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Spatial aggregation and specificity of incidents with wildlife make tea plantations in southern India potential buffers with protected areas

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Abstract: Many wildlife species survive in human-modified landscapes and understanding the opinions of those who share space with wildlife will aid conservation efforts. Using a questionnaire, we assessed the presence of 12 mammal species in 78 tea plantations in the Nilgiris, southern India. We obtained data on (i) plantation size, location, and elevation, (ii) species presence over a year, (iii) type and number of wildlife incidents caused, (iv) financial cost of wildlife damage, and (v) support for wildlife conservation. We used a generalized linear model to assess whether the distance to protected areas, elevation, and plantation size influenced species presence and the effect of these variables and wildlife incidents on support for conservation. Among all species reported, Bonnet Macaque, Wild Boar, and Porcupine were the most widespread, and the former two and the Gaur reportedly caused >50% of damages. Crop damage was the most frequent (74%, n = 244), whereas livestock predation, attacks on people, and infrastructure damage constituted <10% of incidents reported. The cost of wildlife damage was negligible for 72 estates and significant for six. The number of species increased with proximity to protected areas, with increasing elevation and plantation area. Plantation management (62%) supported wildlife conservation, and support increased with decreasing plantation size, increasing distance to protected areas, and with a higher number of species reported, but decreased with increasing incidents of wildlife damage. Mitigating impacts of a few widely distributed species that cause disproportionate damage and compensating those that incur disproportionately high costs could increase support for conservation. Education and awareness programs for the plantation community can further help increase support and participation in wildlife conservation activities. Plantations can thus serve as supplementary habitats for wildlife in regions where hard boundaries between protected areas and human settlements prevail.

Keywords: Conservation attitudes, human-wildlife coexistence, Nilgiri Biosphere Reserve, wildlife damage.

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For **Author details** & **Author contribution** see end of this article.

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INTRODUCTION

The transformation of terrestrial ecosystems into human use areas has driven global biodiversity loss (Vitousek et al. 1997; Johnson et al. 2017) and has forced many species into human-modified landscapes. Although protected areas (PA) safeguard remnant habitats and wildlife, the current global PA network which comprises 14.9% of Earth's land area (UNEP-WCMC et al. 2018) is inadequate for the long-term conservation of several species, particularly those that are wide-ranging (Woodroffe & Ginsberg 1998; Jenkins & Joppa 2009; Di Minin et al. 2016). On the other hand, certain human-modified landscapes such as coffee and tea plantations can provide refuge, foraging grounds, and enable wildlife movement between reserves (Bal et al. 2011; Rathod & Rathod 2013; Guzmán et al. 2016; Kumar et al. 2018). In landscapes that lack intact or protected forests, such plantations can provide supplemental habitats for wild animals (Bhagwat et al. 2008; Krishnan et al. 2019). The survival of many species, however, will ultimately depend on their ability to persist and be tolerated in human-modified landscapes.

Wild animals that are displaced by habitat loss and fragmentation may harm humans, their properties, and their livelihoods (Torres et al. 2018). For instance, in Cameroon, 12 different mammal species damaged cocoa pods in cocoa plantations (Arlet & Molleman 2010). In India, damage by Asian Elephants *Elephas maximus* to a variety of crops causes economic loss to farmers (Ramkumar et al. 2014; Govind & Jayson 2018); and Leopards *Panthera pardus* reportedly attack people and livestock in tea plantations (Sidhu et al. 2017; Kshettry et al. 2020). Such incidents can reduce tolerance for wildlife, lead to retaliatory killing of wild animals, and can also affect ongoing conservation efforts (Nyhus et al. 2000; Marchal & Hill 2009; Kalam et al. 2018); however, under certain circumstances, humans are tolerant of wild animals. For instance, in Africa, farmers tolerated Chimpanzees *Pan troglodytes verus* as they would eat the fruit of the cashew nut and pile the nuts, thereby facilitating harvest by farmers (Hockings & Sousa 2012). In Indonesia, farmers tolerated Orangutans *Pongo abelii* in oil palm plantations and agricultural farms as they were considered harmless (Campbell-Smith et al. 2010); and Islamic religious beliefs protected crop-raiding macaques (*Macaca tonkeana* and *M. ochreata brunnescens*) (Riley & Priston 2010).

