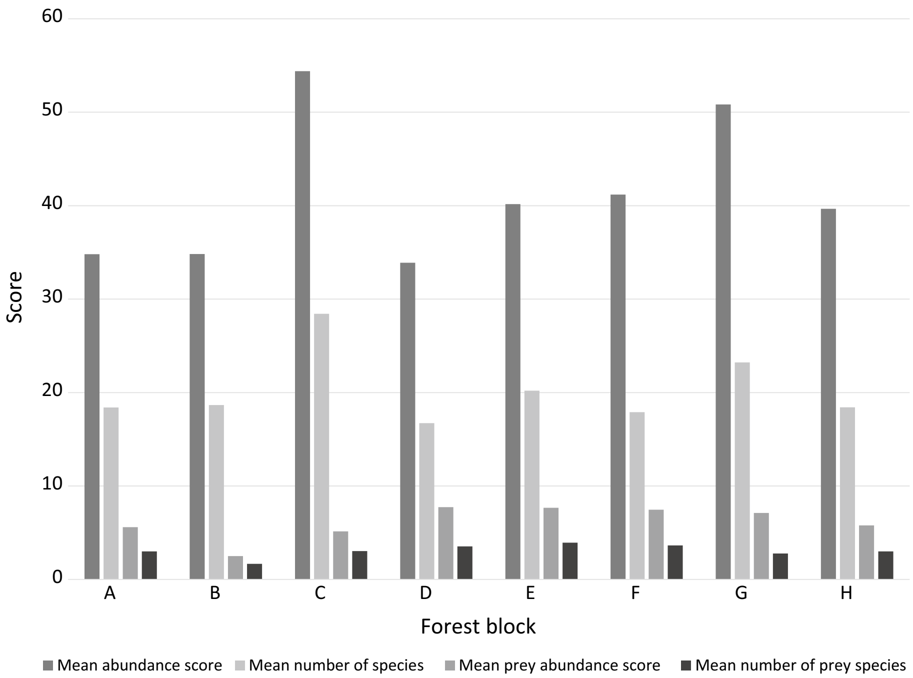

Fig. 2 Mean total number and mean abundance of all species and prey species for each forest block

Species of special interest

The number and abundance of endangered and data deficient species that communities reported show the same pattern as the overall species patterns across the blocks. Fewer species were on the western side in blocks A and B and more were on the eastern side with the greatest mean number and abundance of endangered and data deficient species in blocks C and the four easternmost blocks (E–H) (Fig. 3).

Elephant (EN) and the Malayan porcupine (DD) were the only endangered or data deficient species that were reported occurring in all blocks (see Appendix S1 for summary of endangered and data deficient species). The Indian and Chinese pangolins (both EN), the fishing cat (EN), the black giant squirrel (EN), and the four-horned antelope (DD) were reported occurring in all but one block each.

The pygmy hog (EW) is critically endangered and only known to occur in one location, Manas National Park in northwestern Assam, India. However, four community forest groups reported seeing pygmy hogs in the present or past: one community forest in block F reported seeing pygmy hog commonly, two community forest groups in block E reported seeing pygmy hogs regularly, one community forest reported seeing it rarely, and one community forest in block G reported seeing pygmy hog in the past (Fig. 4). In 2019, our team followed up on these reports with communities but to date have found no evidence of pygmy hog occurring in these locations.

Dhole (EN) is thought to occur outside of our study area to the west of the Baghmati River, but in this study people reported them in the middle of the study site (blocks C, D, and E). Striped hyena (EN) was reported mainly in the western side of the study

Table 3 Summary of species seen in the past for each forest block

Block	Community forests	Community forests reporting at least one species in the past	Community forests reporting at least one species in the past	Species seen in the past	Species seen in the past
	N	N	%	N	
A	5	0	0	0	
B	6	0	0	0	
C	23	10	43	7	Tiger, elephant, wild water buffalo, striped hyena, chital, red giant flying squirrel, wild boar
D	15	1	3	1	Hispid hare
E	15	0	0	0	
F	11	1	9	2	Tiger, common leopard
G	9	7	78	13	Tiger, common leopard, nilgai, wild water buffalo, gaur, jackal, leopard cat, marbled cat, clouded leopard, barking deer, Indian porcupine, dhole, pygmy hog
H	12	5	42	6	Common leopard, tiger, wild water buffalo, striped hyena, Bengal fox, jackal

