particular sector is a subject of concern due to their toxic nature.

Among nutrients, silicate (SiO_4) and ammonia (NH_4) have shown significant increase during post-*Phailin* period in comparison to the pre-*Phailin* period and the same period during the previous year. Silicate concentration was in the range 7.59–43.38 μmol-l^{-1} during pre-*Phailin* period and 11.23–40.38 μmol-l^{-1} during the previous year, whereas it was in the range 19.11–235.19 μmol-l^{-1} in the post-*Phailin* phase (Figure 3). Silicate enrichment in the lagoon might be due to the dilution of silicate-rich silt in the lagoon water resulting due to enhanced river influx. All the sectors were observed with high silicate concentration, among which maximum was in the NS as major tributaries of the lagoon empty into this region. It is established that a change in nutrient affects the phytoplankton composition, distribution and concentration. Therefore, increased concentration of silicate in the lagoon water may promote growth of diatomic species[3].

The concentration of ammonia was in the 5.76–12.05 μmol-l^{-1} range during pre-*Phailin* period and 2.84–43.89 μmol-l^{-1} during the previous year, whereas it was in the 62.05–140.77 μmol-l^{-1} range in the post-*Phailin* phase (Figure 3). Except for OC, the other sectors were observed with high values of ammonia. On an average, ammonia concentration of the lagoon increased 11 and 5 times in comparison to pre-*Phailin* and the same period of the previous year respectively. The potential sources of ammonia into the coastal waters are from terrestrial run-off, excretion by zooplankton or demineralization of organic matter[4]. In the present case, freshwater influx was responsible for enrichment of ammonia in the lagoon. Ammonia is one of the most important nitrogen sources for phytoplankton growth. However, preference for ammonia is group-specific and generally observed in green algae and cyanobacteria. The appearance of freshwater cyanobacterial species in the SS might be also attributed to the enrichment of ammonia. The increased inputs of nitrogen as ammonium may result in a shift in phytoplankton community composition towards a dominance of cyanobacteria and green algae[5].

The heavy rainfall following landfall of cyclone *Phailin* has significantly altered the concentration of silicate and ammonia in the Chilika lagoon. This large variation may lead to alteration in phytoplankton species composition and in turn, will have profound implication on the food web and subsequent lagoon economy. The significant reduction in the salinity also resulted in the appearance of the toxic freshwater cyanobacterias that may be the subject of concern. The lagoon is internationally recognized for its fishery resources that support livelihood of millions of fishermen. The ecological disruption in the lower order food chain may have a significant impact on fishery. Hence continuous monitoring of the Chilika lagoon is essential to address the ecological alterations and recovery status.

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Assessing leopard occurrence in the plantation landscape of Valparai, Anamalai Hills

Interactions between humans and large carnivorous mammals have a long history in Africa[1] and Asia[2]. Some adaptable carnivores with wide ranges occur in landscapes with humans and their increasing interface with people sometimes results in conflicts[3–5]. Encounters between carnivores and people that lead to economic losses due to livestock depredation or injuries/deaths of humans and wildlife[6] may result in negative attitude towards wild carnivores and hinder management and conservation efforts[7].

Negative interactions between humans and carnivores in India may occur due to high human population densities and presence of these species even outside wildlife protected areas (PAs)[8,9]. Among carnivores of the family Felidae, the common leopard *Panthera pardus* has the largest distribution of any wild cat, a diversified diet, and the ability to use various forest types and human-modified land uses such as croplands, and tea and coffee plantations. As leopards in such areas are known to prey on livestock, domestic dog, pig and poultry, and occasionally attack humans resulting in injuries or deaths, they are implicated in conflicts with people[9]. Inadequate understanding of social and ecological context of such conflicts hinders the formulation of effective mitigation and management strategies[10].

