Research Article

Distribution and Habitat Use by Asian Elephants (*Elephas maximus*) in a Coffee-Dominated Landscape of Southern India

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Abstract

Understanding the impacts of land-use mosaics on elephant distribution and the patterns of habitat use is essential for their conservation in modified landscapes. We carried out a study in 205 villages, covering 610 km^2 of plantation–agriculture–forest mosaic of Hassan–Madikeri divisions in southern India, an area of intense human–elephant interactions. We monitored elephant movements, crop damage incidents, and human casualties on a daily basis for a 2-year period (2015–2017) to understand the patterns of elephant distribution across the landscape and habitat-use patterns, resulting in 1,117 GPS locations across six major habitats. Elephants were distributed across the landscape in the first year, but a high concentration of locations were noticed toward northern part of the study area during the second year, owing to clear felling of trees and installation of barriers around coffee plantations, causing an overall shift in their distribution. Investigations into habitat use by elephants revealed that during the day, elephants preferred *monoculture refuges* of acacia, eucalyptus, and so on, and forest fragments, avoiding reservoir, coffee, roads, and habitations. At night, agricultural lands were used more frequently while moving between refuges compared with forest fragments and habitations. Seasonally, forest fragments and agriculture were used significantly more during dry and wet, respectively. Across years, use of monoculture refuges and coffee increased with a corresponding decrease in the use of forest fragments and agriculture. In areas devoid of forest habitats, retention of monoculture refuges which provide shelter for elephants and facilitating free movement through open habitats may help minimize human–elephant conflict and promote coexistence in such land-use mosaics.

Keywords

asian elephant, agriculture, coffee, forest fragment, land-use matrix, monoculture refuges

Introduction

Human developmental activities that transform natural habitats to productive agricultural landscapes and plantations have threatened vast expanse of forest areas and biodiversity. In India, large-scale conversion of natural habitats to production or plantation landscapes has resulted in substantial loss of forest cover and created islands of forests in the Western Ghats (Garcia et al., 2009; Jha, Dutt, & Bawa, 2000; Mudappa, Kumar, & Raman, 2014), a biodiversity hot spot. The resulting fragmentation of natural habitats and increasing anthropogenic pressures, such as presence and expansion of human settlements, agriculture, livestock grazing, encroachments, and so on, has created opportunities for greater contact between people and wildlife, often leading to human–wildlife conflict. Considering that Asian elephants range widely outside protected areas (PAs) into regions of high human density, understanding

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their distribution and the influence of anthropogenic and natural habitats on species use of areas is of paramount importance for management of elephants in altered landscapes (Leimgruber et al., 2003; Madhusudan et al., 2015).

In India, a sizable percentage of the human population lives inside or at the fringes of elephant habitats, on which their livelihoods are dependent (Banerjee & Madhurima, 2013). Outside India too, Asian elephant habitats are under constant threat from the expansion of agriculture and other developmental activities resulting in the fragmentation of natural habitats (Blake & Hedges, 2004; Leimgruber et al., 2003). These fragmented habitats too are under extensive regimes of anthropogenic pressures (e.g., livestock grazing, fuel wood gathering) that compromise its ability to sustain elephants. Pocketed elephant populations with reduced access to resources have thus been pushed out of their natural habitats into adjoining human-modified habitats, leading to intense human–elephant conflicts (Desai, 1991; Madhusudan, 2003). Complicating matters further is the phenomenal ability of elephants themselves to learn and adapt to changes taking place within their ranges, which has also contributed to an increase in overlap and interactions between people and elephants.

The state of Karnataka holds the largest Asian elephant population in India (MoEF, 2017). The villages of the Alur–Sakleshpur–Kodlipet region in Karnataka is dominated by coffee plantations with paddy farms and negligible natural habitat coverage, contiguous with the coffee belt of the Coorg region in the Western Ghats. This region has witnessed intense conflicts owing to around 30 elephants in the recent past (Karnataka Elephant Task Force [KETF], 2012), which forced the state government to implement the recommendation of the elephant task force committee to carry out capture and removal of 22 elephants in 2014 as a measure to mitigate human–elephant conflict (KETF, 2012). Despite such a reactive measure, the area was recolonized by elephants within a year, leading to continued pattern of crop damage and loss of human life.

Elephants, being generalist species, have the capacity to adapt ecologically and behaviorally in modified landscapes. Their use of a mosaic of natural and modified habitats is often determined by resource availability, extent of area available, vegetation type, and pressures associated with modified landscapes (Bal, Nath, Nanaya, Kushalappa, & Garcia, 2011; Fernando et al., 2005; Pillay, Johnsingh, Raghunath, & Madhusudan, 2011; Srinivasaiah, Anand, Vaidyanathan, & Sinha, 2012). Factors such as composition of habitat mosaics, their spatial arrangements, and resource quality influence elephants' preference and selection of habitats (Okello, Njumbi, Kiringe, & Isiiche, 2015). Studies have also shown that factors such as availability of water and nutritional contents in forage determine elephants' habitat use and their range patterns in wet and dry seasons (Chamaille-James, Valeix, & Fritz, 2007; Osborn & Parker, 2003; Pastorini, Nishantha, Janaka, Isler, & Fernando, 2010). In fragmented landscapes, remnant forest patches and habitats with tree cover could provide important food resources and serve as refugia for many wildlife species including elephants outside PAs (Bal et al., 2011; Graham, Douglas-Hamilton, Adams, & Lee, 2009; Mudappa & Raman, 2007). Thus, in such habitats, information on elephant distribution, their use of habitats, and interactions with humans is crucial to coexistence in areas that currently witness severe conflict.