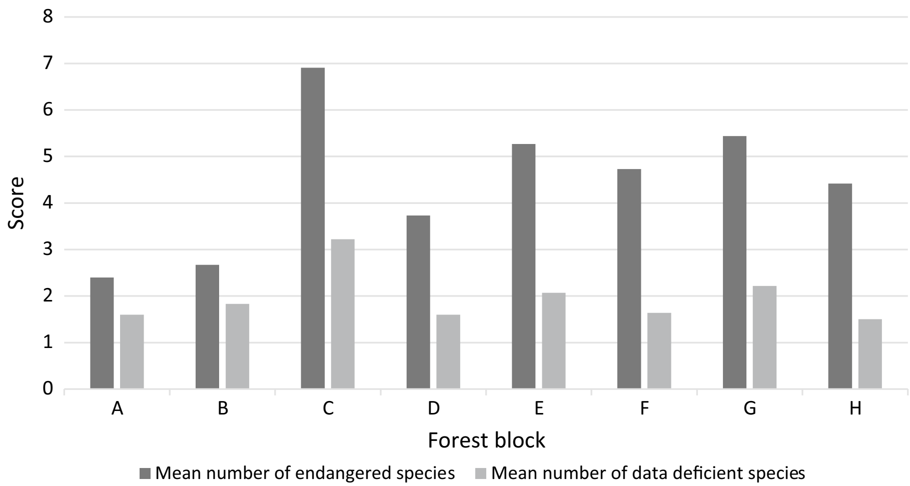

Fig. 3 Mean number of endangered and data deficient species for each forest block

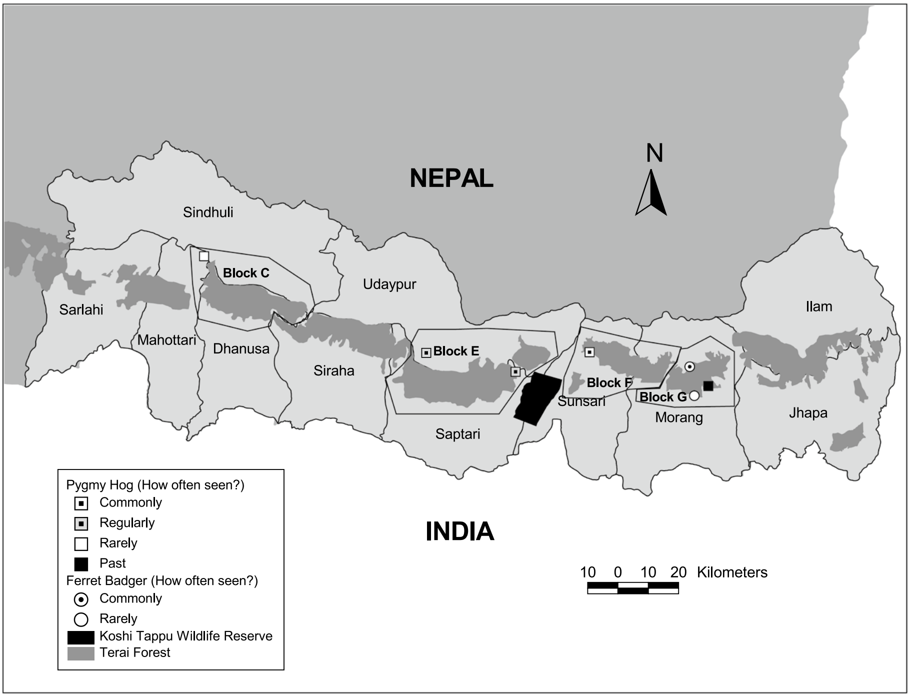

Fig. 4 Reported locations of pygmy hog and ferret badger (note: sites are where interviews were conducted, not actual pygmy hog sightings)

area, which matches the fact that hyena live in drier areas and the western area is drier. Hog deer (EN) was reported mainly in the eastern half of the study site. Gaur (EN) was reported only in block G, where they are known to exist in the wildlife reserve. Sambar (EN) was reported in only two blocks, C and H.