The Valparai plateau in the Anamalai Hills of the Western Ghats, India has experienced human–leopard conflict in the past. Although leopards in the area primarily subsist on wild prey species

(95% of the prey biomass as determined by scat analysis), from 2000 to 2010 there were 45 incidents of livestock depredation that led to injuries of 3 cows (2 calves, 1 adult) and death of 51 livestock comprising 45 cows (27 calves, 18 adults) and 6 adult goats in a single incident[11]. Over the same 11-year period[11], there were leopard attacks on 15 people, which resulted in 5 injuries (2 male, 3 female) and 10 deaths (5 male, 5 female; of the 7 whose ages were known, 6 were children under 10 years of age). These incidents and other reports of leopard presence triggered alarm and public pressure on the Forest Department to capture and translocate them, leading to 12 leopard (7 male, 4 female, 1 unknown) translocations between 2007 and 2012 (ref. 11, unpublished data). Studies from other areas indicate that capture and translocation may have the counter-intuitive and counter-productive effect of increasing conflict and may fail to prevent conflict recurrence[12]. Understanding leopard distribution and occurrence and the context of conflicts are required to select an appropriate, scientific and informed management strategy[13].

Here, we use camera traps to examine leopard occurrence in the Valparai plateau as a preliminary step towards informed and scientific management to minimize human–leopard conflict. The Valparai plateau is a 220 sq. km landscape of tea, coffee and other plantations, containing at least 40 rainforest fragments (less than 1 ha to about 200 ha) and a resident human population of about 75,000 people (crude density of 340 people/sq. km) in Valparai town and surrounding estates[14] (Figure 1 *a*). The main natural vegetation type of the area (elevation range, 700–1500 m; average annual rainfall, 3500 mm) is mid-elevation tropical wet evergreen forest[15]. The presence of forest fragments and suitable habitats within plantations, besides the larger surrounding forest areas in the Anamalai and Parambikulam Tiger Reserves and Reserved Forests, enable persistence of many mammal species[16–18] and leads to occasional incidence of human–wildlife conflicts involving species such as Asian elephants *Elephas maximus* and leopards in the landscape[11,14].

For this study, the Valparai plateau region was divided into three blocks: northern, southern and urban. The northern block has a mix of tea, coffee and *Eucalyptus* plantations with rainforest fragments interspersed within estates of two companies (Parry Agro Industries Ltd and Tata Coffee Ltd). The southern block is predominantly tea with a small patch of *Eucalyptus* plantation, falling entirely within the estates of Bombay Burmah Trading Corporation Ltd (BBTC). A 2 km × 2 km grid was overlaid on the northern and southern blocks, and 8 contiguous grid cells occupying 32 sq. km in each block were selected for survey. Within these grids, plantation roads were surveyed on foot for leopard signs (scats, pugmarks and scrapes). At sign locations and intersections of roads, GPS locations were noted and marked on *Google Earth* to help select camera placement sites. Eight camera-trap sites were selected in the northern block and eight in the southern block, maintaining a minimum distance of 1.5–2.4 km between sites (with the exception of one site that was 0.9 km from the nearest site; Figure 1 *b*), so that each leopard in the area could potentially be photo-trapped[9]. In each site, a pair of cameras was placed on either side of an estate road or trail, to obtain photographs from both sides of any passing animal. The area of the minimum convex polygon that included the camera trap locations in

