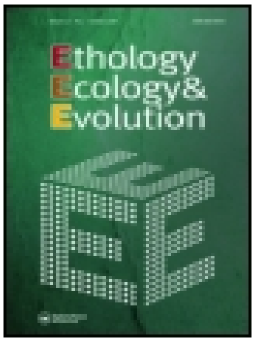

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Using interviews and biological sign surveys to infer seasonal use of forested and agricultural portions of a human-dominated landscape by Asian elephants in Nepal

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Understanding how wide-ranging animals use landscapes in which human use is highly heterogeneous is important for determining patterns of human–wildlife conflict and designing mitigation strategies. Here, we show how biological sign surveys in forested components of a human-dominated landscape can be combined with human interviews in agricultural portions of a landscape to provide a full picture of seasonal use of different landscape components by wide-ranging animals and resulting human–wildlife conflict. We selected Asian elephants (*Elephas maximus*) in Nepal to illustrate this approach. Asian elephants are threatened throughout their geographic range, and there are large gaps in our understanding of their landscape-scale habitat use. We identified all potential elephant habitat in Nepal and divided the potential habitat into sampling units based on a 10 km by 10 km grid. Forested areas within grids were surveyed for signs of elephant use, and local villagers were interviewed regarding elephant use of agricultural areas and instances of conflict. Data were analyzed using single-season and multi-season (dynamic) occupancy models. A single-season occupancy model applied to data from 139 partially or wholly forested grid cells estimated that 0.57 of grid cells were used by elephants. Dynamic occupancy models fit to data from interviews across 158 grid cells estimated that monthly use of non-forested, human-dominated areas over the preceding year varied between 0.43 and 0.82 with a minimum in February and maximum in October. Seasonal patterns of crop raiding by elephants coincided with monthly elephant use of human-dominated areas, and serious instances of human–wildlife conflict were common. Efforts to mitigate

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human–elephant conflict in Nepal are likely to be most effective if they are concentrated during August through December when elephant use of human-dominated landscapes and human–elephant conflict are most common.

KEY WORDS: Asian elephant, human–wildlife conflict, Nepal, occupancy, seasonal use.

INTRODUCTION

Understanding how wide-ranging animals use landscapes in which human use is highly heterogeneous is important for determining patterns of human–wildlife conflict and designing mitigation strategies. To understand patterns of mammalian occupancy over large landscapes, biologists frequently gather sign survey data (Karanth et al. 2011). Although these surveys are frequently focused on forested and other natural habitats, wildlife use of agricultural areas, and other human-dominated portions of a landscape, could conceivably be addressed using sign surveys as well. On the other hand, surveys of local people may provide a more efficient means of determining wildlife use of an area, particularly when use is highly seasonal. Here, we illustrate how information from sign surveys and questionnaires of local people can lead to a more complete understanding of wildlife habitat use in human-dominated landscapes. Specifically, we study how Asian elephants (*Elephas maximus*) use forested and agricultural portions of the landscape in Nepal.

Asian elephants have great ecological and cultural significance throughout Asia (Sukumar 2006). However, they are threatened throughout their range primarily due to habitat loss, human–elephant conflict and poaching for ivory (Jathanna et al. 2015). Asian elephants need large areas to fulfill their seasonal food and water requirement, which often leads to conflicts with humans (Sukumar 1991; Hoare & Du Toit 1999; Williams et al. 2001). As in other range countries (Blake & Hedges 2004; Jathanna et al. 2015; Lakshminarayanan et al. 2016), there is limited understanding on the status and distribution of Asian elephant in Nepal. Nearly 200 wild and another 250 captive elephants are estimated to exist in Nepal (DNPWC 2009) across the narrow and fragmented landscape in Terai and Churia Hills (Pradhan et al. 2011). Understanding the ecological and anthropogenic factors that drive their spatial distribution is crucial to prioritize conservation actions (Jathanna et al. 2015).

Most of the earlier ecological and population studies on elephants in Nepal are limited to small pockets of the Terai Arc Landscape, with a focus on protected areas (Pradhan & Wegge 2007; Pradhan et al. 2008). These studies focused on population size, density and ecology (Pradhan & Wegge 2007). In addition, much of the data on distribution and status are relatively old and may not accurately reflect the current status of the species. This absence of updated data on status and distribution seriously impairs the ability to develop suitable conservation and management strategies. A major management concern in Nepal is the frequent conflict between elephants and people [e.g. crop raiding, property damage, human killings and retaliatory killing of elephants (Choudhury 2004; Pradhan et al. 2011)]. As elephant movement appears to be driven by both seasonal changes in their forest habitat (Pradhan & Wegge 2007) and seasonal crop patterns (Sukumar 1991; Osborn 2004; Campos-Arceiz et al. 2008) it is important to analyze how space use by elephants varies over the course of a year to determine the seasonality of conflict-prone zones at a landscape level.

Elephant population abundances and distributions have been studied using several methods based on both direct sighting (Karanth & Sunquist 1992; Varman & Sukumar 1995) and indirect signs (Dawson & Dekker 1992). Telemetry can be used to study elephants, but it is expensive and logistically challenging. Population size can be estimated at the local scale (i.e. individual reserves) but extrapolation from these local scales to large areas (i.e. regional or national scale) will vary widely in reliability (Blake & Hedges 2004; Jathanna et al. 2015). Occupancy modeling, on the other hand, offers a useful alternative for estimating distributions and space use (MacKenzie et al. 2006) at a relatively low cost over regional or national spatial extents (Jathanna et al. 2015). Moreover, participatory research surveys can also be incorporated with occupancy models to account for imperfect reporting. These surveys can also help to quantify human–elephant conflict (Goswami et al. 2014).