Data deficient species of particular interest include the ferret badger and the marbled and golden cats. The ferret badger is very rare and little is known about them in Nepal. It was reported in only two community forests in block G (Fig. 4). Interestingly, it was reported in the area where the fourth and fifth co-authors of the study, who are mammal experts familiar with the species in Nepal, predicted it might be before we began analysis of the data. The marbled and Asiatic golden cats were reported primarily in the middle section of the study area.

Discussion

Our results provide landscape-level data on wildlife species and the potential conservation value of different forest blocks in terms of wildlife and tiger prey diversity and abundance, loss of species, and endangered and data deficient species. Overall, forest blocks C and G in the middle of the study area have the greatest diversity and abundance of wildlife species and tiger prey species (Fig. 5). The blocks with greatest potential threats, based on the number of species seen in the past but not in the present, are block C on the western side and the two easternmost forest blocks (G and H). The loss of species reported on the

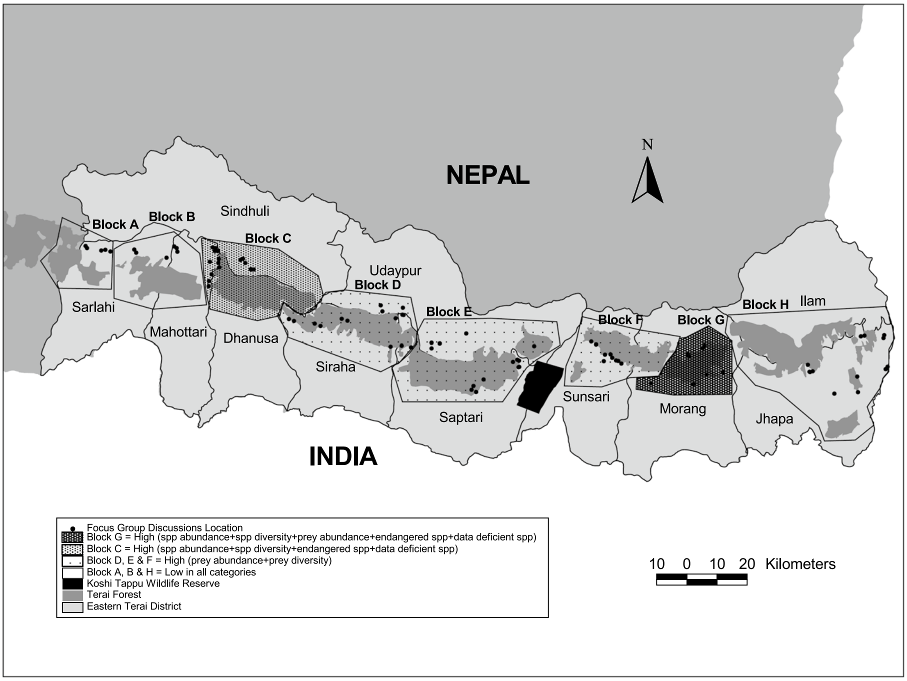

Fig. 5 Summary of blocks in terms of species diversity, tiger prey species, species loss, and species of conservation interest

eastern side corresponds with the overall lesser biodiversity in the easternmost blocks. The largest number of species of interest (endangered and data deficient) are found in block C and the eastern forest blocks E through H.

These results also provide helpful information for further study of the presence and distribution of specific species. For example, further studies on the ferret badger might want to focus on the two forest blocks where communities reported their presence.