Identifying the extent of human tolerance for wildlife, and the factors that reduce and promote tolerance, is crucial for the conservation of wildlife in human-modified landscapes (Treves & Bruskotter 2014). Interviews and surveys are widely employed to assess tolerance to wildlife presence among local communities. For instance, they have been used to assess tolerance towards (i) wildlife presence, (ii) economic loss to wildlife, and (iii) responses towards conservation initiatives (Fulton et al. 1996; Arjunan et al. 2006; Kansky & Knight 2014). In this study, we used questionnaire surveys to assess wildlife presence and support for wildlife conservation in tea plantations in the Nilgiri Biosphere Reserve (NBR), which is part of the Western Ghats (a global biodiversity hotspot) of India.

The NBR comprises of six critical PAs and is an important region globally for the conservation of the Asian Elephants, Bengal Tiger *Panthera tigris*, Nilgiri Tahr *Nilgiritragus hylocrius*, and the Critically Endangered White-rumped Vulture *Gyps bengalensis*. Since the British colonization in the 19th century, however, montane evergreen forests (known locally as 'sholas') and montane grasslands in the NBR have been transformed into agricultural fields, monoculture plantations, and other land uses (Prabhakar & Gadgil 1995). As a result, many monoculture plantations adjoin PAs and include open grassy expanses, swamps, patches of forest along streams, fuel-wood plantations, and degraded forest fragments that support rich flora and fauna (Shankar & Mudappa 2003; Kumara et al. 2004). A critical shortcoming of the NBR is that it has been designed without a transition zone, which is mandatory as per UNESCO guidelines for biosphere reserves (Daniels 1996; Puyravaud & Davidar 2013; UNESCO 2019). Hard boundaries affect both humans and wildlife. Therefore, a transition zone, where human activities are more compatible with conservation, may help reduce these impacts. Assessing wildlife presence in tea plantations and human tolerance of wildlife in the NBR would help understand whether plantations can act as transition zones in this region. Moreover, tea is a non-edible crop and can thus reduce economic losses caused by wildlife.

We conducted our survey in the Nilgiris District (henceforth Nilgiris) in the NBR. We surveyed 78 small and large tea plantations to assess (i) wildlife presence in each plantation, (ii) estimate damages caused by wildlife and its financial costs, and (iii) assess support for wildlife conservation among plantation managers. We tested the hypotheses that support for wildlife conservation would be positively associated with increasing (a) plantation size, and (b) distance to PA, and negatively associated with (c) higher incidents of damage, and (d) their increasing costs.

METHODS AND MATERIALS

Study area

The Nilgiris (2,452km^2) lies between 11.6–11.91 ^{0}N and 76.21–77.03 ^{0}E in the state of Tamil Nadu (Figure 1). This region is mountainous with elevations ranging from 900–2,500 m. The heterogeneous landscape and climate (von Lengerke 1977) support diverse vegetation types including lowland tropical rainforests, deciduous forests, thorny scrub vegetation, upper montane shola forests, and grasslands (Prabhakar & Pascal 1996). Forests cover 1,426km^2 (Department of Economics and Statistics 2016) constituting 58% of the total area and several important PAs such as Mudumalai Tiger Reserve (321km^2) and Mukurthi National Park (78km^2) are located here.

The district has a human population of around 700,000 (Census of India 2011). There are six administrative subdivisions called taluks, of which we surveyed three: Gudalur (726km^2), Kotagiri (397km^2), and Coonoor (229km^2). Gudalur lies on the western side of the Nilgiri Plateau at a lower elevation (≈1,000m) and receives an annual rainfall of around 2,300mm. Kotagiri and Coonoor lie on the upper plateau (>1500m). Kotagiri is situated along the northern slopes and receives an annual rainfall of 800–1,500 mm, whereas Coonoor lies east of the plateau and receives 1,200–1,500 mm annual rainfall.

The Nilgiris District is also an important tea growing region in southern India, and plantations of tea and coffee have replaced a high proportion of native grasslands and montane forests (Kumar & Bhagavanulu 2008). Today, the plantations range from smallholdings (<10ha) to over 400ha (Tea Board India 2003) and cover about 23% (560km^2) of the district area (Department of Economics and Statistics 2016). Several tea plantations in the Western Ghats are also next to PAs, and they provide a permanent or transitory habitat for many species, including those that are endangered (Shankar & Mudappa 2003; Kumara et al. 2004).

