Research article

Asian elephant *Elephas maximus* habitat use and ranging in fragmented rainforest and plantations in the Anamalai Hills, India

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Abstract

The persistence of wide-ranging mammals such as Asian elephants in fragmented landscapes requires extending conservation efforts into human-dominated landscapes around protected areas. Understanding how elephants use such landscapes may help facilitate their movements and reduce conflict incidence. We studied elephants' use of fragmented habitats and ranging patterns of focal herds in a landscape of rainforest fragments embedded in tea, coffee, and *Eucalyptus* plantations in the Anamalai Hills. Elephant herds entering this landscape were tracked daily between April 2002 and March 2006, resulting in 985 GPS locations of herds obtained across six major habitats. Natural vegetation in rainforest fragments and riparian habitats, despite low coverage in the landscape, was preferred by elephants during the day. At night, elephants preferred riparian vegetation, avoided other habitats such as swamps and settlements, while the remaining habitats were used proportional to availability. Use of rainforest fragments and riparian vegetation increased over three years of study with a corresponding decline in the use of tea monoculture. Among plantation habitats, coffee, and *Eucalyptus* were used significantly more during wet and dry seasons, respectively. The concentration of elephants along a major riparian system in the center of the landscape emphasized the role of water and food availability in habitat use during the dry season. Protection of rainforest fragments, secondary vegetation along rivers, and regulated and sequential felling (instead of clear-felling) of *Eucalyptus* along elephant movement routes will help retain forage, cover, and passage routes of elephant herds and may reduce direct human-elephant encounters in such fragmented landscapes.

Key words: Asian elephant, habitat use, ranging pattern, rainforest fragments, plantations

Received: 30 March 2010; Accepted: 16 May 2010; Published: 28 June 2010

Cite this paper as: Kumar, M. A., Mudappa, D. and Raman, T. R. S. 2010. Asian elephant *Elephas maximus* habitat use and ranging in fragmented rainforest and plantations in the Anamalai Hills, India. *Tropical Conservation Science* Vol. 3 (2)143-158. Available online: www.tropicalconservationscience.org

Introduction

Habitat loss, degradation, fragmentation, conversion, and resource exploitation due to human activities result in alterations of the extent and spatial configuration of habitats available for wild species [1]. Especially in tropical forests, habitat fragmentation often restricts wild fauna to habitat 'islands' [2]. Wide-ranging animals, exemplified by species such as Asian elephants (*Elephas maximus*) and African elephants (*Loxodonta africana*), are threatened by many human activities. For Asian elephants, large scale conversion of forests to monoculture plantations, croplands, and developed areas, has drastically reduced and fragmented available habitats [3 – 6]. This has resulted in compression of elephant herds in protected areas causing escalation of human-elephant conflict in the adjoining human-dominated landscapes [7]. Landscape variables such as spatial heterogeneity in vegetation cover [8], seasonal change in resource availability [9], and human density [10, 11] influence elephant distribution and use of natural and man-modified habitats, and patterns of human-elephant conflict and encounters [5, 12]. Close and frequent encounters between humans and elephants in landscapes with settlements and croplands have detrimental effects on long-term conservation of elephants [13]. As a result of fragmentation and the ensuing interspersion of human habitation, cultivation, and natural habitats, conflicts between humans and elephants are now widespread across Africa [14 – 16] and Asia [17 – 19]. In such situations, understanding the relationships between landscape elements such as human habitations, habitat remnants, and elephant activity is an important area of research [14].

The availability of food, water, and cover are fundamental factors influencing the distribution of large-bodied herbivorous mammals [18, 20]. In African elephants, use of habitats increases with proximity to water and high proportions of vegetation cover, as well as in areas devoid of human settlements [21]. Although Asian elephants use forest habitats ranging from semi-arid dry thorn to wet evergreen forest, they attain highest densities in the moist and dry deciduous forests that contain substantial grass and bamboo forage [4]. Within tropical wet evergreen rainforests, openings in rainforest vegetation may contribute to increased use by elephants, when accompanied by greater availability of edible forage such as grasses and bamboos [4, 22]. In parts of southern India with larger tracts of forest characterized by east-west gradients in rainfall and a corresponding gradient of dry to moist vegetation types, Asian elephants show seasonal movements and use of these habitats influenced by water and forage availability [4, 23]. However, such large landscapes dominated by natural vegetation occupy only a portion of the distributional range of Asian elephants.

For India, it is estimated that of the remaining 46,880 km² of wildlands (defined as large areas of natural vegetation unaffected by habitat fragmentation over time periods long enough that natural ecological processes dominate [24]), only 12% is recorded as protected wildland within the larger geographical range (151,309 km²) of Asian elephants in the country [24]. In the Western Ghats of southern India, large-scale loss and conversion of forests to monoculture plantations, agriculture, hydro-electric projects and reservoirs, transportation networks, and developed areas have drastically reduced and fragmented Asian elephant habitats [25, 26]. Much of the remaining rainforest in the Western Ghats now occurs as habitat fragments amid man-modified landscapes [27, 28]. Although several studies have addressed the issue of elephant-human conflict, there has been little research on Asian elephant habitat use and movements in such fragmented landscapes. The paucity of research on habitat use and ranging across fragmented landscapes outside protected areas was also highlighted in a recent study on African elephants that also noted the importance of such studies for elephant-human conflict resolution in altered landscapes [29].