In this article, we focused on (a) overall distribution of elephants across villages in Alur–Sakleshpur–Kodlipet region and (b) habitat use by elephants and their preference of natural or anthropogenic habitats in a coffee- to paddy-dominated landscape. Results from this study may be helpful for the management and conservation of elephants in other human-dominated landscapes.

Materials and Methods

Study Area

The southern Indian state of Karnataka, which intersects the Western and Eastern Ghats, presently harbors about 5,300 to 6,200 wild elephants over an area of 14,500 km^2, which is about one fifth of the elephant population of the country (KETF, 2012). The region bounded by the Hassan and Madikeri divisions of Karnataka, Western Ghats, largely comprises of coffee plantations and paddy fields with forest fragments ranging from 150 to 300 ha in size. The chosen study area comprises of 205 villages located in the Alur, Sakleshpur, and Somwarpet Taluk, covering an area about 619 km^2. The study region is home to nearly 30 elephants and over 100,000 people dependent on coffee plantations and agriculture for their livelihoods. The area is dominated by coffee plantations in the upslope areas, with paddy grown in the valleys. Human presence and activity in coffee was noticed throughout the year, while in paddy habitat, agricultural activity peaked seasonally between August and January. Most of the coffee is owned by small growers (less than 10 ha; Market Research & Intelligence Unit Coffee Board, 2016) who also cultivate paddy; however, there are also a few big national and multinational companies such as Tata Coffee Limited and Indian Builders Corporation that own coffee plantations here. There are several forest fragments, monoculture plantations including *Acacia*, teak, and *Eucalyptus*, and a few abandoned coffee plantations in the study region, where human presence and activity is minimum. Elephants in the region invariably forage or move through plantations and subsistence

agriculture, which inevitably results in high incidence of conflicts (Appayya & Desai, 2007).

Study Design and Methods

Tracking and distribution of elephants. We tracked elephants through direct observations, or indirect signs such as fresh dung, tracks, feeding signs, and incidents of damage to property, on daily basis for 2 years between 2015 and 2017. On each day, we located elephants in the study area using information gathered from local informants and from the previous days tracking. During the daily tracking, which was carried out by a team of researchers and field assistants, a GPS reading was taken at each elephant presence or signs; elephant locations during the night were obtained early the next morning based on information from the previous day. Along with GPS locations collected during the tracking of elephants, we have also recorded village name and habitat type. This GPS data were used to map and describe the distribution patterns and intensity of use of villages by elephants in the study area. Identification of elephants was carried out using photographs and physical markings such as ear shape, persistent lumps, cuts on tail or ears, degree of ear folding, and so on (de Silva et al., 2013; Goswami, Madhusudan, & Karanth, 2007; Moss, 2001).

Habitat stratification of the study region. We have stratified the study area into six major habitat types (Figure 1(a) and (b)), which are listed as follows:

Coffee: A predominant commercial crop covering an area of 24,525.9 ha or 39.9% of the study area.

Agriculture: The agriculture habitat is primarily dominated by paddy with seasonal crops of maize, ginger, and so on. It covers an area of 800 ha or 12.9% of the study area.

Monoculture refuge: The monoculture refuge habitat includes Acacia, teak and *Eucalyptus* plantations, and coffee plantations that have been abandoned for over 10 years. This habitat covers 216.9 ha or 0.3% of the study area.

Natural vegetation: Natural vegetation includes all reserved forests, making up 4,707.07 ha or 7.6% of the study area.

Backwaters: The backwaters habitat is comprised entirely of the backwater area of the Hemavati Reservoir and forms 2,226.51 ha or 3.6% of the study area.

Others: Others includes townships, residential clusters in villages, open livestock grazing areas, and roads, forming 22,321 ha or 36% of the study area.

The study region receives both the southwest and northeast monsoons, between June and November every year. Hence, each year was divided into two main seasons: dry and wet. The dry season lasts from December to May, and wet season spans between June and November.