Methods

We surveyed 78 small and large tea plantations in the three regions mentioned earlier, from January to

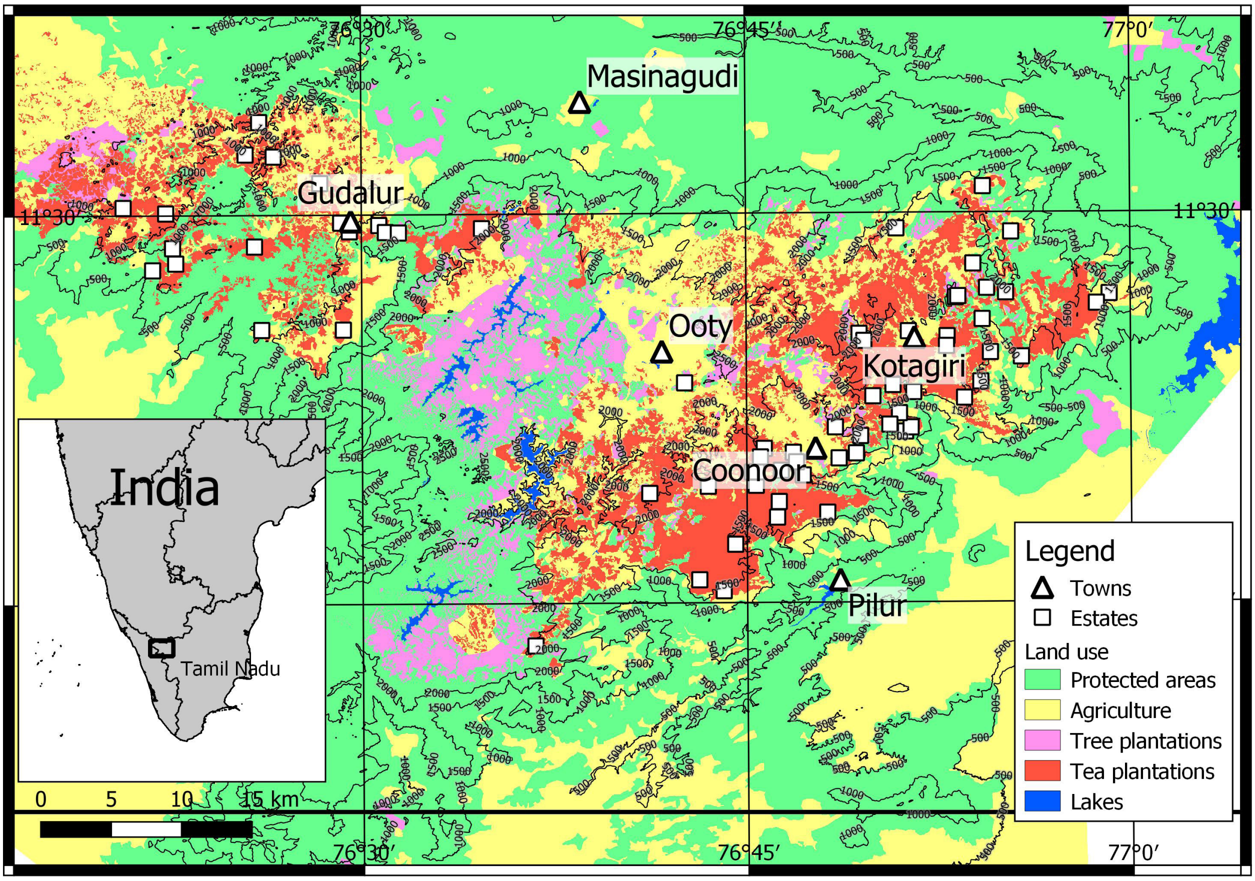

Figure 1. Map of the study area indicating location of all plantations surveyed in Nilgiris District.

March 2011. We first obtained a list of tea plantations from the offices of the United Planters Association of Southern India (UPASI) in Gudalur and Coonoor. During our survey, we came across many plantations that were not members of UPASI, that we also included. We categorized all reserved forests that have a lower level of protection, tiger reserves, and national parks that are strict nature reserves, as PAs in this study.