This study indicated that elephant use of habitats and movement rates 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 [29]. It also highlighted the value of retaining habitat refugia in landscapes outside protected areas for enhancing connectivity and reducing the negative effects of habitat fragmentation for conservation of elephant populations.

Here, we examine patterns of Asian elephant's habitat use in a fragmented landscape in the Western Ghats of southern India, over a three-year period (2002-2003, 2004-2006), paying specific attention to seasonal use of habitats and ranging over a two-year period (2004-2006). The study region, in the Anamalai hills, being dominated by commercial plantations with embedded habitat fragments and surrounded by larger protected areas, is a representative landscape posing similar challenges to conserving large wildlife species such as elephants [28, 29]. Our research was motivated by the following questions: (1) how do elephants use the different habitats in the mosaic of plantations and forest remnants in a fragmented landscape? (2) how does habitat use vary temporally (diurnally and seasonally)? These results are integrated with information on ranging patterns to identify critical areas of use within the plantation landscape and identify implications for the management of habitat remnants for conservation of Asian elephants

Methods

Study area

The Anamalai-Parambikulam Elephant Reserve in the Western Ghats of south India is believed to contain over 1,000 elephants in an area of 3558 km², within which, nearly 60% of the area is highly fragmented due to the development of transportation networks and human density [23]. This study was carried out in the 220 km² area of the Valparai plateau in the Anamalai hills, which is surrounded by the Anamalai Tiger Reserve (987 km², 10º 12' N to 10º 35'N and 76º 49' E to 77º 24'E), Eravikulam National Park, Parambikulam Wildlife Sanctuary, and Vazhachal Reserved Forests (Figure 1).

The Valparai plateau is dominated by monoculture plantations of tea, coffee, and *Eucalyptus,* with interspersed habitats such as rainforest fragments, riparian vegetation, and swamps and settlements. The commercial plantations on the plateau are mostly owned by six major national and multinational companies and a host of smaller estates. There are nearly 40 rainforest forest fragments ranging in size from 0.3 ha to 100 ha dispersed across the plateau in private lands [28]. Tea is the major crop in the plateau with coffee plantation limited to an area of about 2,500 ha with few companies. *Eucalyptus* plantations are raised in tea estates as fuel clearings to meet energy requirement of tea factories.

Riparian vegetation is restricted to a number of small and large rivers traversing the plateau. The natural vegetation in the region, receiving around 3,500 mm of rainfall annually from the southwest and northeast monsoons, is classified as mid-elevation tropical wet evergreen forest of the *Cullenia-Mesua-Palaquium* type [30]. Altitude ranges between 900 m and 1,450 m above sea level. Scattered human habitations with about 100,000 people (average human density of 455 people/km²) occur in the Valparai plantation landscape.