Here, we use occupancy models to analyse data from both sign surveys and interview questionnaires to gain a more complete understanding of wildlife use and human–wildlife conflict than either approach would offer in isolation. In particular, our objective is to estimate elephant habitat use, including seasonal use of agricultural land, as well as human–elephant conflict throughout the Terai and Churia regions in Nepal.

METHODS

Study area

The study area encompasses Nepal's Terai and Churia regions (Fig. 1).The Terai lies in the most southern part of Nepal and borders with India. The Terai is the northernmost portion of the Ganges floodplain and is a highly fertile flat land of alluvial deposits. The Churia is located north of the Terai and includes three physiographical and geographic zones: the Churia Hills, Dun Valleys, and Bhabar (Johnsingh et al. 2004). The Churia Hills are young mountains composed of sandstones and conglomerate, and run parallel to the southern boundary of the Mahabharat Range (Chanchani et al. 2014). The Bhabar is characterized by a low-gradient terrain with porous, coarse alluvium and boulders. The Dun Valleys, also known as the inner Terai, are the valleys in between Churia Hills.

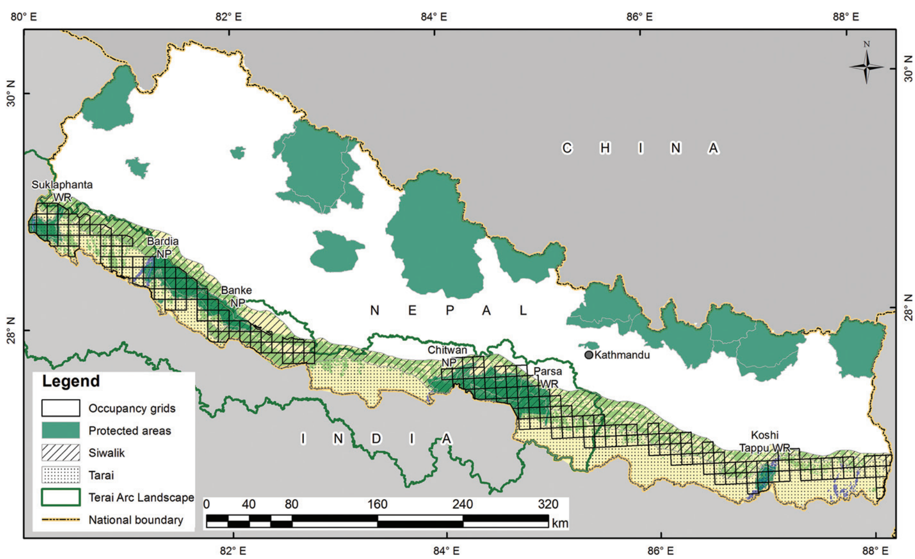

Fig. 1. — Map showing Nepal's Terai and Siwalik region along with protected areas and occupancy survey grids (10 × 10 km^2) overlaid. Each occupancy grid was further sub-divided into four girds of 5 × 5 km^2 for the human questionnaire survey.

The Terai and Churia have a sub-tropical monsoonal climate with four distinct seasons defined here as winter (mid-December/mid-March), pre-monsoon (mid-March/mid-June), monsoon (mid-June/mid-September), and autumn (mid-September/mid-December). Mean monthly temperatures range from 35–40 °C in the hottest months (May/June) to 14–16 °C in mid-winter (January) (Jackson et al. 1994). The mean annual rainfall ranges between 1138 and 2680 mm, with over 80% of the rain occurring during the 3 monsoon months and greater amounts of rain in the more Eastern portions of the region.

Until the early 1900s, most of Nepal's Terai and Churia were covered by forests, grasslands, wetlands, and rivers. Malaria was prevalent throughout the Terai until eradication efforts in the mid-1950s, which facilitated rapid transmigration from the middle hills of Nepal. At present, the Terai region covers only ~ 14% land area of the country but contains more than half of Nepal's population (CBS 2011). Increases in human populations were associated with widespread forest clearing in the lowlands. According to the most recent forest inventory (DFRS 2015) only 20.87% of the Terai is covered by forest (canopy cover > 10%) or other wooded land (tree canopy 5–10% and shrubs). The Churia has a higher percentage of forest cover (73.56%) than the Terai; however the Churia's current annual rate of deforestation of 0.18% (DFRS 2015) is the highest in Nepal.

The Terai and Churia contain five national parks, a wildlife reserve, six buffer zones, and one conservation area, which provide habitat for endangered species including elephants, tigers, and rhinos. In addition, there is a large amount of forest outside of the protected areas that are managed by government (national forest) or communities (community forest), or jointly managed (collaborative forest). The Terai Arc Landscape (TAL) was established in 2000 in recognition of the importance of these forests to landscape conservation (Wikramanayake et al. 2004). Two thirds of the Nepal's Terai and Churia lies within the TAL, which envisions connecting the protected areas by forest corridors and providing additional habitat for wildlife.