Questionnaire Survey

We used a structured questionnaire (Appendix A1 in supplementary data) which focused on: (i) location of the plantation office, (ii) size of plantation, and (iii) distance to PAs. Using a global positioning system (GPS), we recorded the location of each plantation office and used this as the point for geo-referencing. We then calculated the distance to PAs using a GRASS geographic information system (GRASS GIS). Further, we asked about the (iv) sighting frequency of 12 mammalian species, (v) incidents of crop and infrastructure damage, livestock depredation, and attacks on humans, and (vi) financial costs of wildlife damage over one year (January 2010 to January 2011). Last, we inquired about (vii) the management's support for wildlife conservation (positive/negative).

We selected 12 species that could cause different types of damage: Asian Elephant, Gaur, Wild Boar *Sus scrofa*, Sambhar *Rusa unicolor*, Muntjak *Muntiacus muntjak*, Sloth Bear *Ursus ursinus*, Bonnet Macaque *Macaca radiata*, Crested Porcupine *Hystrix indicus*, and Indian Giant Squirrel *Ratufa indica* that could raid crops and cause infrastructure damage; Bengal Tiger, Leopard, and Dhole or Asiatic Wild Dog *Cuon alpinus* that could prey on livestock. Photographs of these mammals were shown to interviewees to reduce error in identifying the wildlife in question. We did not carry out any independent field survey to verify the presence or absence of these species.

We initiated the survey by first contacting and interviewing plantation managers to ascertain wildlife present on their premises and to gauge whether their company supported wildlife conservation or not. We then interviewed one ground-level supervisor to corroborate wildlife presence and damages. Wherever possible, we verified wildlife presence by going through records of wildlife sightings maintained by plantation staff under the Rainforest Alliance Certification. We also interacted with villagers living around the periphery of the plantations to crosscheck and verify the data collected from the plantations we surveyed.

Wildlife presence and species richness

When a species was reported to be present in a plantation, we coded it as 1 and its absence as 0. All the species presence were summed up in a plantation, to get an estimate of the total number of species (species richness) reported. If present, we asked for sighting frequency, which was also coded: never = 0, daily/weekly = 1, regular monthly = 2, occasionally once a year = 3.

Wildlife incidents

We categorized the reported crop and infrastructure damage, livestock depredation, and attacks on humans, as 'wildlife caused incidents' and not as 'human-wildlife conflict' for reasons mentioned by Davidar (2018). We used a binary score for each type of incident reported in a plantation, 1 if reported and 0 if not reported. We summed up all the incidents reported over the year, by species and for each plantation.

Financial costs of wildlife damages

Plantation managers provided financial data on wildlife damage over a year (January 2010 to January 2011). If the cost of wildlife damage was negligible, they were not recorded by the management team and hence not provided to us. Besides documenting the financial cost of wildlife damage, comparing them with other components can help determine the actual cost incurred and how significant the financial loss can be to those affected. We used the cost of preventing insect pest damage (pesticide usage) in tea plantations as a baseline of financial cost control to compare the damage caused by wildlife. The estimated cost of wildlife damage and pesticide usage per hectare over the year in each plantation was noted in Indian Rupees and converted to United States Dollar (USD) using the rates prevalent during the study period.

Support for wildlife conservation

We coded the responses towards support for wildlife conservation as 0 if negative and 1 if positive, however, many plantation managers did not provide a response, which we recorded as 'no response'. Hence during the analysis, we recoded the responses as 0 if negative, 1 if positive, and 2 if 'no response'. We ran two sets of analysis, one with the negative responses and another where we merged the 'no response' category with negative response category. We did so because negative opinions may have repercussions if the results of the survey were placed in the public domain (Newmark et al. 1993; Gillingham & Lee 1999; Liu et al. 2011).

Data analyses

We used the software R 3.2.3 (R Core Team 2016) for statistical analysis. We conducted exploratory analysis on the size, distribution of plantations, elevation, and proximity to a PA. We calculated the distance from the point of geo-referencing (plantation office) to the nearest PA using the v.distance module of GRASS-GIS 7.2 (GRASS Development Team 2017).