Analysis. To standardize the data, as the number of GPS locations collected each day would vary, and we could not always avoid spatial autocorrelation between sampling points on field, we used a randomization procedure to select only one out of the multiple GPS locations taken in each 12-h day and 12-h night period. Thus, of the total of 1,765 elephant locations, we have used a subset of 1,117 locations (2015–2016: 407 of 741 locations and 2016–2017: 710 of 1,024 locations) for the purpose of analysis.
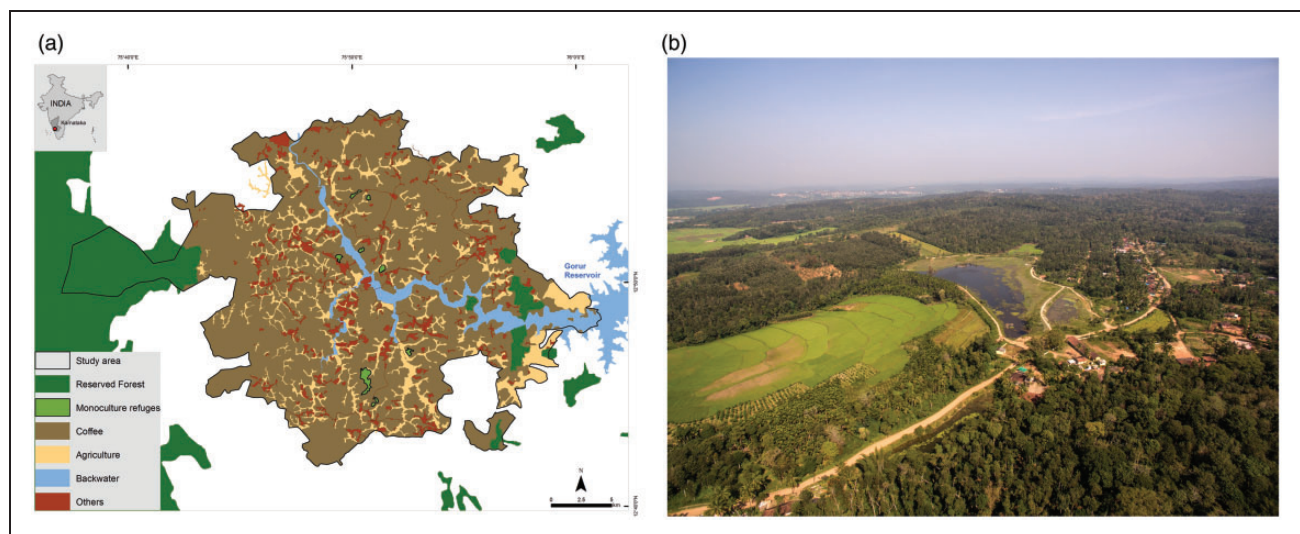

Figure 1. (a) Map of the study area showing mosaic of natural and anthropogenic habitats in Alur–Sakaleshpur–Kodlipet region. (b) Aerial image of the land-use mosaic of the study area (right panel). Photo credit: Kalyan Varma.

To understand the overall distribution of elephants, we overlaid the GPS data set onto a map of the study area. To further estimate the intensity of use of villages by elephants, we first calculated the density of GPS locations in square-kilometer grids within each village boundary and then calculated a mean density, representing intensity of use, for each village. To visually represent differences in intensity of use of villages by elephants, we created a color-coded map using Arc GIS version 9. We have also performed cluster analysis, in Geographical Data Analysis (GeoDa) 1.12 software, developed by Anselin et al., (2006), to identify the *hot spots* or high mean density of elephants per village, across villages. We have tested for significance in the difference between cold- and hot-spot clusters in the study area, for both years, using the K-means clustering method with two predefined clusters (Cluster 1 is cold spots and Cluster 2 is hot spots) and 1,000 iterations. We used a ratio of between-clusters sums of square errors to total sums of square errors (SSE ratio) as a measure of cluster validation, where an SSE ratio nearing 1 suggests high between-cluster variance and low within-cluster variance.

To visualize patterns of elephant distribution in relation to habitat type, we mapped village and habitat extents using a combination of Survey of India topographic sheets, Google Earth maps, and shape files received from the State Forest Department which we verified using GPS locations collected in the field and overlaid the GPS data set. To understand the overall habitat use by elephants, we compared frequencies of observed GPS locations with those that we predicted, based on the area available under each habitat type, using a χ^2 goodness-of-fit test. To further determine the preference or avoidance of habitats by elephants, we have used the Manly selection ratios (Manly, McDonald, Thomas, McDonald, & Erickson, 2003) by comparing the observed number of elephant locations in each habitat type to those we expect based on the proportion of each habitat type available. Significance of selectivity ratio (wi) was determined using log-likelihood χ^2 and 95% confidence intervals for each habitat category; a selectivity ratio >1 indicates disproportionate preference, and values <1 indicate avoidance of a habitat (Manly et al., 2003). We have repeated similar analyses for day and night locations to determine the differences in habitat preference or avoidance by elephants in relation to time of the day. We have carried out this analysis using *AdehabitatHS* package (Calenge, 2011) developed in the R statistics and program environment version 3.5.1 (R Development Core Team, 2018). To determine the seasonal and interannual variation in the use of various habitat types by elephants, we compared the percentage frequency of locations for each habitat type using a χ^2 contingency table (Zar, 1999).

Results

We tracked a herd of elephants and individuals numbering 30, with 8 adult males, 10 adult females, 8 juveniles, and 4 young calves that moved across the fragmented landscape of the study region. Between March 2015 to February 2016 (Year 1) and October 2016 to September 2017 (Year 2), a total of 1,765 elephant locations were obtained, of which we used a subset of 1,117 GPS locations for analysis.

Elephant Distribution and Intensity of Use

Although elephants were evenly distributed across villages from north to south, with a concentration of elephants around monoculture plantations during the Year 1, but there was a shift in their distribution with high concentration of elephant locations toward the north in Year 2. (Figure 2(a) and (b)). Mean intensity of elephant locations per unit area increased from Year 1 (0.67 ± 0.11) to Year 2 (1.6 ± 0.41) across villages. Cluster analysis revealed clearly identifiable cold spot and hot spots of elephant density (Figure 2(c) and (d)), and although hot spots were present in the southern part of the study area in Year 1, they were not present in Year 2, following a similar pattern as the previous result. A post hoc comparison of clusters across years revealed that clusters were more clearly defined in Year 2 (SSE ratio of 0.9), as compared with Year 1 (SSE ratio of 0.7, Table 1).