Survey design and allocation of effort to elephant sign surveys versus human questionnaires

Elephants in Nepal are confined to the Churia and Terai. We divided all elephant reported habitats across Nepal into 10 × 10 km grids based on the average home range of a female elephant (ca 100 km^2, Fernando et al. 2008). A total of 167 grids of 10 × 10 km^2 were identified throughout the Terai of Nepal. During the survey design, the amount of forest cover in each grid was calculated from the forest cover data in digital topographic maps available from the Survey Department of Nepal. Survey effort in a grid was in proportion to the amount of forest coveras detailed below. Each 10 × 10 km grid cell was also divided into four 5 × 5 km sub-grids, and human questionnaires surveys were conducted in sub-grids that contained a village. A total of 139 grids with > 10% forest cover were surveyed for elephant signs, while questionnaires were administered in 158 of these survey grids (more details on both methods).

Elephant sign surveys

In each grid, up to four linear features (e.g., trails, stream beds, etc.) approximately 5 km in length were identified in topographic maps produced by Department of Survey, Nepal. Survey effort (i.e., the number of linear features surveyed) was proportional to forest cover and varied from one in grids with less than 25% forest cover to four linear features in grids with 0.75% forest cover (Karanth et al. 2011). A team of wildlife technicians consisting of two to four people surveyed along the river beds or dusty roads carefully and searched for elephant foot tracks, dung piles or any other signs. Animal signs (dung or foot prints) were recorded at 1 km intervals. Wildlife technicians were trained on data-collection methodology and survey design (Appendix) before field surveys. The first author and a coauthor (B.S. Thakuri) continuously monitored the field surveys and checked the data quality. All surveys were carried out during the months of November/February, when elephant signs are likely to persist for many days. Since these linear features were not connected in one single line and were usually separated, we chose to analyse data using a simple single-season occupancy framework (MacKenzie et al. 2002) where each 5 km linear feature was treated as a replicate, rather than in the correlated detection framework (Hines et al. 2010). Although using spatial replicates over temporal replicates can be problematic in general, such concerns are not as important if the species of interest is highly mobile relative to the spatial grain of interest over the period during which closure is assumed (Kendall & White 2009).

We considered the following potential covariates for occupancy: (1) the total length of streams in the grid cell, (2) the total length of rivers in the grid cell, (3) forest management type (protected area, community forest and national forest), (4) human population density, and (5) forest cover. Streams and rivers data were derived from digital topographic maps of 1:25,000 scale produced by Survey Department of Nepal between 1995 and 1996 (http://ngiip.gov.np/index.php). Forest cover data were obtained from Forest Resources Assessment (DFRS 2015), and human population density was derived from Gridded Population of the World (V4) of NASA for the year of 2015. A priori, we hypothesized that occupancy would be positively related to streams, rivers, and forest cover, and negatively related to human population density. Correlations between these potential predictors were low ($|r| < 0.40$) with the exception of human population density and forest cover, which were highly negative correlated ($r = -0.70$). While we still considered models with both population density and forest cover, we carefully examined these results for evidence of multicollinearity, and in the end neither of these covariates was present in the best models. We expected occupancy to be highest in the protected area. We also tested hypotheses that detection probability might vary by management zone and by whether the linear feature was associated with water (e.g., river and stream banks). A priori, we predicted that detection would be higher on linear features associated with water, and that detection probability would be higher in protected areas because of higher densities of elephants in protected areas and/or differences in the behavior of elephants in protected areas. We considered all possible combinations of occupancy and detection covariates but only report models within 10 AIC of the top model that do not include uninformative parameters (sensu Arnold 2010). Analyses of biological survey data were conducted in PRESENCE (version 9.7).

Questionnaire survey

To understand monthly elephant use of human-dominated landscapes and the extent of human–elephant conflict, a questionnaire survey was conducted across the study area except the grids that entirely fall into the protected areas or forests, as there were no villages. Each 10×10 km^2 grid was further divided into four sub-grids of 5×5 km^2, and up to three respondents were selected for the questionnaire survey in each sub-grid from the forest fringe areas (< 2 km from nearest forest). A semi-structured questionnaire was developed and field-tested in buffer zone of Chitwan National Park with five respondents. The finalized questionnaire incorporated feedback of field test and was reviewed and approved by the Nepal Government as part of permission for the project, prior to use in the field. Generally, the interview was conducted in village tea shops or other public places where interviewees were in leisure and had sufficient time to complete the interviews. Only adults (aged of > 18 years) who had lived within the area for 5 years or more were interviewed. Questionnaires were anonymous and voluntary, and only included questions related to wild animals and damage done by wild animals. Questionnaires were conducted only by staff of the National Trust for Nature Conservation, who received training in research ethics.

Each interviewee answered a series of questions relating to elephant presence over the preceding year and human–elephant conflict over the past 5 years. Interviewees reported the months during the prior year in which elephants were observed in the general area. Interviewees also reported the months during the last 5 years during which crop-raiding behavior had occurred; however, we aggregated crop-raiding data into four seasons for analysis. For damage to house or property or human death or injury, which have previously been shown to occur less frequently (Pant et al. 2016), interviewees were asked only if it had occurred in the last 5 years. Human–elephant conflict data were analyzed in a series of single-season occupancy models (i.e., one model for damage to property, another for human death, etc.). For each category of human–wildlife conflict, occupancy is interpreted as a probability of one or more human–elephant conflicts either over the whole 5-year period (for property damage and human injury/death) preceding the interview or over 5 years of that particular season (for crop-raiding data). For all categories, detection probability is interpreted as the joint probability that an interviewee was aware of the conflict and reported the conflict. All single-season analyses based on human surveys were simple models in which detection probability and occupancy were assumed constant.