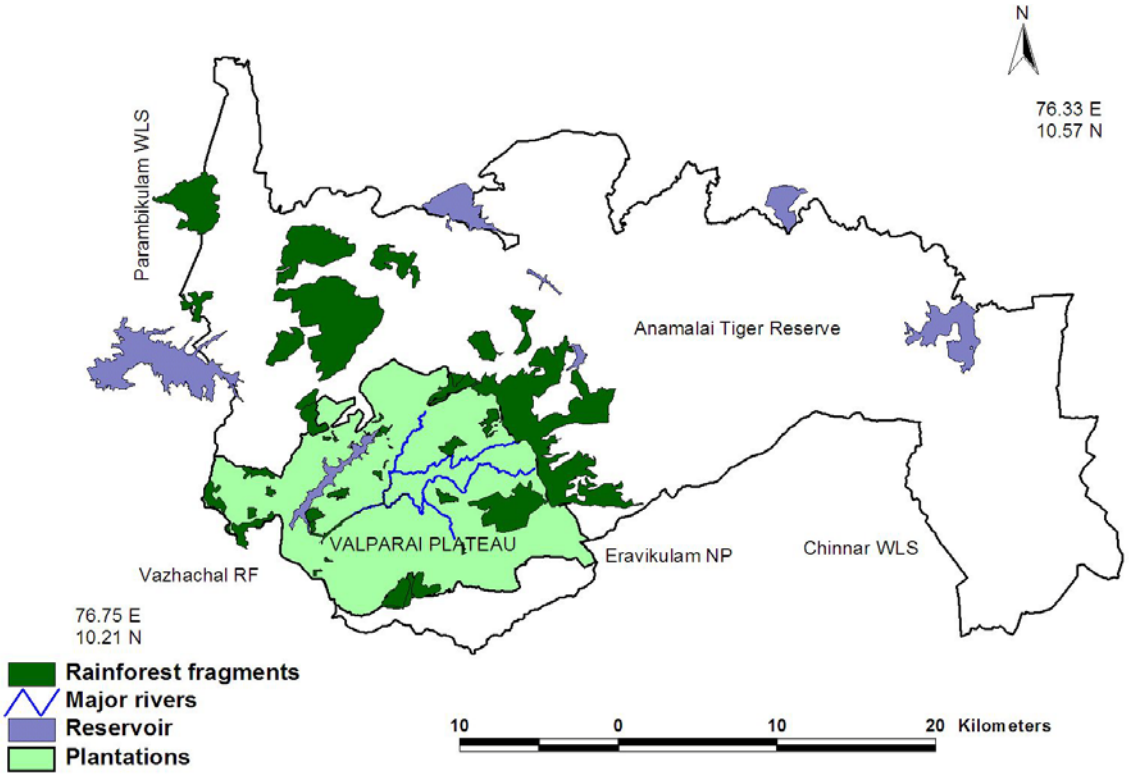

Fig. 1. Map of study area showing plantations (light green) with rainforest fragments (dark green) and major riparian areas (blue lines) in relation to surrounding protected areas in the Anamalai hills, India.

Study design and elephant tracking

In order to examine patterns of elephant habitat use, we stratified the Valparai plateau into six broad habitat types, which included three plantation types (tea, coffee, and *Eucalyptus*), rainforest fragments, riparian vegetation, and others (mainly swamps and settlements). The study was designed to examine elephant habitat use by recording (comparing) frequencies of elephant locations in each habitat through systematic records of elephant locations from direct observations and herd tracking. Radio-collaring of elephants was not possible during this study; however, field conditions of visibility, access into plantations, and a network of estate roads and informants enabled locating all herds that came into plantations on a daily basis and tracking them to obtain regular locations along movement paths. Since the location data represented continuous and systematic sampling, as in the case of radio-collaring, it can be usefully applied for assessing habitat preference (by comparison with proportion of area available under each habitat in the landscape), and temporal (diurnal and seasonal) variation [21, 29].

Direct sightings, fresh signs such as dung, and information from local informants were used to locate elephants within the plantation landscape. Once an elephant herd was located, it was followed for recording its location and habitat parameters such as habitat type, distance of nearest forest fragment,

distance of nearest human settlement, etc., on each subsequent day until the herd moved out of the private plantations into the surrounding protected areas. Night-time movement of elephants was tracked using fresh signs of dung, footprints, and feeding signs to the location where elephants were seen on the previous day. Daytime locations and nighttime tracking locations (at 500 m intervals on the tracked route) were recorded using a Global Positioning System (GPS, Garmin 12 XL) handset. Two regular herds that frequented plantations were intensively followed for a period of two years between April 2004 and March 2006.

Elephants were observed with a pair of Nikon 8 × 42 binoculars and individuals identified based on physical markings such as cuts, size, and shape of holes in ears, lumps on the body, and shape of the tail, besides verifying age-sex composition and size of the herd [31, 32]. For every GPS location obtained for herds, we recorded date, season, time of the day, estate name, name of the company, habitat, surrounding habitat within 500 m, the approximate distances to nearest human colony and forest fragment, and the presence of a *Eucalyptus* patch within a radius of 1 km.

A 1:50,000 Survey of India map of the study area was digitized using MAPINFO and Arc View (version 3.2) computer software [33]. Mapping of forest fragments and human settlements was done using the track option in the GPS handset while walking around fragments. The digital data were imported into Arc View as shape files to overlay on the Valparai plateau map.

Analysis

For most days, multiple GPS locations were obtained while recording movements of elephant herds. As such locations may not be independent, for all analyses we used a randomization procedure to select only one day and one night GPS location for each 24-hour period. These data were used to estimate percentage use of habitats (represented by the frequency of locations obtained relative to total number of locations) and plotted on the study area map to examine patterns of ranging of elephants. For some analyses, riparian vegetation and rainforest fragments were grouped as natural vegetation. The frequencies of elephant locations in the five main habitat strata (tea, coffee, *Eucalyptus*, natural vegetation, and other) were compared to frequencies expected based on the proportion of area under these habitats in the Valparai plateau to assess habitat selection using Manly's selectivity ratio [34]. Significance of this ratio of observed use to expected use was tested using a log-likelihood χ^2 and 95% confidence intervals; selectivity ratios (w_i) significantly >1 indicate preference whereas values significantly <1 indicate avoidance of the habitat stratum [34, 35]. The analysis was repeated separately for daytime and nighttime locations to examine diurnal variation. The analysis was carried out using the "adehabitat" package [36] as implemented in the R statistics and programming environment [37].

The Anamalai Hills receive both the southwest and northeast monsoons, between June and November. Hence, the year was divided into two main seasons: dry (December to May) and wet (June to November). To examine seasonal variation in elephant distribution and use of habitats, we compared percent frequency of locations in each habitat type, for the two herds using a chi-square contingency table test [38]. We applied additive partitions of 6×2 chi-square contingency table [39] to further identify significant differences in the contingency table. The locations of Herd 1 and Herd 2 were plotted on a grid map to calculate the home range within the Valparai plateau using a 100% minimum convex polygon using Arc View (version 3.2).