We used a generalized linear model (GLiM) with Poisson link to analyze whether the distance to a PA, elevation, and size of a plantation influenced species richness. One assumption of the GLiM is the independence of observations, and since plantations that are close to each other may have the same issues, we tested whether the response variable was spatially autocorrelated. The Moran's I indicated no spatial autocorrelation ($p = 0.18$) of the response variable. We also used a GLiM but this time with quasi-Poisson distribution (due to overdispersion of data), with the same explanatory variables to analyze their effects on wildlife damage incidents. In both cases, we included all variables and interactions and then simplified by stepwise deletion comparing models with the AIC and ANOVA. We stopped the model simplification when the AIC was lowest, or the ANOVA became significant. We eliminated two estates, one for which we could not obtain geographic coordinates and another with an exceptionally large area (8,000ha).

We examined a few potential causes that could prompt individuals to approve or disapprove of wildlife conservation efforts. We named the dependent variable as "Attitude," and our explanatory variables were (i) distance to PA from plantation office, (ii) size of the plantation, (iii) species richness (of the studied species), and (iv) number of incidents of wildlife damage.

We used a GLiM to determine the association between the four explanatory variables and support for wildlife conservation. We used the binomial link function as the dependent variable was binomial. We conducted two logistic regression analysis using two sets of variables. The first set excluded all the 'no response' answers and included only positive and negative responses. The second set combined 'no response' answers with the negative responses. The first logistic regression started with all variables but no interactions, due to lack of power. The second logistic regression started with all variables and interactions. Both were simplified by stepwise deletion as above.

We analyzed data of those estates that reported costs of pesticide usage and those that also reported wildlife damage. We first used log-transformation to obtain a normal distribution. We then performed a Shapiro-Wilk normality test to confirm normality. Because one sample was small, we compared the log-transformed arithmetic means with a t-test to verify whether wildlife damage costs were similar to insect pest-control costs.

RESULTS

Location, plantation size, and distance to protected areas

The 78 plantations surveyed ranged in area from 5 to 8,094 ha and occurred at elevations between 700 to 2,300 m (Figure 1). Of these, 20 were in Gudalur, 22 in Kotagiri, and 36 in Coonoor (Appendix A2 in supplementary data). Tea was the primary crop in all plantations: 57 cultivated only tea, 21 grew coffee in addition, and 23 grew spices. The average distance to a PA was 2.4km, and the maximum distance was 10 km. Twenty-one plantations were situated less than one kilometer from different PAs and 56 further away (Appendix A2 in supplementary data). We were unable to obtain the GPS coordinates for one plantation.

Wildlife presence and species richness

There was a median of eight species reported per plantation with a range from 0 to 12. The most widely distributed species were the Bonnet Macaque (across 91% of the plantations), followed by Wild Boar (85%) and Porcupine (78%) (Figure 2). On the other hand, the Tiger (33%), Dhole (32%), and Muntjak (13%) were rarely reported (Figure 2). There was a significant positive correlation between the total number of species in a plantation and proportion of charismatic species, such as the Tiger and Dhole (Spearman rank correlation S_r = 0.350116, p = <0.01).

GLiM simplification produced the most parsimonious model with three variables that were correlated with species richness (Table 1): distance to a PA, elevation, and interaction between distance to a PA and plantation size. Species richness was significantly and negatively correlated with distance to a PA ($p = 0.00104$) (Table 1), tended to increase with increasing elevation, and was weakly and positively associated with the interaction between increasing distance to a PA and larger area, therefore larger plantations further away tended to have more species (Table 1).

Wildlife incidents

A total of 244 wildlife-related incidents were reported over one year, with an average of three incidents per