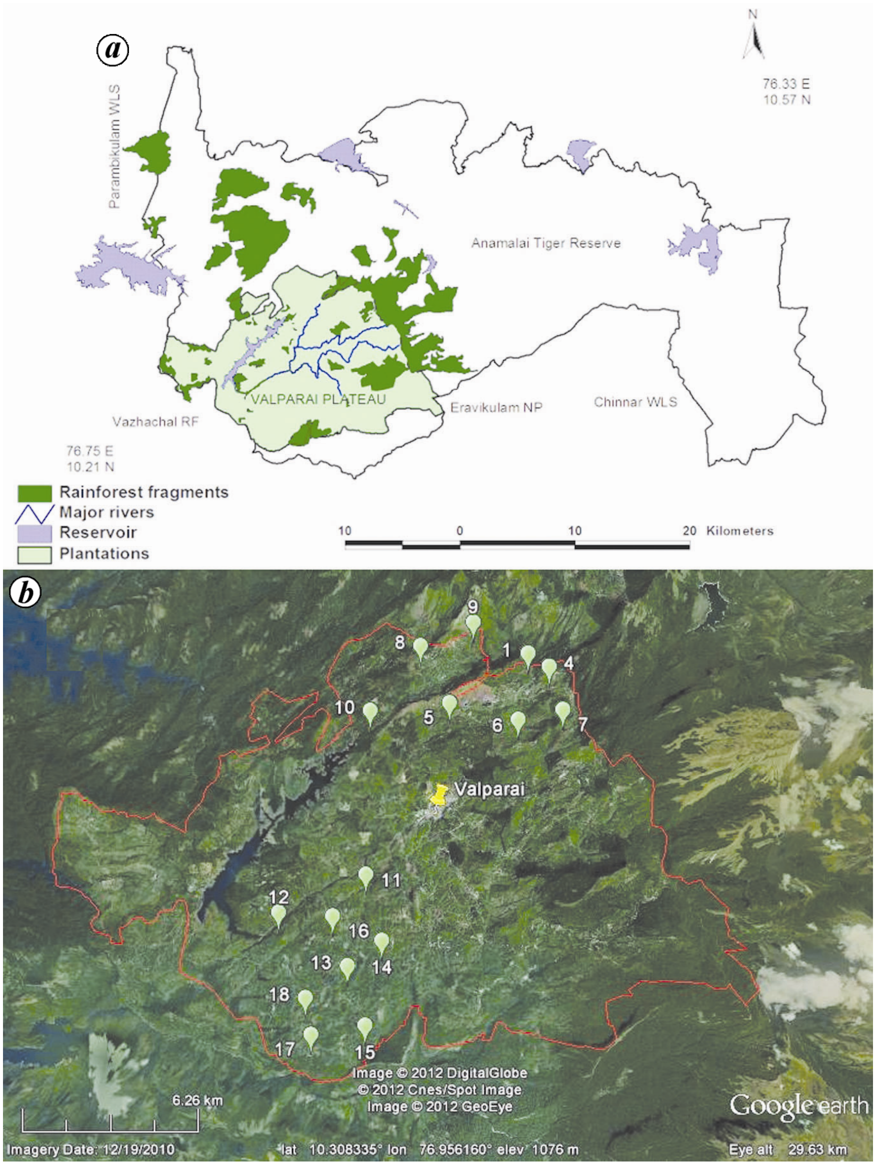

Figure 1. ***a***, Map of the study area showing location of Valparai plateau (shaded area) adjoining Anamalai Tiger Reserve and other protected areas. ***b***, Satellite image of Valparai plateau (red border) showing camera-trap sites in the northern and southern blocks and Valparai town (image courtesy: *Google Earth*).

the northern and southern blocks was 13.4 sq. km and 12 sq. km respectively. In the urban block, comprising the two towns of Valparai and Rottikadai, camera-trapping sites were selected based on earlier reports of leopard sightings by local people or the research team. Six sites (four in Valparai, two in Rottikadai) were selected for camera-trap placement with an average distance of 0.5 km between sites. Only one camera was placed in each site to minimize risk of theft.

Camera-trapping was conducted between May and July 2012 using 16 camera traps (10 Bushnell Trophycam infrared cameras, four Deercam Scouting camera DC-200 and two CEDT (Centre for Electronics Design and Technology, Indian Institute of Science, Bangalore) cameras). The cameras were tied 35–40 cm above ground in each camera-trap site. In the northern and southern blocks, one Bushnell camera was paired with either Deercam or CEDT cameras, the former kept active throughout the day (24 h, recording photograph date and time) and the latter (Deercam and CEDT cameras) turned off during the day depending on the intensity of human activity to prevent unnecessary exposures. Deercam cameras were checked frequently and photographic film rolls were replaced when required. Camera-traps were active for 10–11 consecutive days in each site. In the urban block, one Bushnell camera was placed in each site, kept active overnight and removed in the morning, as a precaution against theft or damage. Cameras were active for 10 consecutive days.