Results

Use of fragmented habitats

Of the total 985 elephant locations in a three-year period (between April 2002 and March 2006), a higher percentage of locations (32%) were in tea plantations as compared to other habitats: *Eucalyptus* (17%), coffee (13%), rainforest fragments (22%), and riparian vegetation (11%). Natural vegetation, including rainforest fragments and riparian vegetation, made up 33% of all observations although it covered only <5% of the plateau compared to 62% for plantations. We found a significant positive selection for riparian vegetation (Manly's selectivity index w_i = 108.5, SE = 8.50, $P < 0.008$ with Bonferroni adjustment) natural vegetation (w_i = 5.5, SE = 0.28, $P < 0.001$) and *Eucalyptus* (w_i = 4.1, SE = 0.25, $P < 0.001$) and in contrast, we found significant avoidance of tea plantations (w_i = 0.55, SE = 0.02 $P < 0.001$) and other habitats (w_i = 0.25, SE = 0.03, $P < 0.001$), while overall use of coffee plantations did not differ significantly from availability (w_i = 0.94, SE = 0.07, P = 0.37; Figure 2). Selectivity of major habitats also differed significantly from each other (Bonferroni classes based on 95% CI of w_i).

There was a highly significant difference in the use of habitats by elephants between day and night (χ^2 = 467.89; df = 5; $p < 0.001$; Figure 3a). During daytime, elephants were more frequently recorded in natural vegetation in forest fragments and riparian vegetation (51%) as compared to plantations of coffee (13.6%), *Eucalyptus* (23.4%), and tea (6.1%). Selectivity of habitats was similar to the above pattern, with highly positive selection of riparian vegetation (w_i = 169.6, SE = 15.5, $P < 0.001$), natural vegetation (w_i = 8.0, SE = 0.46, $P < 0.001$) and *Eucalyptus* (w_i = 5.9, SE = 0.44, $P < 0.001$) and avoidance of tea plantations (w_i = 0.10, SE = 0.02, $P < 0.001$) and other habitats (w_i = 0.42, SE = 0.07, $P < 0.001$), with no significant selectivity of coffee (w_i = 1.02, SE = 0.11, P = 0.85; Figure 3b). Selectivity of all major habitats also differed significantly from each other. At night elephants used tea more frequently (68%) than any other habitat followed by coffee (12.4%). Tea was mainly used to move between sites with natural vegetation. Although riparian vegetation was still positively selected (w_i = 25.2, SE = 7.9, P = 0.002) and other habitats avoided (w_i = 0.33, SE = 0.07, $P < 0.001$) at night, the remaining habitats were used according to availability (Bonferroni $P > 0.008$): natural vegetation (w_i = 1.1, SE = 0.26, P = 0.58), *Eucalyptus* (w_i = 1.8, SE = 0.32, P = 0.02), tea (w_i = 1.1, SE = 0.04, P = 0.04) and coffee plantations (w_i = 0.93, SE = 0.12, P = 0.57; Figure 3c). Riparian vegetation, other habitats, and the remaining four habitats (as a group) formed significantly different Bonferroni classes.

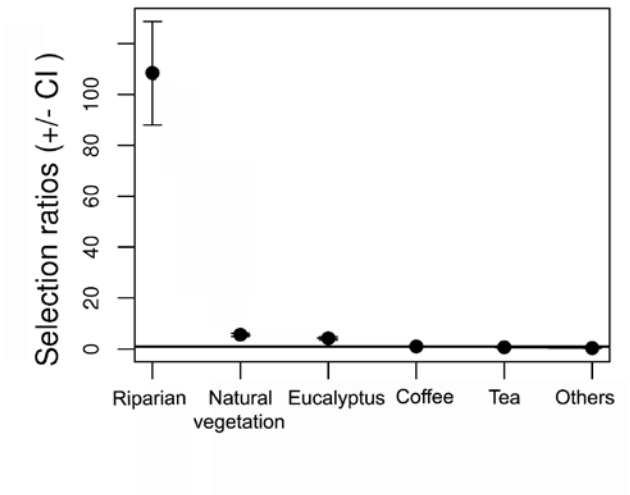

Fig. 2. Overall selectivity of main habitats by elephants in the Valparai plateau as indexed by Manly's selectivity ratio (w_i). Vertical bars represent 95% confidence intervals.