Reports of elephant use of human-dominated areas were analyzed using dynamic (multi-season) occupancy models, which estimate occupancy in the initial month (January) and then changes in occupancy (local colonization and local extinction) over the following months (MacKenzie et al. 2003, 2006). For the dynamic model, we considered models where colonization, extinction, and detection probability were allowed to be either constant or time-specific. We also considered the constrained model in which extinction and colonization sum to 1, which corresponds to a model in which occupancy/use in month, $t + 1$, is independent of occupancy/use in the preceding month, t. A priori, we predicted that elephant use of human-dominated portions of the landscape would be highest during the autumn months when many crops preferred by elephants are available (Pant et al. 2016). We expected to see increased local colonization in these months, followed by increased local extinction in the winter months, as elephants lowered their use of these areas. We also hypothesized that detection probability would be greatest in these months, as detection probability often reflects higher abundance or intensity of use in occupancy surveys (Royle & Nichols 2003). Analysis of questionnaire data was conducted in PRESENCE (version 9.7).

RESULTS

Signs surveys of forested areas

A total of 349 five-kilometer linear features were surveyed for elephant signs across 139 survey grids, and elephant signs were recorded from 65 grids (naïve estimate of occupancy equal to 0.47). The best model included streams in the occupancy portion of the model, but with a negative sign, contrary to our a priori hypothesis (Figs 2A, 3). A model with community forest in the occupancy portion of the model also received modest support and indicated that elephant use was lower in grids that included primarily community forest (Fig. 2B). A model with constant occupancy was also competitive and estimated occupancy at 0.57 (SE = 0.06) across surveyed grid cells. Analysis of the elephant track surveys provided strong support for the hypothesis that detection probability is lowered in community and national forests relative to protected area (Table 1, Fig. 2D).

Monthly elephant use of human-dominated landscapes derived from questionnaires

A total of 745 individuals were interviewed from 21 districts of Terai and Churia, providing information on monthly use of the area in the past year, and levels of human–elephant conflict over the preceding 5 years. Out of 158 survey grids where interviews were conducted, respondents reported that elephants were present in 127 grids (80.3%) for some period of time in the previous year. The best model of monthly elephant use in grid cells occupied by humans included month-specific colonization, extinction, and detection probability, and received very strong support over competing models (ΔAIC > 10). Models in which the sum of extinction and colonization was constrained to equal 1 were poorly supported, suggesting that use of a particular grid cell is highly dependent on whether it was used in the prior month. Initial probability of use during January was estimated at 0.51 (SE = 0.05) and declined through the spring and pre-monsoon

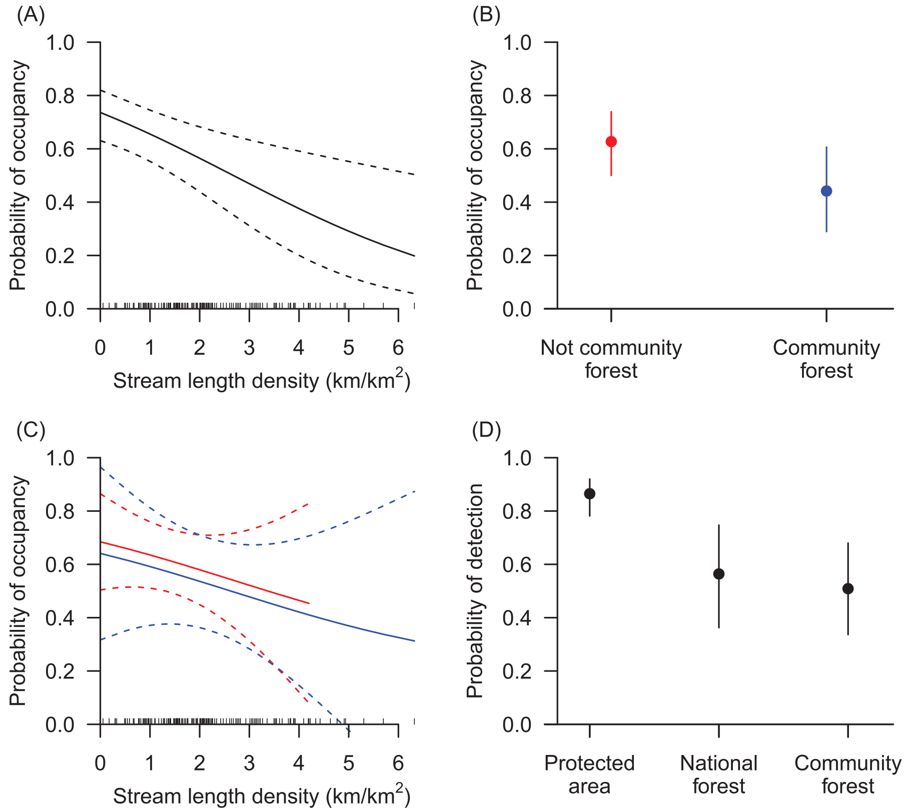

Fig. 2. — Unconditional estimates of elephant occupancy and detection probability. (A) In the best model, occupancy is negatively related to the density of streams in a grid. (B) In a second competitive model, occupancy is explained by whether forests in the grid are predominately community or not community forest (i.e., national forest or protected areas). (C) Model averaged results are primarily shaped by these two covariates. (D) Probability of detection differed between three forest types.

months, as extinction was relatively high, and colonization was low (Fig. 4A–C). During the monsoon and early-autumn months, colonization increased, and extinction declined, leading to increasing use of the human-dominated landscape. During the last part of autumn, declining colonization and increased extinction led to a decline in elephant use of the human-dominated portions of the landscape (Fig. 4A–C). The probability that respondents reported that elephants were present when they were present was relatively constant across most months around approximately 0.30–0.35, with the exception of October and November, when it increased to 0.52 (SE = 0.02) and 0.53 (SE = 0.02) respectively (Fig. 4D).