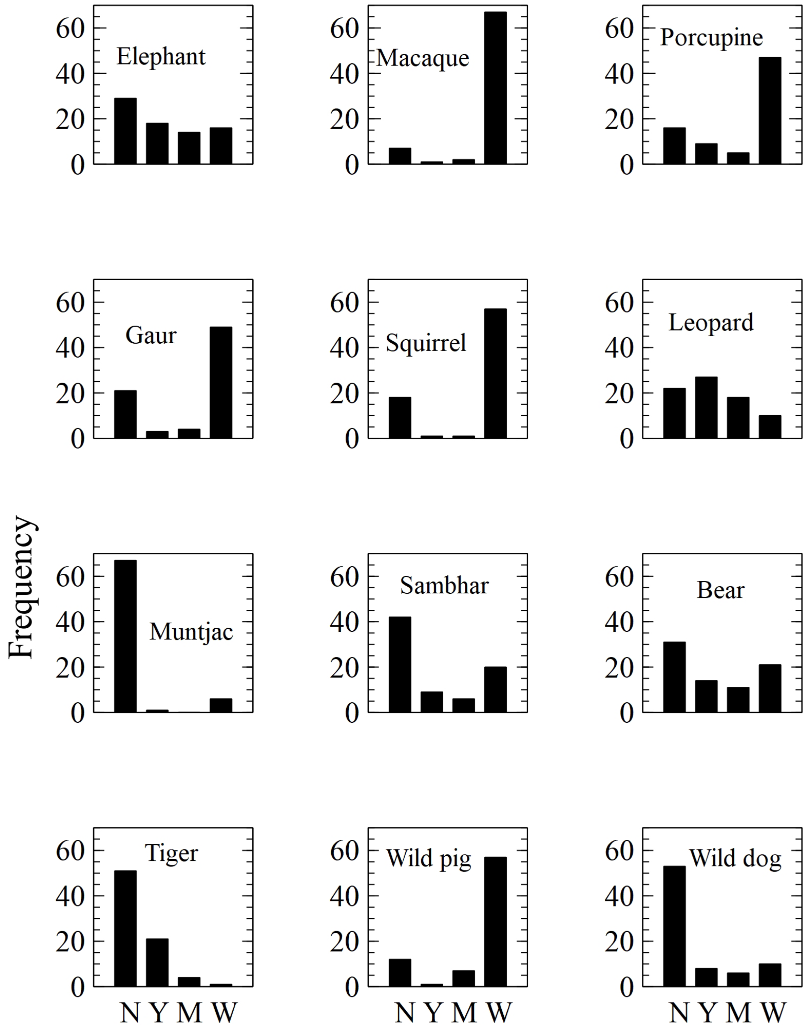

Figure 2. Frequency (%) of wildlife sightings of the 12 species surveyed across 78 tea plantations
X axis labels: N=Never, Y=Yearly, M=Monthly and W=Weekly

Table 1. Results from GLiM analysis of variables associated with species richness across 76 plantations.

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.5220585	0.2295756	6.630	3.36e-11
Distance	-0.0842639	0.0257034	-3.278	0.00104
Elevation	0.0003574	0.0001399	2.555	0.01061
Distance: Area	0.0001418	0.0000453	3.130	0.00175
Null deviance: 70.896 on 75 degrees of freedom **Residual deviance: 55.537 on 72 degrees of freedom** **AIC: 345.97**				

year per plantation (Appendix A2 in supplementary data). There was no significant effect of distance to a PA, elevation, or plantation size on the number of wildlife incidents reported. Overall, the Bonnet Macaque, Wild Boar, and Gaur were implicated in over 50% of the total incidents. Crop damage, such as uprooting tea bushes, damage to trees, and raiding vegetable gardens, caused mostly by the Gaur (20%), Bonnet Macaque (19.4%), and Wild Boar (18.3%) were reported in 74% of plantations (Figure 3). The other incidents were less frequent: livestock predation by Leopard or Tiger constituted 9%; infrastructure damage mostly by Bonnet Macaques

Table 2. Support for wildlife conservation across 76 tea plantations in the Nilgiris.

Region	Responses n (%)			Total
	Negative	Positive	No Response	
Gudalur	1 (5.2)	9 (47.4)	9 (47.4)	19
Kotagiri	2 (9)	13 (59)	7 (32)	22
Coonoor	2 (5.7)	25 (71.4)	8 (22.9)	35
Total	**5 (6.5)**	**47 (62)**	**24 (31.5)**	**76**

The differences between the three regions were not significant (Log likelihood chi square = 6.592, df = 4, p = 0.159).