Seasonal and inter-annual variation

Elephants used coffee more frequently in the dry season (18%) than during the wet season (9.4%) while using *Eucalyptus* more in the wet (22.2%) than during the dry season (9%; Table 1). This seasonal variation in use of *Eucalyptus* and coffee contributed to significant overall difference in elephant use of habitats (χ^2 = 38.47; df = 5; $p < 0.001$). Further differences among habitats in seasonal use were identified using additive partitioning chi-square analysis. Open habitats such as swamps and tea did not differ significantly in seasonal use by elephants but use of open habitats differed significantly from the use of *Eucalyptus* (χ^2 = 20.52; df = 1; $p < 0.001$). Further, coffee significantly differed from the swamp, tea, and *Eucalyptus* habitats (χ^2 = 16.90; df = 1; $p < 0.001$). When coffee was included with swamp, tea, and *Eucalyptus*, there was no significant difference in the seasonal use of these plantations (combined open and tree-covered habitats) and natural vegetation (χ^2 = 0.44; df = 1; $p > 0.75$). This suggests that seasonal differences in habitat use emerge mainly from elephant use of habitats that provide shelter and food as compared to open habitats such as swamp and tea.

Table 1. Frequency of elephant locations during dry and wet seasons in various habitats in the fragmented landscape of the Valparai plateau, Anamalai hills, India.

Habitat	Dry		Wet	
	Observed frequency (%)	Expected frequency	Observed frequency (%)	Expected frequency
Tea	128 (32.0)	125	179 (30.6)	182
Coffee	72 (18.0)	52	57 (9.7)	77
Eucalyptus	36 (9.0)	67	130 (22.2)	99
Forest fragment	92 (23.0)	89	126 (21.5)	129
Riparian vegetation	46 (11.5)	45	64 (10.9)	65
Other	26 (6.5)	22	29 (5.0)	33
Locations (*N*)	400		585	

We found significant inter-annual variation in use of habitats by elephants (χ^2 = 37.5; df = 10; $p < 0.001$; Figure 4). The use of rainforest fragments nearly doubled from 13.7% in year 1 (2002-03) to 27.2% in year 2 (2004-05) and 26% in year 3 (2005-06). Similarly, the use of riparian vegetation also increased from 9.9% in year 1 to 12.6% and 10.7% in years 2 and 3, respectively. In contrast, there was a substantial (38%) decrease in the use of tea from 39.1% in year 1 to 29% and 24.1%, in years 2 and 3, respectively. Elephants did not appear to use other habitats such as coffee, *Eucalyptus*, and open grass and swamps differently over the years.

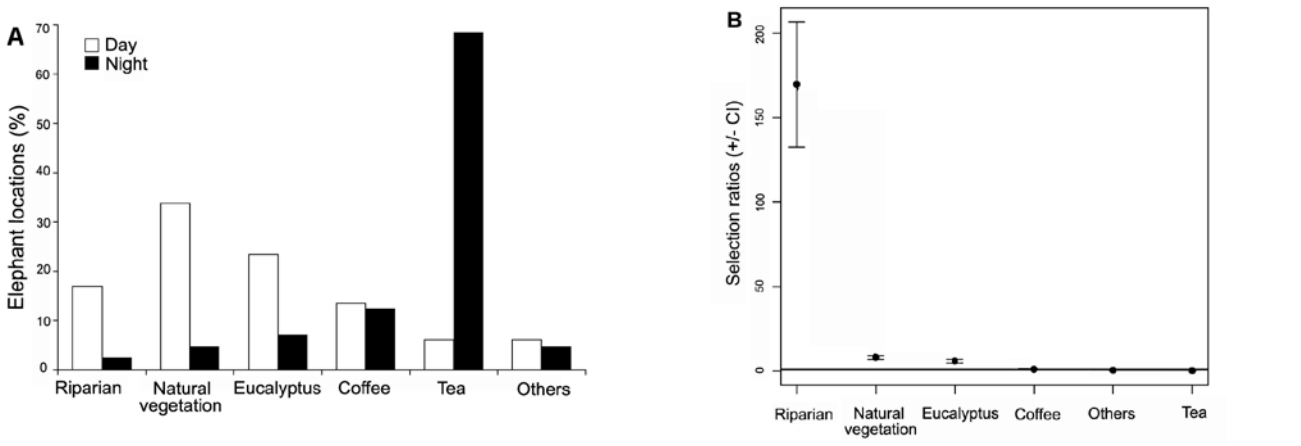

Fig. 3. Variation between daytime and nighttime use and selectivity of habitats by elephants on the Valparai plateau. A: Percentage of elephant occurrence in various habitats during day (n = 589 locations) and night (n = 396*)* on the Valparai plateau, Anamalai hills. B: Daytime selectivity of habitats by elephants on the Valparai plateau as indexed by Manly's selectivity ratio (w_i) with 95% confidence intervals. C: Nighttime selectivity of habitats by elephants on the Valparai plateau as indexed by Manly's selectivity ratio (w_i) with 95% confidence intervals.

Ranging pattern

The home range of the two elephant herds spanned a major part of the Valparai plateau, especially around the central portion (Figure 5). Areas in the northern part of the plateau were predominantly used by Herd 1 whereas areas in north east were largely used by Herd 2. The minimum convex polygon home range was 122 km² for Herd 1; and 114 km² for Herd 2 with a home range overlap of 97 km².