Incidence of human–elephant conflict and seasonal timing of crop raiding

Seasonal estimates of crop-raiding occurrence over the 5 years prior to the interviews followed a similar pattern to elephant use over the preceding year. The proportion

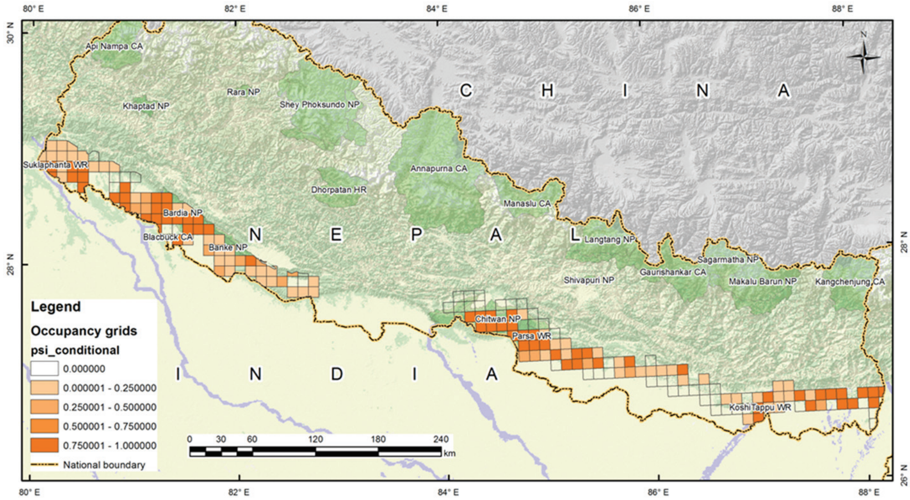

Fig. 3. — Conditional estimates of elephant occupancy in the surveyed grids.

of grid cells with one or more instance of crop raiding in the last 5 years during the pre-monsoon was estimated at 0.56 (SE = 0.06), increasing to 0.70 (SE = 0.07) and 0.82 (SE = 0.07) in the monsoon and autumn respectively before dropping in the winter to 0.67 (SE = 0.05). During the prior 5 years, it was also estimated that 0.69 (SE = 0.04) of grid cells had one or more instances of damage to houses or other property, and 0.58 (SE = 0.06) of grid cells had one or more deaths or major injuries attributable to human–elephant conflict.

DISCUSSION

Our results indicate that Asian elephants use both forested and human-dominated portions of the Terai landscape over the course of the year. Estimates of occupancy/use during the period of sign surveys (November/February) were comparable between forested areas (0.57 ± 0.06) and non-forested, human-dominated areas (November: 0.70 ± 0.04; December: 0.57 ± 0.05; January: 0.50 ± 0.05; February: 0.43 ± 0.05). Sign surveys provide a high-quality snapshot of elephant use of forests during a single season including high probabilities of detection in protected areas (0.87 ± 0.03) and lower detection probabilities in national forests (0.56 ± 0.10) and community forests (0.51 ± 0.09). Our finding of a negative relationship between elephant use of forested areas and the frequency of streams was not expected, but this could indicate a negative response to factors correlated with streams as opposed to avoidance of streams per se. For example, grids dominated by community forest had 59% more streams than grids in protected areas or national forests, and community forests were negatively associated with occupancy in the second best model (Table 1). Similarly, areas with more streams are more likely to be settled by people and used for agriculture. In addition, water may not be as limiting in the season when surveys were conducted as compared with the dry, hot pre-monsoon season.

Table 1.

Top models for biological survey data. All models with informative parameters are presented. Values are estimates followed by standard errors in parentheses. The negative log-likelihood of a model is a measure of the model fit to the data. AIC combines this measure of fit with a penalty for complexity based on the number of parameters, and better models have a lower AIC. ΔAIC is the value obtained by subtracting the lowest AIC in the model set from all models and indicates the distance between the best model (ΔAIC = 0) and other model formulations. NA indicates that the corresponding parameter was not estimated in a particular model.

Occupancy/use			Detection probability					
Intercept	Stream	Community forest	Intercept (protected area)	Community forest	National forest	Number of parameters	Negative log -likelihood	ΔAIC
1.0 (0.3)	– 0.004 (0.001)	NA	1.9 (0.3)	– 1.6 (0.5)	– 1.8 (0.5)	5	344.1	0
0.5 (0.3)	NA	– 0.8 (0.4)	1.9 (0.3)	– 1.6 (0.5)	– 1.7 (0.5)	5	346	1.9
0.3 (0.2)	NA	NA	1.9 (0.3)	– 1.6 (0.5)	– 2.0 (0.4)	4	348.8	2.8
1.0 (0.3)	– 0.004 (0.001)	NA	1.4 (0.2)	– 1.4 (0.4)	NA	4	353.3	7.2
0.5 (0.3)	NA	– 0.7 (0.4)	1.4 (0.2)	– 1.3 (0.4)	NA	4	355.1	9
0.3 (0.2)	NA	NA	1.5 (0.2)	– 1.6 (0.4)	NA	3	357.9	9.8