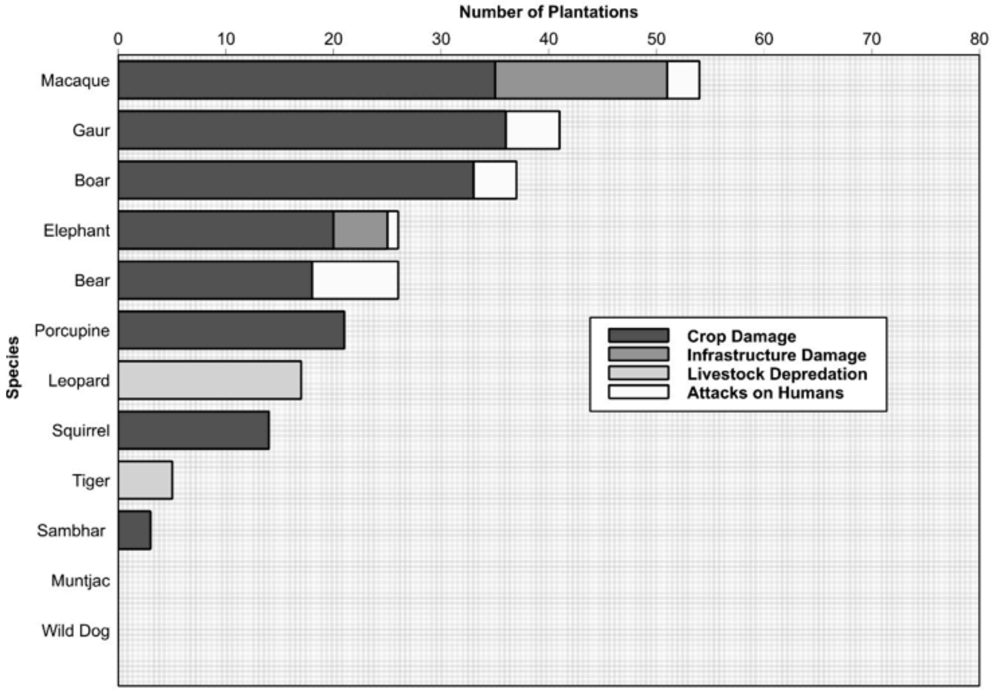

Figure 3. The number and type of wildlife incidents reported per species over a year (January 2010 to January 2011) by the 78 plantations.

and occasionally by Elephants was 8.5%, and attacks on people mostly by the Sloth Bear and Gaur was 8.5% (Figure 3).

Financial costs

A total of 37 estates provided financial data on pesticide usage and had an average (exponentiated log-transformed average) INR 1,682 $ha^{-1}yr^{-1}$ (1 USD= 45 INR during the study period; USD 37.4) (Appendix A2 in supplementary data). On the other hand, the cost of wildlife damage was nil or negligible for 72 estates (Appendix A2 in supplementary data). The six estates that reported a loss due to wildlife had an average (exponentiated log-transformed average) cost of INR 243 $ha^{-1}yr^{-1}$ (USD 5.4) (Appendix A2 in supplementary data). The cost of pesticide usage was significantly higher than the cost incurred due to wildlife damage (Welch two-sample T-test = 3.6, df = 7.3, $p < 0.01$).

Support for wildlife conservation

Overall, 62% of respondents supported conservation, 6.5% did not, and 31.5% did not respond (Table 2). There was no significant difference between the responses across the three regions, possibly because there were too few negative responses (log-likelihood chi-square = 6.592, df = 4, p = 0.159). Plantation managers in Gudalur, however, had the lowest percentage of positive and no responses among the three taluks, indicating ambiguous attitudes towards conservation.

The first GLiM, which included only negative and positive responses, indicated that plantation managers supported wildlife conservation when there were more

Table 3. Results of GLiM analyses on variables associated with support for wildlife conservation among 76 plantations in the Nilgiris.

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-5.955607	2.203375	-2.703	0.00687
Distance	1.130861	0.560615	2.017	0.04368
Area	-0.013464	0.006077	-2.216	0.02672
Species richness	1.174853	0.380301	3.089	0.00201
Incidents	-0.982413	0.458589	-2.142	0.03217
Distance: Area	0.016226	0.007016	2.313	0.02073
Distance: Species richness	-0.382859	0.153184	-2.499	0.01244
Area: Incidents	0.004312	0.002351	1.834	0.06660
Distance: Area: Incidents	-0.003560	0.001859	-1.915	0.05555
Distance: Species richness: Incidents	0.061742	0.024890	2.481	0.01312
Null deviance: 101.054 on 75 degrees of freedom Residual deviance: 65.263 on 66 degrees of freedom AIC: 85.263				

species present on their premises (p = 0.0401). The second GLiM where the 'no response' answers were merged with the negative responses increased the significance of this relationship (p = 0.00201, Table 3, also Appendix A3 in supplementary data).