For Herd 1, of the 295 locations during the two-year period, 139 and 156 were recorded during the dry and wet seasons, respectively. Herd 1 moved in areas largely dominated by coffee towards the northern part of the plateau during the dry season, whereas during the wet season, movement appeared to be higher in the north and middle of the plateau along the Nadu Ar and Sholayar rivers. For Herd 2, of the total 335 locations, 109 and 226 locations were recorded during the dry and wet seasons, respectively. In

the dry season, the herd frequented the center of the plateau along the Nadu Ar and Sholayar rivers, mainly covering about 35 km² of the area. During the wet season, the herd moved from the center to the northeast part of the plateau, covering an area of about 50 km².

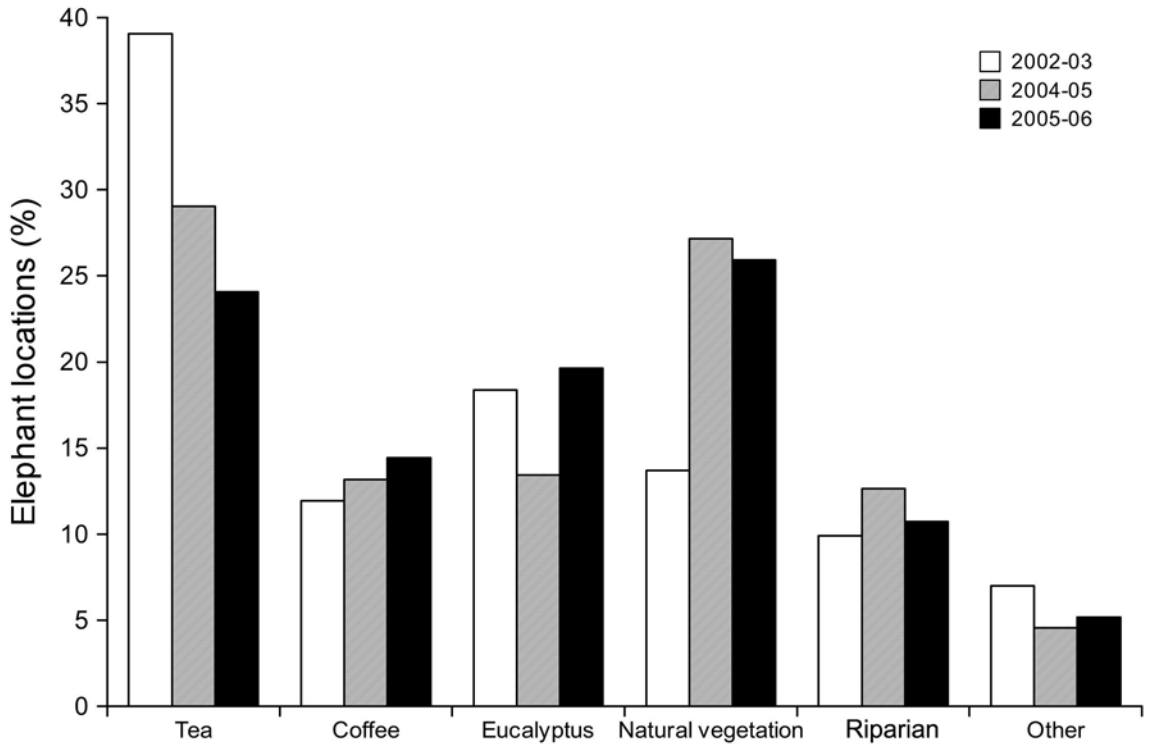

Fig. 4. Inter-annual variation in the use of habitats by elephants on the Valparai plateau. Analysis based on habitats corresponding to elephant locations obtained during 2002-3 (n = 343 locations), 2004-5 (n = 372), and 2005-6 (n = 270).

Discussion

In the plantation-forest mosaic of the Valparai plateau, elephants used rainforest fragments and vegetation along rivers more than areas under plantation crops when considered relative to availability (Fig. 6). This indicates the importance of natural vegetation for elephants in such plantation landscapes. Some degraded rainforest fragments on the plateau contained secondary vegetation providing favorable habitat and forage for elephants. The presence of reeds (*Ochlandra*) along streams and in forest fragments also encouraged elephants' use of natural habitats [40]. Among plantation crops, coffee and *Eucalyptus* seemed to be more important habitats than tea in areas devoid of natural vegetation. Availability of tree canopy along with secondary vegetation and grass growth in plantations of coffee and *Eucalyptus* appeared to provide cover and fodder for elephants. Moreover, as coffee is a seasonal fruit

crop and *Eucalyptus* plantations are felled for fuel only once in seven years, elephants may use these areas more due to the lower human activity, unlike in tea plantations that witness more intensive, year-round tea-leaf harvest and agricultural operations. Thus, coffee and *Eucalyptus* plantations act as important habitats in the plantation landscape of the Valparai plateau.

Elephant usage of habitat was also influenced by the time of the day, with natural vegetation areas being preferred by day and greater usage of tea plantations at night. This pattern may be attributed to greater time spent on feeding and other activities in areas which provide fodder and cover during the day, while tea plantation was mainly used for movement between foraging areas at night. Tea, a non-palatable crop, involves intensive human activity during the day and the elephants' low preference during the day may be a form of risk-avoidance behavior with movements through such open habitats more likely at night [29].