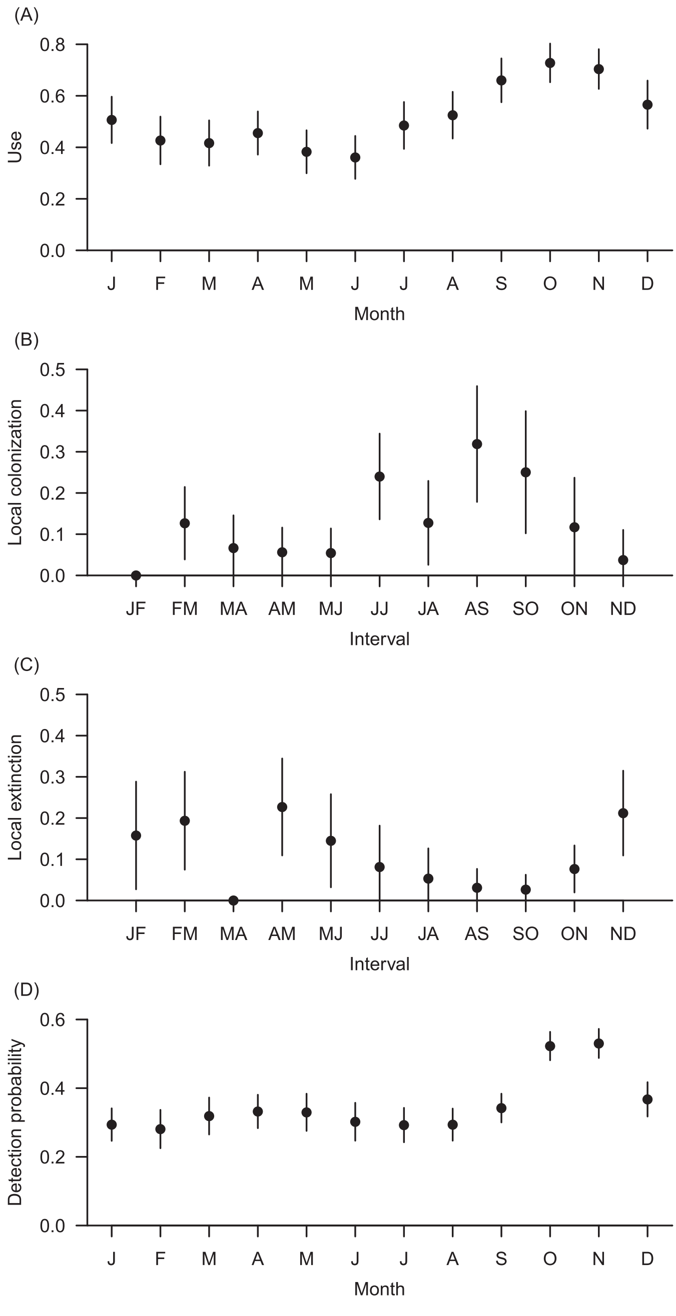

Fig. 4. — Monthly use of human-dominated areas, associated dynamic parameters (local colonization and local extinction), and detection probability based on questionnaire data. (A) Use of human-dominated landscapes peaks during September through November as a result of (B) increased colonization in preceding months, and declines afterwards as colonization declines, and (C) extinction increases. (D) Detection probability increases in October and November as well.

Questionnaire surveys provide a rich, complementary view of non-forested areas in the Terai. Elephant occupancy/use of these human-dominated landscapes varies over different months peaking during the late monsoon and early autumn period (Fig. 4). In a prior analysis, Acharya et al. (2016) found that the seasonal timing of elephant-related human injuries and fatalities was similar, with fewer events during summer and peak rates of injuries and fatalities in the late autumn. Support for Markovian models (i.e., models where occupancy in a given month is dependent on whether it was occupied the prior month) over non-Markovian models (i.e., models where colonization is equal to 1 – extinction) indicates that elephants use the same parts of the human-dominated landscape for many months in a row. This period is also when crops preferred by elephants (e.g. rice and maize) are most abundant in the human landscape, and it is not surprising that crop raiding peaks. While our questionnaires did not evaluate the seasonal timing of damage to houses or human deaths, they do suggest that both these forms of human–elephant conflict were common across the landscape in the 5-year period prior to the surveys. Future work will focus on the seasonal timing of property damage and human deaths as these types of conflict often contribute to negative perceptions of elephants and retaliation.

More broadly, our study illustrates how use of both biological and social surveys can lead to a more complete understanding of animal use across landscapes in which human use is highly heterogeneous. Whereas surveys of animal signs by well-trained experts provide estimates of occupancy/use, animal sign surveys are less useful in human-dominated parts of mixed landscapes and only provide estimates at one point in time. In contrast, a single questionnaire can provide information over various time scales. Here, we examined the frequency of elephant conflict in the preceding 5 years, as well as elephant presence over the 12 months prior to the surveys. At the same time, questionnaires have weaknesses, including the increased potential for false positives, which are known to bias occupancy estimates even when they are infrequent (Royle & Link 2006; Miller et al. 2011). We sought to minimize the potential for false positives with our questionnaire design. Future work using questionnaires could benefit from integrating expert interviews and/or biological surveys that have much lower rates of false positives with regular questionnaires to minimize the impacts of false positives using models that allow for false positives (Royle & Link 2006; Miller et al. 2011).

Efforts to mitigate human–elephant conflict are likely to be most effective if they are concentrated during August through December when elephant use of human-dominated landscapes and human–elephant conflict are most common. Given the intelligence of elephants and the seasonal timing of elephant use of human landscapes during a period when water and presumably forage are plentiful in both forested and human-dominated portions of the landscape, it is possible that elephants are drawn to agricultural areas with preferred forage, as opposed to being forced to abandon forested areas. On the other hand, elephant use and detection probability in national and community forests versus protected areas provide weak evidence that the use of an area by elephants can be driven by human activities, and there may be ways to increase the elephant occupancy in forests outside protected areas.