Use of Natural and Anthropogenic Habitats by Elephants

There was a significant variation in overall use of habitats by elephants (Yates $\chi^2 = 64,030.02$, $df = 5$, $p < .001$, Figure 3(a)). Elephants were seen most frequently in monoculture refuges (45.6%, $n = 509$). In contrast, coffee (32.8%, $n = 366$), backwater (0.4%, $n = 4$), and other habitats (2.1%, $n = 24$) of townships, vacant areas, and roads were used less frequently. Natural vegetation (6.8%, $n = 76$) and agriculture (12.4%, $n = 138$) seem to be used in proportion to the area available.

Bonferroni confidence intervals showed that there was an overall significant positive selection for monoculture refuges by elephants (Manly's selectivity index: wi = 151.9, standard error [SE] = 4.967, $p < .001$ with Bonferroni adjustment), while coffee (wi = 0,827, SE = 0.035, $p < .001$), back water (wi = 0,099, SE = 0.05, $p < .001$), and other habitats (wi = 0,06, SE = 0.012, $p < .001$) were significantly avoided. However, the use of natural vegetation (wi = 0,895, SE = 0.099, $p = .291$) and agricultural (wi = 0,958, SE = 0.076, $p = .58$) habitats did not differ significantly when compared with predicted locations (Bonferroni significance $p > .008$, Figure 3(b)).
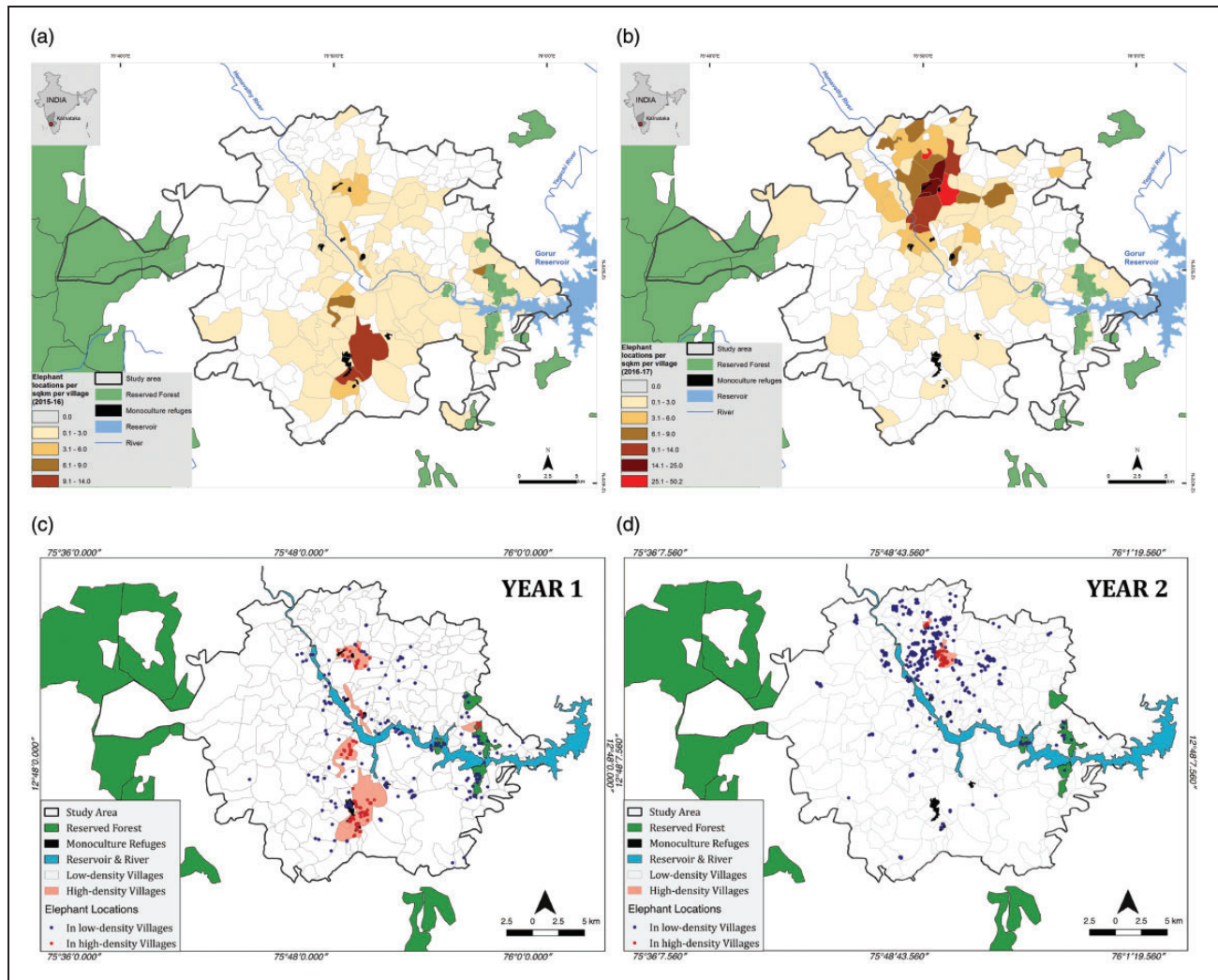
Figure 2. (a and b) Intensity of elephant locations across villages in Year 1 (left panel) and Year 2 (right panel) in the study region. (c and d) Maps indicating cold and hot spots based on high and low density of elephant locations across villages.

Table 1. Indicating Ratios Within and Between Hot- and Cold-Spot Clusters Based on Sum of Square Estimates in Years 1 and 2 in the Study Region.