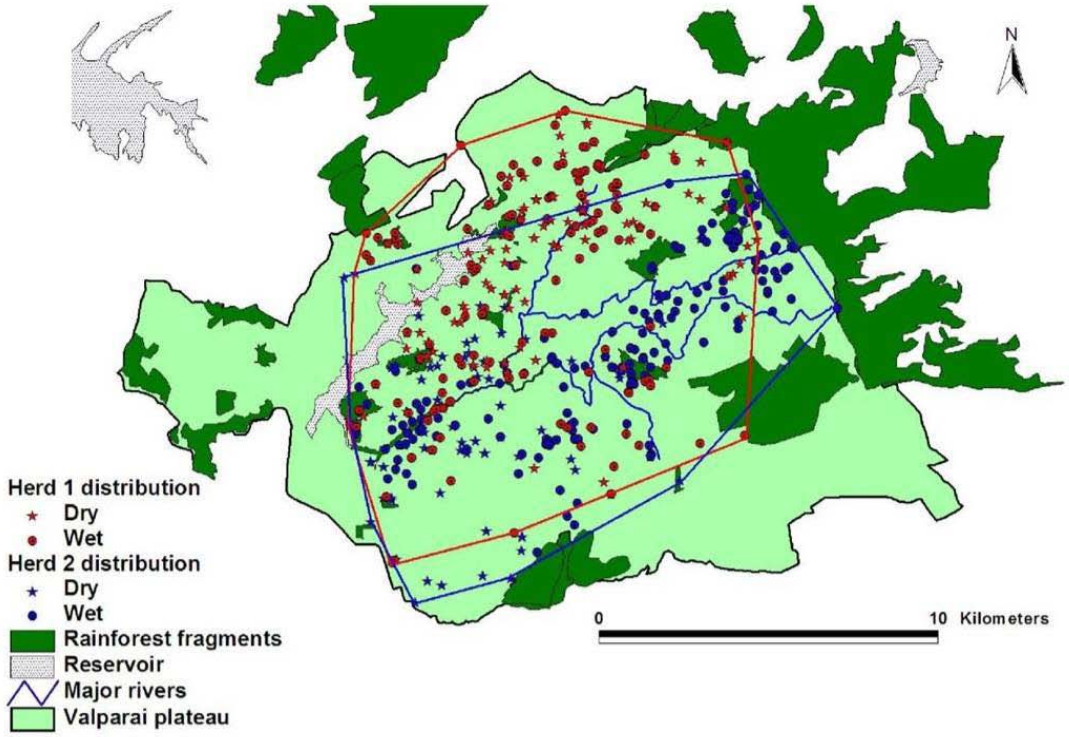

Fig. 5. Distribution of elephant locations of Herd 1 (in red) and Herd 2 (in blue) during the dry season (stars) and wet season (circles). The red and blue lines represent the 100% Minimum Convex Polygon of locations of the respective herds ranging within the Valparai plateau over the study period.

Across years, an increased use of natural vegetation with a gradual decrease in the use of tea plantations by elephants was recorded. The reduced use of natural vegetation and a high percent use of tea in Year 1 (2002-03) are possibly related to poor monsoon (286 cm) and relative dry conditions that prevailed in two preceding years. Higher rainfall in the subsequent years of Year 2 (2004-05, 316 cm) and Year 3 (2005-06, 436 cm), comparable to the long-term annual rainfall average of 350 cm for the region, resulted in increased use of natural vegetation and decreased use of tea plantations by elephants. The rainfall pattern influences seasonal change in natural vegetation and water availability, which are critical for elephant activity and their use of habitats [9]. Scanty distribution of water in prolonged dry conditions have negative effects on structure of woody plants [41] and result in low productivity in natural habitats [42]. In dry conditions, swampy areas in the middle of tea are the only places that provide grass for elephants. Exposure of fresh grass due to receding levels of water under dry conditions and the adaptability of Asian elephants to feed on coarse grasses as compared to African elephants [43] may explain their increased use of tea plantations during the prolonged dry conditions of 2002-03. Better rainfall in the subsequent years may have had a positive impact on the regeneration of palatable species resulting in increased elephant use of their preferred habitat (natural vegetation) [44] and decline in the use of tea in subsequent years. When environmental conditions are more favorable in habitats with tree cover such as forest fragments, *Eucalyptus*, and coffee, elephants may reduce use of open habitats such as tea in order to avoid possible encounters *with humans. Elephants are known to traverse human-modified habitats with increased speed [45], in order to reduce the time spent in unprotected areas and to access relatively secure or vegetation-covered habitats [46].*

Fig 6. Asian elephant use of plantation habitats such as tea (A), coffee (B) and Eucalyptus (C), and natural vegetation habitat of riparian vegetation (D). Photos by authors.