We do not propose that these results are an accurate or reliable representation of biodiversity in southeastern Nepal. However, they are indicators of wildlife presence and abundance that can help prioritize areas for additional research and complement traditional wildlife survey techniques (Berkes et al. 2000). The data is probably more accurate for some species than other species. For example, people's perceptions of large and charismatic wildlife, such as elephants, is usually fairly accurate (Meijaard et al. 2011), while species that are small, cryptic, and difficult to distinguish from other species may be less accurate (Caruso et al. 2017). Although studies have found that people's knowledge is more accurate than predicted for smaller "non-charismatic" species (Turvey et al. 2014; Pan et al. 2016; Nash et al. 2016). For example, 90% of people were able to recognize pangolin in Hainan, China (Nash et al. 2016).

We note that there are additional factors that may influence people's knowledge of the forest and awareness of wildlife species. For example, in Block C, people's perceptions of wildlife diversity and abundance may be influenced by a non-government organization, Community Development and Advocacy Forum (CDAFN), who assisted us in conducting the focus groups. CDAFN has have been conducting water and irrigation projects in the area since 2006 and recently won the WWF Nepal Conservation Award (2019) for their work, which includes the construction of water conservation ponds. The ponds are primarily for the conservation of water for irrigation, but they have recorded more than 10 species of wildlife using the ponds. Project activities may have influenced people's perceptions in three ways, all of which could be true. Project activities may have: (1) increased the number of species in the area and the numbers of wildlife; (2) increased people's awareness of the wildlife in their forests and the likelihood that they see wildlife; and/or (3) have biased people to report more species of wildlife and greater numbers.

What are the landscape conservation implications of our results? There are many different ways our results can be incorporated into landscape conservation planning and prioritization of areas for conservation and research. In terms of prioritizing areas for conservation, areas with low diversity in the west and east of the study area might be prioritized because they may be bottlenecks, isolating the forests in the middle. On the other hand, forest blocks in the central area, which have more wildlife diversity, might be prioritized in order to ensure the continued existence of wildlife species in these areas. In terms of tiger conservation, because the forest blocks with tiger prey species are located in the middle of the area, this may indicate that the potential for tiger to expand from Chitwan and Parsa National Parks into eastern Nepal is limited without efforts to increase prey species on the western side of the study area. In terms of research, the greater reporting of species loss in the most eastern forest blocks and block C would be interesting to explore further. Does it indicate a higher number of threats to species in these areas and/or greater forest degradation? Or are communities more aware about biodiversity and so are more sensitive to species loss?

In addition to complementing wildlife surveys and helping to prioritize area for conservation, the survey process and results also help to build a foundation for wildlife conservation with local communities by raising their awareness and beginning a dialogue about wildlife (Steinmetz et al. 2006). It provides a place to start a conversation with communities about wildlife in their forests and the relationship of their forests to the corridor. For example, following up on the survey work, our team has conducted wildlife monitoring workshops and have initiated camera trapping in areas on either side of the Koshi Tappu Wildlife Reserve. Ultimately, research and projects like this will provide communities the information they need to integrate wildlife conservation into their community operational plans.

Conclusion

The forests of southeastern Nepal are of conservation interest because of their importance for human populations that depend on them for ecosystem services and because of the diversity of species that live within them. Forest in the middle of study around on either side of Koshi Tappu particularly has potential for wildlife conservation while the forest on the western and eastern side represent potential corridors to link forests and protected areas across the landscape. This study demonstrates the potential usefulness of community surveys to describe wildlife across a large landscape and how community knowledge can highlight areas of special interest and areas that may benefit from additional conservation investment and research.

Acknowledgements We would like to thank the community members, CFUG committee members, and forest guards who participated in this study and gave their time and expertise. We would like to thank Birendra Mahato and Shiva Mahato at Green Society Nepal for coordinating the survey and assisting with focus groups. We also thank Community Development & Advocacy Forum Nepal (CDAFN) for conducting the focus group discussions and collating the data. Thanks also to Shankar Luitel for assisting with focus groups on the eastern side of the study area and Baburam Mahato of the Nepal Tiger Trust for his help in the initial reconnaissance of the study area. We would like to acknowledge Dr. Rob Horwich, director and founder of Community Conservation, Inc., who had the vision for an eastern wildlife corridor and initiated and funded the survey but unfortunately passed away before the study's completion.

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