		Centroid	Within-cluster SSE	Between-cluster SSE	SSE ratio
Year 1	Cluster 1 (cold spot)	−0.628088	48.2837	783.194	0.703047
	Cluster 2 (hot spot)	1.11834	282.522		
Year 2	Cluster 1 (cold spot)	−0.414715	137.204	976.652	0.876708
	Cluster 2 (hot spot)	2.1121	0.143364		

Note. SSE = sum of squared error.

Elephants' use of habitats differed significantly in relation to the time of the day ($\chi^2 = 585.5$; $df = 5$; $p < .001$, Figure 4(a)). During the day, we observed that a high percentage of elephant locations were in monoculture refugees (58.9%, $n = 509$) as compared with coffee, agriculture, and other habitats; natural vegetation (9%, $n = 76$) was used only during the day, while at night, elephants used agriculture (48.7%) and coffee plantations (47.2%) more frequently. The use of backwater and other habitats was similar irrespective of the time of the day. Selectivity of habitats by elephants during the day was similar to overall habitat use, with
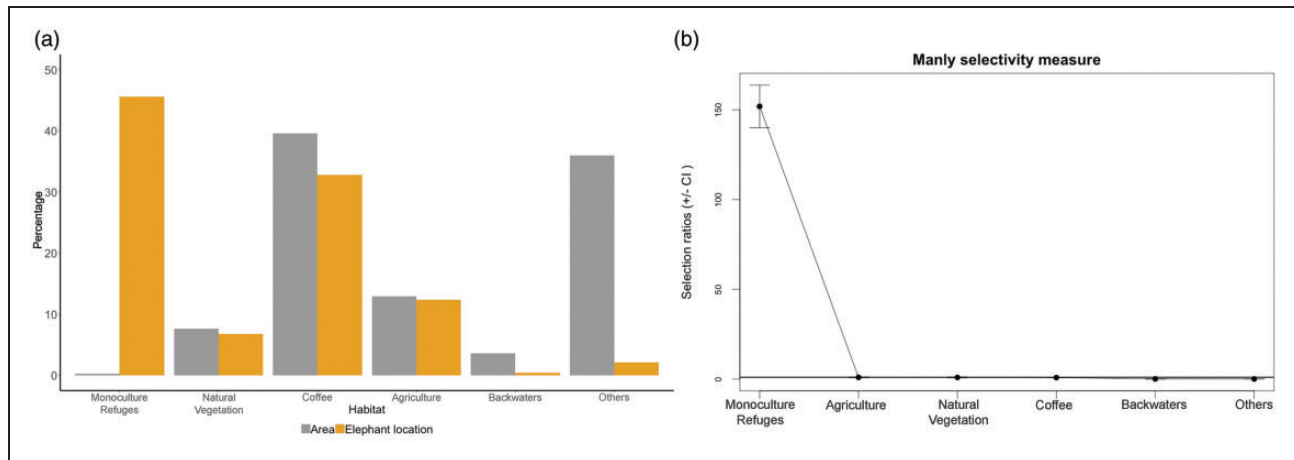
Figure 3. (a) Use of habitats by elephants in relation to the area available for each habitat type. (b) Overall selectivity of main habitats by elephants in the Alur–Sakaleshpur–Kodlipet region of Hassan and Madikeri divisions as indexed by Manly selectivity ratio (wi) with 95% confidence intervals.

highly positive selection of monoculture refugees (wi = 199.37, $SE = 5.619$, $p < .001$), a significant avoidance of coffee (wi = 0.710, $SE = 0.039$, $p < .001$), agriculture (wi = 0.055, $SE = 0.022$, $p < .001$), backwater (wi = 0.099, $SE = 0.057$, $p < .001$), and other habitats (wi = 0.056, $SE = 0.013$, $p < .001$), while natural vegetation (wi = 1.182, $SE = 0.129$, $p = .159$) was used in accordance with the availability (Bonferroni $p > .008$; Figure 4(b)). At night, elephants selected agriculture positively (wi = 3.776, $SE = 0.235$, $p < .001$) but avoided natural vegetation (wi = 0.000, $SE = 0.00$, $p < .001$), backwater (wi = 0.103, $SE = 0.102$, $p < .001$), and other habitats (wi = 0.072, $SE = 0.027$, $p < .001$). Although habitat selection ratios were high for coffee (wi = 1.193, $SE = 0.077$, $p = .012$) and monoculture (wi = 3.690, $SE = 2.119$, $p = .204$), they were not significantly different from availability of respective habitats (Bonferroni significance $p > .008$; Figure 4(c)).

Seasonal and Interannual Difference

Elephants used monoculture habitats more or less similarly in both dry (45.2%) and wet seasons (46%); however, coffee was used more frequently by elephants in dry (35%) than in the wet season (30.2%). While the use of natural vegetation was higher in dry (10.3%) than in wet (2.9%), agriculture was more frequently used during wet season (17.3%) than in the dry season (7.6). This seasonal difference in the use of natural vegetation and agriculture significantly contributed to the overall seasonal use of habitats by elephants ($\chi^2 = 56.64$, $df = 5$, $p < .005$, Table 2).

We found significant difference in the use of habitats by elephants across years (Pearson's $\chi^2 = 72.05$; $df = 5$; $p < .001$, Figure 5). The use of coffee and monoculture

plantations increased from 41.3% to 48% and 28.7% to 38.1% in the Year 1 and Year 2, respectively. In contrast, elephant's use of natural vegetation areas decreased substantially from 15% in Year 1 to 2.1% in Year 2, and a marginal decline in agricultural habitat from 13.3% in Year 1 to 11.8% in Year 2. Elephants did not appear to use backwater and other habitats differently over years.