The sampling effort was measured as the sum of the number of nights camera pairs in each site were active (expressed as trap-nights). Successive photographs of the same species, which were separated by more than 30 min, were recorded as independent encounters[19]. In each block, we calculated the photo-capture rate for each species as the number of photographs of that species taken by a camera-pair divided by the total number of trap-nights, and multiplied by 100 to express photo-capture rate as number of captures per 100 trap-nights. Among any of the cameras in a block, the minimum number of trap-nights to obtain the first photograph of a leopard was noted and used as a measure to compare with other studies. Photographs of people, chiefly plantation workers commuting and working in the plantation, were obtained but not considered for analysis. Individual identification of leopards was not possible as most night-time images from the infrared cameras were blurred and inadequate to distinguish rosette patterns on the pelage.

In 225 trap-nights, we obtained 20 independent leopard photographs, at 2, 2, and 4 sites, and corresponding photo-capture rate of 3.5, 10 and 15 in the northern, southern and urban blocks respectively (Figure 2 *a* and *b*, Table 1). All leopard photographs obtained were of solitary animals during nighttime, except one at 1700 h at a site in the northern block. At one site in the southern block, two leopard photographs taken within 30 min of each other were considered as a single photo-capture; at the same site we obtained six leopard photographs on five days (we could not ascertain if these were of one or more individuals).

We obtained photographs of 12 other species of mammals in the northern and

Figure 2. Camera-trap images of carnivores and prey species in the Valparai plantation landscape. ***a***, Leopard in tea estate; ***b***, Leopard with lights of Valparai town in the background; ***c***, Dhole; ***d***, Sloth bear; ***e***, Indian crested porcupine; ***f***, Indian wild pig; ***g***, Indian muntjac; ***h***, Sambar.

Table 1. Sampling effort, leopard occurrence and photo-capture rates in the three blocks in Valparai plateau, Anamalai hills, India

	Northern block	Southern block	Urban block
Sites	8	8	6
Trap-nights	85	80	60
Sites with leopard photographs	2	2	4
Number of leopard photographs	3	8	9
Photo-capture rate (photographs per 100 camera trap-nights)	3.5	10	15
Number of trap-nights to first photograph of leopard	8	18	8

Table 2. Photo-captures of mammals in the Valparai plateau, expressed as the number of photographic captures per 100 camera trap-nights

Species	Northern block	Southern block	Urban block*
Indian crested porcupine	22.3 (19)	46.25 (37)	0
Indian wild pig	15.2 (13)	32.5 (26)	5 (3)
Indian muntjac	14.1 (12)	5 (4)	0
Gaur	11.7 (10)	12.5 (10)	0
Common leopard	3.5 (3)	10 (8)	15 (9)
Sambar	9.4 (8)	1.2 (1)	0
Black-naped hare	4.7 (4)	7.5 (6)	3.3 (2)
Stripe-necked mongoose	3.5 (3)	6.25 (5)	1.6 (1)
Small Indian civet	3.5 (3)	2.3 (2)	0
Dhole	1.2 (1)	7.5 (6)	0
Sloth bear	4.7 (4)	0	0
Asian elephant	1.1 (1)	0	0
Brown mongoose	0	1.2 (1)	0
Unknown	8.2 (7)	11.2 (9)	0

Number of photographs obtained is provided in parantheses.
*Photo-capture rates are of photographs obtained during night, as the cameras were placed only during night in the urban block.

southern blocks, including five carnivores: sloth bear *Melursus ursinus*, dhole *Cuon alpinus*, small Indian civet *Viverricula indica*, brown mongoose *Herpestes fuscus* and stripe-necked mongoose *H. vitticollis* (Figure 2 *c* and *d*, Table 2). Of the 207 photographs obtained in total, the most frequently photographed mammal was the Indian crested porcupine *Hystrix indica* (27%, *n* = 56 photos). Other species photographed were Indian muntjac *Muntiacus muntjak*, black-naped hare *Lepus nigricollis*, sambar *Rusa unicolor*, Indian wild pig *Sus scrofa*, gaur *Bos gaurus* and Asian elephant *Elephas maximus* (Figure 2 *e–h*). In the urban block, photographs of domestic pig, domestic dog, domestic fowl, cattle, wild pig, black-naped hare, stripe-necked mongoose and humans were obtained, but photo-capture rates of humans and domestic animals were not calculated due to proximity to human settlement.