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DISCLOSURE STATEMENT

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APPENDIX

*Asian elephant (*Elephas maximus*) occupancy in Nepal: Study design summary*

June, 2012
Blocks: the study area is divided into Western and Eastern Block according to the UTM Zone (Projection System)

1. Western Block: Kanchanpur to Chitwan (Terai Districts)
2. Eastern Block: Chitwan to Jhapa (Terai Districts)

Projection system:

1. Western Block (Kanchanpur to Chitwan): WGS 1984 UTM Zone 44N
2. Eastern Block (Chitwan to Jhapa): WGS 1984 UTM Zone 45N

Grids layout in the Blocks:

1. Western Block: With an option (detailed information given in Table A1)

5 × 5 km
10 × 10 km

2. Eastern Block: With an option (detailed information given in Table A2)

5 × 5 km
10 × 10 km

Table A1.

Summary of information with different grids options (i.e. 5 × 5 km or 10 × 10 km) in the Western Block.

Western Block (Kanchanpur to Chitwan)				
	No. of grids (5 × 5 km)	No. of grids (10 × 10 km)	Area of forest/ grassland in km^2 (based on 5 × 5 km grids)	Area of forest/ grassland in km^2 (based on 10 × 10 km grids)
Forest/grass coverage (< 25%)	149	116	365.498	855.220
Forest/grass coverage (25–50%)	85	61	828.216	2303.274
Forest/grass coverage (50–75%)	135	41	2156.429	2640.226
Forest/grass coverage (75–100%)	306	50	6720.764	4275.306
Total	675	268	10,074.025	10,074.025

Table A2.

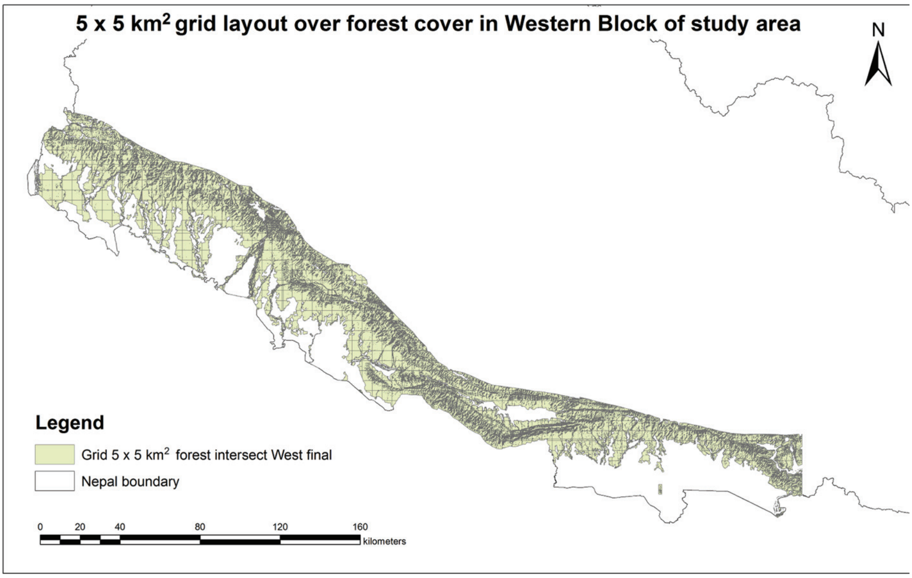
Summary of information with different grid options (i.e. 5 × 5 km or 10 × 10 km) in the Eastern Block.

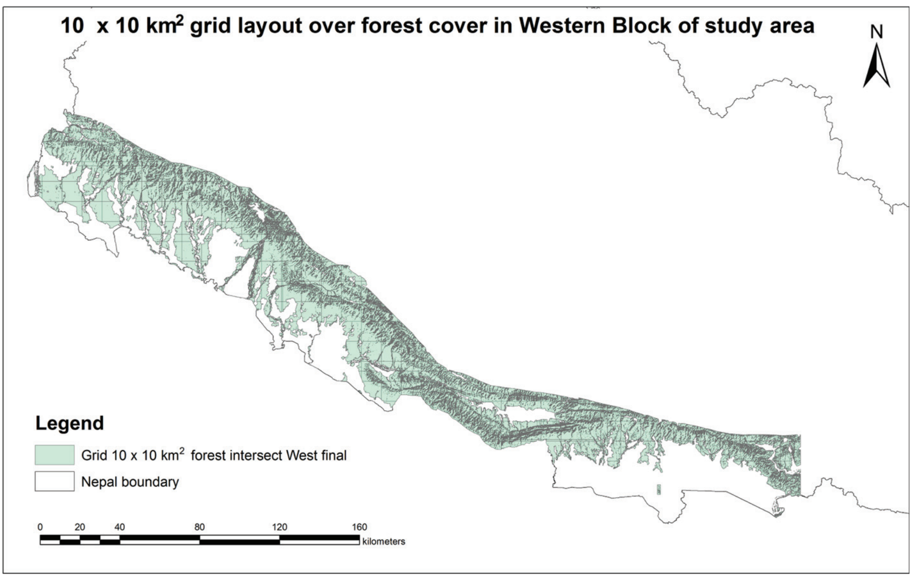
Eastern Block (Chitwan to Jhapa)				
	No. of grids (5 × 5 km)	No. of grids (10 × 10 km)	Area of forest/ grassland in km^2 (based on 5 × 5 km grids)	Area of forest/ grassland in km^2 (based on 10 × 10 km grids)
Forest/grass coverage (< 25%)	221	68	474.798	637.954
Forest/grass coverage (25–50%)	87	31	805.558	1133.846
Forest/grass coverage (50–75%)	82	30	1291.265	1848.874
Forest/grass coverage (75–100%)	163	30	3667.838	2618.786
Total	553	159	6239.459	6239.461