Discussion

In the context of rapidly declining elephant habitats due to fragmentation and human developmental activities, understanding elephants' distribution and their use of habitats has been of paramount importance for elephant conservation (Jathanna, Karanth, Kumar, Karanth, & Goswami, 2015). India supports the largest Asian elephant population in Asia, but only about 16% of their range forms part of the existing PA network (Leimgruber et al., 2003). Agricultural expansions for subsistence food requirements and cash crop plantations in or adjoining prime elephant habitats have been negatively impacting the survival of elephants in anthropogenic habitats, leading to intense human–elephant conflicts (Graham, Notter, Adams, Lee, & Ochieng, 2010; Kumar, Mudappa, & Raman, 2010; Madhusudan, 2003).

Elephant Distribution and Intensity Across Villages

In the coffee- to paddy-dominated habitat mosaic of Hassan, elephant distribution and their intensity of use of villages varied between years. In Year 1 (2015–2016), elephant were distributed across the landscape in a north–south direction with varying degrees of intensity across villages. Large-scale felling of trees in about 350
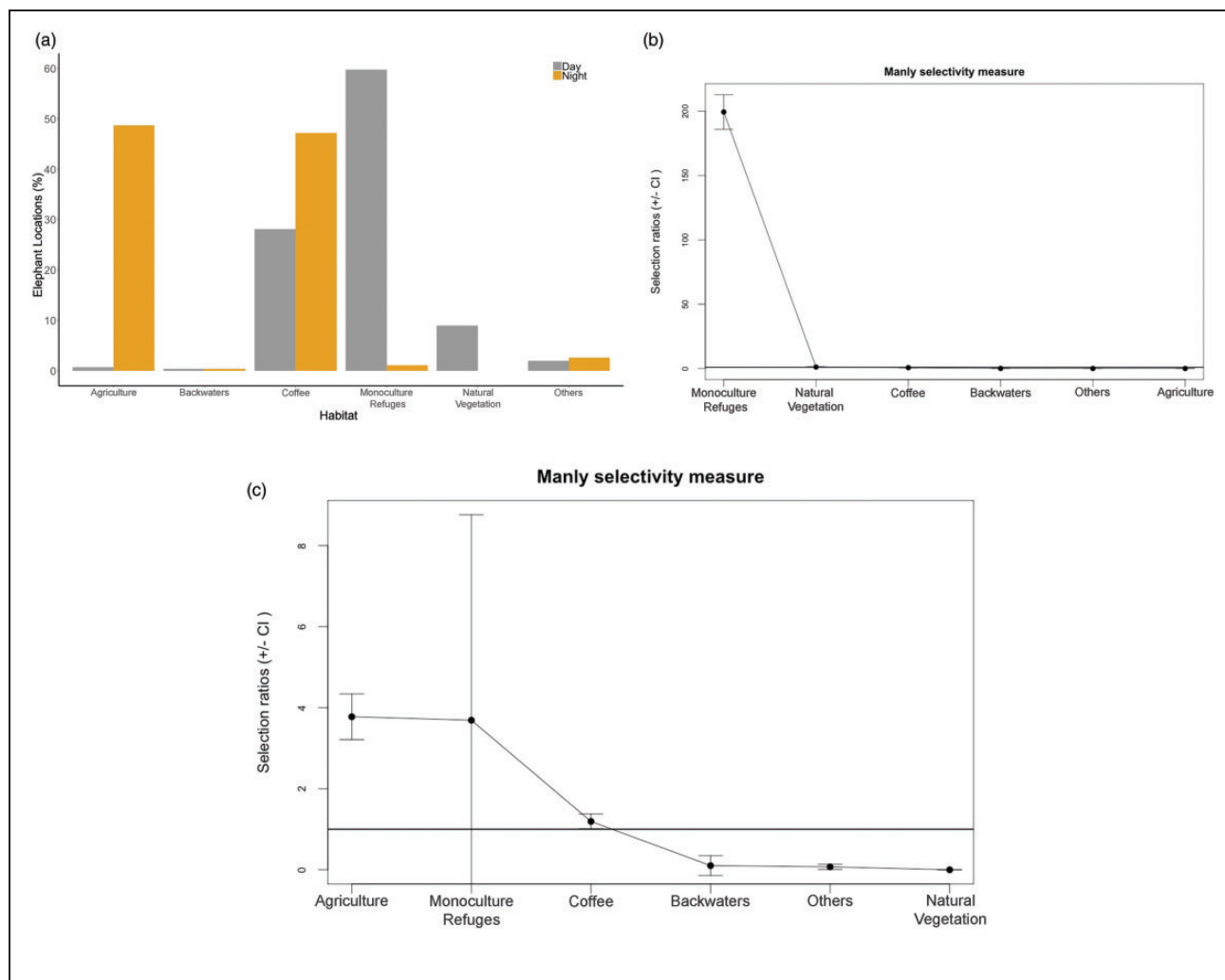
Figure 4. (a) Percentage use of major habitats by elephants during the daytime and nighttime in the study area. (b) Daytime selectivity of habitats as indexed by Manly selectivity ratios (wi) with 95% confidence intervals in the study region. (c) Nighttime selectivity of habitats as indexed by Manly selectivity ratios (wi) with 95% confidence intervals in the study region.

Table 2. Frequency of Elephant Locations in Various Habitats During Dry and Wet Seasons in the Coffee-dominated Landscape of the Hassan Region.