Leopard occurrence as assessed by camera-trapping in the Valparai plateau appeared to be more frequent than in other landscapes. The number of trap-nights (8–18) required to obtain the first photograph of the leopard in our study was lower compared to some other studies in Asia (94 in Taman Negara National Park, Malaysia[20] and 144 in Nam Et-Phou Louey National Protected Area (NEPLNPA), Laos[21]). The capture rate was high in urban units compared to other blocks, possibly due to high resource availability like garbage and animal waste around meat shops, but it could also be because camera-trap sites were located close to each other in urban units. Among the few good images obtained, we identified two different leopard individuals in the Valparai town area in mid-2012. The higher photo-capture rate in the southern block was because we obtained five leopard photographs in the same camera-trap site on different days, possibly the same individual and not necessarily indicating more leopards. Better cameras that can produce clear images are necessary in order to identify individuals. The sampling in this study was, however, restricted to only a portion of the Valparai plateau, and a small period during the late dry season and early wet season during the southwest monsoon. As recent research from elsewhere suggests that leopard home ranges are less than 15 sq. km in human-use landscapes (M. Odden *et al.*, pers. commun.) the area surveyed in the present study may span 1–2 leopard ranges. Further camera-trapping, over a larger area and time period, is therefore needed to estimate other parameters such as area occupied by leopards and population density on the Valparai plateau.

The photo-capture rates of wild prey species in our study area were also higher compared to a similar multiple-use landscape in NEPLNPA, Laos[21], where mean capture rates varied from 0.08 to 4.26. Almost all mammal species recorded in the adjoining Anamalai Tiger Reserve (earlier Indira Gandhi Wildlife Sanctuary) are also known to occur in fragments in the Valparai landscape and densities of many species do not differ substantially between PAs and private rainforest fragments[17]. An earlier study found higher abundance of wild prey in rainforests than in plantations, with variation in prey species encounter across land-use types: Indian crested porcupine more frequent in tea plantations, Indian muntjac more frequent in coffee, and species like sambar and Indian spotted chevrotain *Moschiola indica* more frequent in rainforests and intermediate in coffee[11]. The camera-trapping rate of these prey species in the present study conforms to these habitat differences, as species like Indian muntjac and sambar were more frequently encountered in the northern block (containing more forest fragments and coffee), whereas Indian crested porcupine was more frequent in the southern block (comprising mostly tea).

While no conflict incidents (attacks on livestock or people) occurred during the present study itself, between 2008 and the study period, there were eight leopard attacks on humans (four fatalities) in the southern block, mainly in BBTC estates. This incidence was higher than that in the northern block (single incident leading to fatality) and urban block (two incidents leading to injuries, ref. 11, unpublished data). While causes for increased conflict in the southern block are unknown, the present study suggests that leopard occurrence itself does not directly relate to higher conflict as leopard occurrence was comparable in the other two blocks over the same period. A study in a similar landscape of tropical moist deciduous forests surrounded by cultivated land and tea plantations in northern West Bengal, from 2001 to 2008, recorded 243 leopard attacks on humans (including five fatalities), 90% of the cases being from tea estates[22]. In NEPLNPA[21], 583 livestock (buffalo, cow) depredation events due to large carnivores were reported from 28 villages between 1993 and 2002. Although leopard photo-capture rate was higher in our study area, the number of conflict incidents involving humans or livestock is lower than that in the other areas. Lower conflict incidence in the Valparai landscape may be due to higher prey abundance and fewer households owning livestock and because livestock are frequently accompanied by herders during the day. As there were no conflict incidents in parts of the landscape and as leopards occurred both in areas with and without conflict, the study suggests that the mere presence of leopards does not determine occurrence or intensity of conflict in human-use landscapes.

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