Elephants switch from browsing to grazing from the dry to wet seasons [4], corresponding to the seasonal availability in Africa [8, 47] and in Asia [48, 49]. On the Valparai plateau, elephants used coffee plantations more in the dry season and *Eucalyptus* plantations more during the wet season. Coffee plantations are used more frequently by elephants during the dry season, possibly due to the presence of grass under tree cover and browse from native shade trees. Moreover, as most of the coffee picking is restricted to three months (November - January) in a year, elephant use of coffee plantation corresponds to a period of minimal human activity during most of the dry season. Natural vegetation was important in both seasons for elephants. The retention of natural vegetation in forest fragments and riparian vegetation is important because the protein component in the browse in these habitats is significant in the diet of elephants [50]. Further degradation of rainforest fragments will lead to proliferation of weeds such as *Lantana camara* and *Chromolaena odorata* that suppress the growth of native plants, thereby reducing food resources for elephants. There are no quantitative data, however, on resource availability and seasonal variability in modified habitats such as plantations. Future studies that directly measure availability of water and resources such as forage and cover would be necessary to ascertain which of these resources are most influential in elephant use of natural and man-modified habitats (Fig. 7).

At the larger landscape level, the ranging pattern of elephants clearly indicates that substantial areas are used outside the designated protected areas. Although these herds ranged over a large part of the plateau, this includes only a part of their home range as these herds were noticed moving into surrounding protected areas. Consistent movements over certain non-overlapping areas by the two focal herds indicate fidelity to home ranges, which has been noticed in other studies [51]. Both herds did not seem to have substantial seasonal differences in ranging patterns within the plateau; however, the high concentration of locations of both herds along the three major tributaries and the Sholayar river during the dry season suggests a significant influence of water and food resource availability [52] in regulating their ranging and movement on the plateau.

Fig. 7. Asian elephant use of rainforest fragment (left). Human-elephant interactions are common during elephant movements across mosaic of habitats on the Valparai plateau (right). Photos by authors.

Implications for conservation

Humans and elephants have lived in close proximity to each other over centuries and they appear to coexist in altered landscapes. The Asian elephant is listed as an endangered species under Schedule I of Indian Wildlife Protection Act 1972, which enables high protection for elephants under Indian law. Patchy distribution of rainforest fragments and riparian vegetation on the plateau would benefit from wide-ranging species such as elephants as they act as seed dispersal agents in regeneration of natural vegetation. An icon of Indian society, the Asian elephant has been integral to cultural and religious festivals of people in India. The Valparai plateau with its 100,000 people living in plantations celebrates the elephant presence in festivals indicating their positive attitude towards pachyderms in this region.

Human-elephant conflicts on the Valparai plateau have not been intensive as compared to many other places in India [40]. High tolerance levels of people towards elephants are evident from the fact that there has been no retaliatory killing of elephants by people in the last 16 years in this region (M. Ananda Kumar, unpublished data). Active participation by local companies along with scientific conservation organizations in restoring rainforests to improve the quality of forest fragments has been a major step that would foster elephant conservation and also benefit highly endangered species such as the lion-tailed macaque (*Macaca silenus*) on the Valparai plateau [28].

Improved management, wildlife enforcement, and awareness programs would facilitate unhindered movement of elephants across plantations and promote human-elephant coexistence in the Valparai region. In highly fragmented landscapes, such as the Valparai plateau, forest fragments and riparian vegetation play important roles in the ecology of elephants. Conserving these patches and protecting them from further degradation is crucial for conservation of elephants as they are highly dependent on natural vegetation despite its patchy distribution. Retention and restoration of natural vegetation along rivers would develop connectivity between forest fragments for elephants. Such a step would facilitate easy passage of elephants and help decrease human-elephant direct encounters [40]. Preventing conversion of plantation habitats such as coffee with shade tree cover to tea plantations would help retain food and cover resources and facilitate elephant movement between forest fragments. Sequential or regulated felling and strict imposition of “no logging zone” of *Eucalyptus* at least 20 m on either side of rivers will act as shelter belts for elephants during their movement and will help reduce human-elephant conflicts.

Acknowledgments

We thank US Fish and Wildlife Service, USA, the Rufford Small Grants Foundation for Nature Conservation, UK, the WWF Nepal, and the Sea World and Busch Gardens Conservation Fund, USA for financial support. We are grateful to plantation companies, especially Parry Agro Industries Ltd, Tata Coffee Ltd, Tea Estates India Ltd, Bombay Burmah Trading Corporation Ltd, Periya Karamalai Tea Company Ltd, and a number of plantation managers for supporting our work on private lands. We thank the Tamil Nadu Forest Department, especially G. Sivamani, other forest staff, and informants for providing local support. We are especially grateful to Ajith Kumar, M. D. Madhusudan, Mewa Singh, and several colleagues at NCF for their encouragement and discussions. Special thanks to Dr. Peter Leimgruber for his inputs into the manuscript. We thank G. Moorthy, T. Dinesh, and A. Sathish Kumar for assistance in the field. We thank the editor, Dr. Alejandro Estrada for his valuable suggestions and two anonymous reviewers for useful comments and their immense help to improve this paper.

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