	Dry		Wet	
Habitat	Observed frequency (%)	Expected frequency	Observed frequency (%)	Expected frequency
Monoculture	267(45.2)	269	242(46)	240
Coffee	207(35)	194	159 (30.2)	172
Natural vegetation	61(10.3)	40	15(2.9)	36
Agriculture	45 (7.6)	73	93 (17.7)	65
Backwater	4(0.7)	2	0 (0)	2
Others	7(1.2)	13	17(3.2)	11
Grand total	591	591	526	526

ha of abandoned coffee estates in the central region of the study area and installation of solar fences around these areas restricted movement of elephants toward villages in northern part in Year 2 (2016–2017). Such

drastic changes with the inclusion of physical barriers, the presence of large holdings of coffee (more than 50 acres), scattered acacia plantations, and the absence of forest fragments toward the north resulted in the
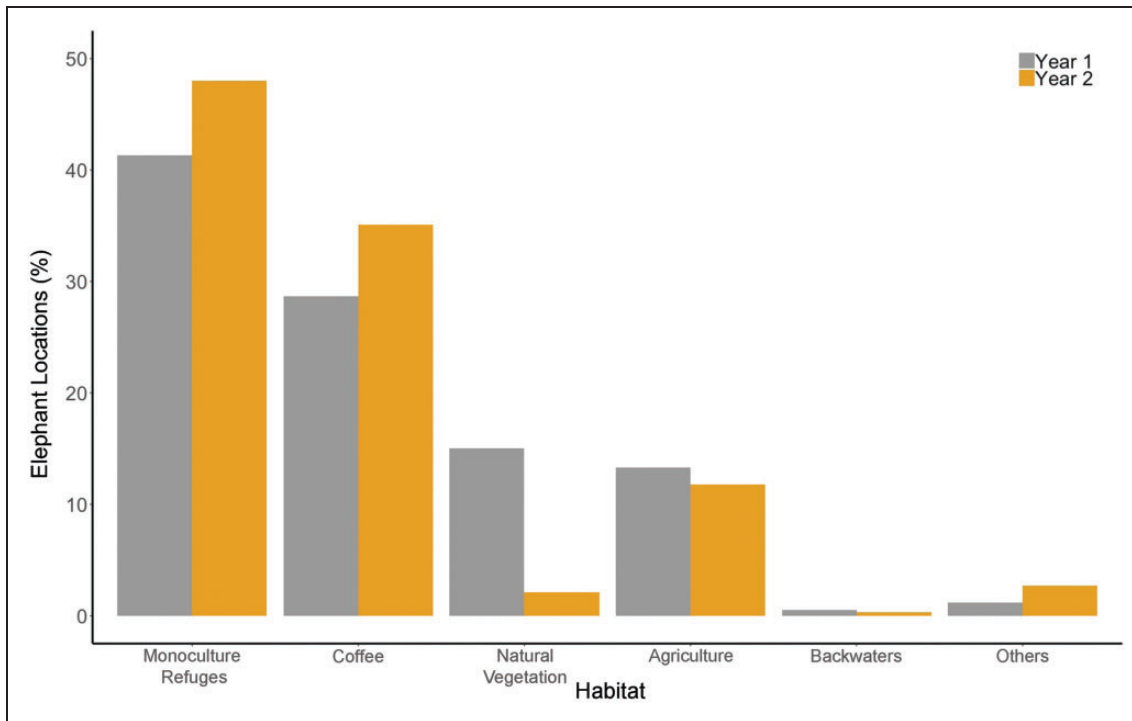
Figure 5. Percentage of elephant locations in various habitats indicating interannual variation between 2015 to 2016 ($n = 407$) and 2016 to 2017 ($n = 710$).

increased use of coffee and monoculture refuges and reduced access to natural vegetation habitats for elephants in the second year; this also resulted in an escalation of human–elephant conflict, by deflecting elephants' movements into neighboring anthropogenic areas, as also noticed elsewhere (Fernando et al., 2015). Moreover, reactive measures of elephant drive operations in the face of increased conflict may have adverse impacts on behavior and physiology of elephants (Kumar & Singh, 2010; Vijayakrishnan, Kumar, Umapathy, Kumar, & Sinha, 2018).

Elephant Use of Habitat Mosaic

Elephants could potentially range outside PAs, survive in reasonable numbers in human-dominated landscapes, and benefit from forest–agriculture matrices, despite pressures associated with anthropogenic landscapes (Calabrese et al., 2017; Leimgruber et al., 2003; Madhusudan et al., 2015). However, space use by elephants is influenced by distribution of resources, vegetation type, changes in land use, and presence of human disturbance within in their distributional range (Hoare & Du Toit, 1999; Roever, van Aarde, & Leggett, 2012). The study region has been intensively and widely used by breeding herds and males. Overall, elephants preferred monoculture plantations of acacia, eucalyptus, and abandoned coffee and reserved forests remnants more than other habitats when compared with their

availability. Hence, retention and protection of existing monoculture and natural vegetation habitats are critical for the survival of elephants in the region.