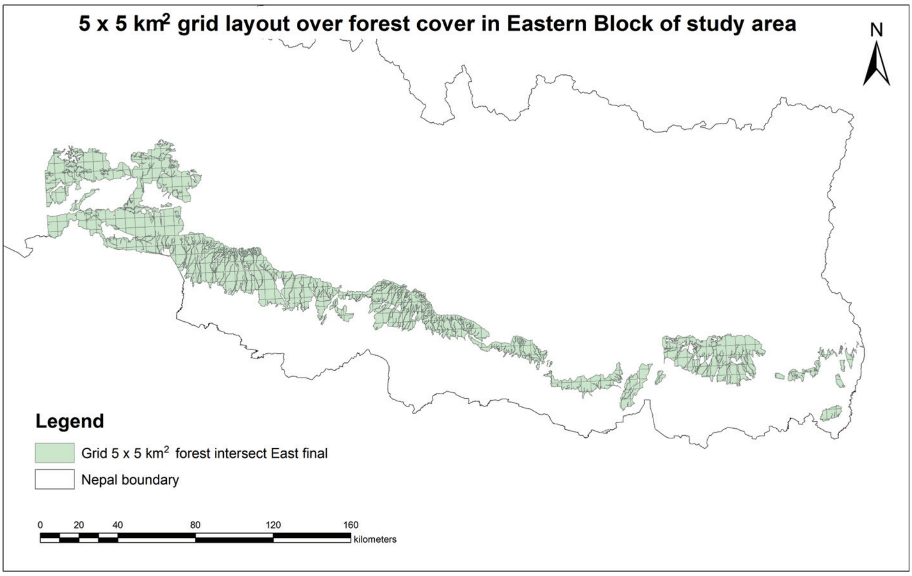
Table A3.

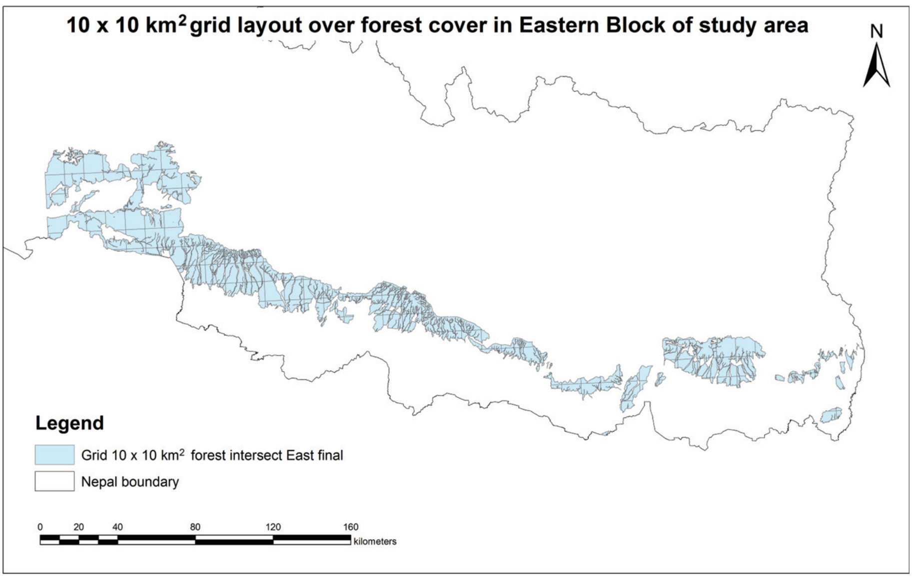
Summary of information with different grid options (i.e. 5 × 5 km or 10 × 10 km) in the whole study area.

Whole Study area (Terai districts of Nepal)				
	No. of grids (5 × 5 km)	No. of grids (10 × 10 km)	Area of forest/ grassland in km^2 (based on 5 × 5 km grids)	Area of forest/ grassland in km^2 (based on 10 × 10 km grids)
Forest/grass coverage (< 25%)	370	184	840.296	1493.174
Forest/grass coverage (25–50%)	172	92	1633.774	3437.12
Forest/grass coverage (50–75%)	217	71	3447.694	4489.1
Forest/grass coverage (75–100%)	469	80	10,388.6	6894.092
Total	1228	427	16,313.48	16,313.49


5 x 5 km2 grid layout over forest cover in Western Block of study area
N
Legend
Grid 5 x 5 km2 forest intersect West final
Nepal boundary
0 20 40 80 120 160
kilometers


10 x 10 km2 grid layout over forest cover in Western Block of study area
N
Legend
Grid 10 x 10 km2 forest intersect West final
Nepal boundary
0 20 40 80 120 160
kilometers


5 x 5 km2 grid layout over forest cover in Eastern Block of study area
N
Legend
Grid 5 x 5 km2 forest intersect East final
Nepal boundary
0 20 40 80 120 160
kilometers


10 x 10 km2 grid layout over forest cover in Eastern Block of study area
N
Legend
Grid 10 x 10 km2 forest intersect East final
Nepal boundary
0 20 40 80 120 160
kilometers