Elephant usage of habitats was also influenced by the time of the day, with greater usage and high preference for monoculture refuges during daytime, whereas at night, elephants preferred agricultural fields but avoided backwater, natural vegetation, and others. Natural vegetation and monoculture refuges, together, represent less than 8% of the total landscape, contain secondary vegetation with minimum human interference, and play a key role in providing shelter and forage for elephants. Nevertheless, absence of water resources in these habitats may push elephants into neighboring agriculture fields and coffee estates to access water bodies such as tanks or ponds. We also recognize that elephant use of habitats during the day may have been influenced by the activity of people in coffee plantations, agriculture fields, open areas of backwater, and residential units. Graham et al. (2009) indicated that elephants' movement and use of habitats are based on a risk-minimization strategy with concomitant diurnal differences in habitat use, whereby habitats presenting more risk tend to be used more by night than by day. At night, elephants seem to access water in perennial agriculture ponds (Pastorini et al., 2010) and palatable crops such as paddy, maize, and so on, which resulted in crop damage incidents while moving between areas of tree cover (Bal et al., 2011;

Sukumar, 1990). Recently, with the initiation of creating water sources for agriculture as a part of state government scheme, there have been many ponds dug to provide water for agricultural crops and coffee estates in the study region. These water bodies may be beneficial for cultivation but may positively influence elephant densities, regulate their movements (Chamaille-James et al., 2007), and impact human–elephant relationships in the study region. Elephants often use agriculture, especially at night in the study region, thus exploring the influence of agricultural ponds and characteristics of crops on elephant distribution and their use of habitats would bring more insight to understanding their use of modified landscapes. However, in the absence of natural vegetation areas, such as forest fragments and monoculture refuges, elephants may be forced to increase their use of coffee, agriculture, and residential areas, which may intensify direct encounters between people and elephants and crop damages in the study region (Figure 6(a)). On the other hand, elephants used habitats such as backwater and others including village residential areas and roads, less frequently at night, probably as a strategy to avoid risks associated with open areas and anthropogenic pressures such as human presence and sand mining activity at night in backwater areas of reservoir (Granados, Weladji, & Loomis, 2012; Srinivasaiah et al., 2012).

Seasonal and Interannual Use of Elephants

Elephants' selectivity of habitats vary due to resource availability, vegetation type, human presence, landscape features, and cropping patterns in natural and altered habitats in wet and dry seasons (Granados et al., 2012; Hoare & Du Toit, 1999; Webber, Sereivathana, Maltby, & Lee, 2011). Seasonally, forage availability in natural vegetation habitats and presence of water and grass in coffee seem to influence elephants' use of these habitats more frequently during hotter months of the dry season, which is similar to the patterns found in other studies (Bal et al, 2011; Kumar et al., 2010; Shannon, Mackey, and Slotow, 2013; Sitompul, Griffin, Rayl, & Fuller,

Figure 6. (a) Frequent interactions between people and elephants is a regular occurrence in agriculture fields. Photo credit: Ashwin Bhat. (b) Coffee is an important habitat, which provides forage and water for elephants. Photo credit: Vinod Krishnan. (c) Paddy attracts elephants to farm lands which often lead to incidents of crop damage. Photo credit: Vinod Krishnan. (d) Monoculture refuges such as acacia and eucalyptus provide shade and secondary vegetation for elephants in the study region. Photo credit: Rajkumar.

2013; Figure 6(b)). However, in the wet season, elephants used agriculture habitat more frequently than in the dry season. Agriculture is primarily dominated by paddy, grown in the fallow regions amid coffee plantations, as a subsistence seasonal crop which lasts for about 4 to 6 months in a year between August and January, covering most part of wet season. Paddy is known to attract elephants due to its high palatability, a preference for matured crops close to the harvest period (Nyhus & Tilson, 2000; Figure 6(c)), leading to incidents of crop damage (Nyhus & Tilson, 2000; Sukumar, 1990). Elephants, being a generalist species, are known to adapt well in modified landscapes, which have limited natural forage resources in fragmented forests (Kumar, Vijayakrishnan, & Singh, 2018). However, in areas devoid of natural vegetation or limited forage availability in forest fragments amid production landscapes, monoculture refugees play a primary role as shelter, and presence of secondary vegetation and bamboo in these refuges support elephants in both seasons (Figure 6(d)). Future studies focusing on spatial and temporal patterns of forage availability and influence of environmental variables would be necessary to identify the determining factors in elephants' use of natural and human-use landscapes (Lakshminarayanan, Karanth, Goswami, Vaidyanathan, & Karanth, 2015; Rood, Ganie, & Nijman, 2010; Sitompul et al., 2013).

Implications for Conservation

India, being one of the most populated countries in Asia with the highest number of Asian elephants, also has a sizable population of people live either inside or in close proximity to elephant habitats. Thus, creating exclusive zones for people and elephants may not be practical in most landscapes. Elephants, being habitat generalist, have the capacity to adapt to diverse habitats, exhibit opportunistic and behavioral plasticity in human-dominated landscapes (Bal et al., 2011; Srinivasaiah et al., 2012). Thus, it is essential to retain and protect existing patches of monoculture and remnants of natural habitats in landscapes such as Hassan.

Given that there are around 30 elephants at present, thinning or clear felling of monoculture refuges or removal of natural habitat remnants may force elephants to increase their use of coffee estates and agriculture fields, pushing them close to human habitations which may aggravate human–elephant conflict. It is essential to understand elephant movements, spatial factors influencing their use of habitat mosaics, and reasons for occurrence of human–elephant conflict to ensure conservation of elephants in human-dominated areas. The existing PA network in elephant range states constitutes a small percentage of area and a substantial elephant population range outside PAs in human-use areas.

Therefore, a landscape-level management strategy must be employed to enhance the coexistence between people and elephants (Calabrese et al., 2017).

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