Conservation support increased with an increasing number of species reported in a plantation; with increasing distance from PA, and among larger plantations situated further away (Table 3). Although incidents generally decreased support, it was modulated by greater wildlife presence in larger plantations further away (Table 3). Plantations opposed to, or ambiguous about conservation were generally larger, and/or with a higher number of incidents reported (Table 3). The last three interactions between (i) area and incidents, (ii) distance, area and incidents, and (iii) distance, species, and incidents were marginally significant and/or complex.

DISCUSSION

Human-wildlife 'conflict' is a global issue that encompasses a wide range of species, events, and settings, many of which have the potential to harm both humans and wildlife (Dickman 2010). Incidents with wildlife are often presented with synthetic variables such as economic loss to farmers and livestock owners, human injuries and mortalities, and loss of human livelihoods (e.g., Acharya et al. 2016; Acha et al. 2018; Govind & Jayson 2018). Although these variables help us understand the intensity and extent of incidents with wildlife, it would be incorrect to infer or depict human-wildlife conflict as a uniform and pervasive threat, from which anyone and everyone may suffer. Moreover, such views can diminish support for wildlife conservation and make conflict management even harder.

On the other hand, several studies reveal key patterns/differences in human-wildlife conflict events. For instance, human-wildlife interactions are limited in developed countries due to lower dependency on forest ecosystems but are far greater in developing countries because there is a higher dependency on forests, particularly for rural livelihoods, agriculture production and development (Anand & Radhakrishna 2017). Similarly, only a few species are known to cause extensive damage. For instance, 32 species caused damage across 11 protected regions in India, but only six were responsible for most incidents (Karanth & Kudalkar 2017). In Zimbabwe, of five carnivorous species, the Lion *Panthera leo* and Spotted Hyaena *Crocuta crocuta* were held responsible for most livestock depredation events (Loveridge et al. 2017). In Nepal, four (out of 12 species) caused maximum damage to human property and life (Lamichhane et al. 2018). Similarly, in our study, we show that (i) most of the damages are created by species that are not dangerous, (ii) incidents of damage to human property and life are spatially clustered and can probably be avoided, (iii) economic cost due to wildlife damage is in general low when compared to other costs such as that of preventing insect pest damage, and (iv) support for conservation is relatively high.

About 50% of wildlife-related incidents, mostly crop damage, were caused by a few species such as the Bonnet Macaque, Wild Boar, and Gaur. Whereas counter-intuitively, increased diversity of wildlife increased support for conservation. This could be because plantations supporting a higher proportion of the 12 species selected for this survey, significantly reported the presence of charismatic species such as the Tiger and Dhole. Moreover, economic costs were disproportionately borne by a few plantations and higher costs were mostly because of wild Elephants destroying fences and infrastructure. Therefore, reducing impacts of a few pest species, and perhaps mitigation of Elephant damages in a few plantations, could have disproportionate effects on conservation attitudes in this region.

Many plantations with significant wildlife species were not adjacent to PAs, indicating that these plantations support resident populations of widespread generalist species such as Bonnet Macaques and Wild Boar. These species were also considered chronic pests. The abundance of Bonnet Macaques in forests in peninsular India is very low, and the species is fast disappearing from its original habitats owing to expanding ranges of the Rhesus Macaque *Macaca mulatta* (Erinjery et al. 2017); however, it is ubiquitous in human settlements due to its adaptability to human food and refuse (Pillay et al. 2011).

The presence of charismatic species such as the Tiger and Dhole were reported in estates with more wildlife. The aesthetic value of several wildlife species could elicit favorable responses. For instance, de Pinho et al. (2014) reported that several species perceived as beautiful garnered more conservation support by agro-pastoralist communities living around Amboseli National Park, in southern Kenya.

There was considerable support for wildlife conservation among plantation managers. Surprisingly, support was lower in larger-sized plantations, especially those located closer to PAs. Studies have however shown that in general, wealthy farmers with larger agricultural holdings are better able to buffer the economic costs of wildlife damage (Naughton-Treves & Treves 2005; Zimmermann et al. 2005). In this case, however, large industrial plantations were less tolerant of wildlife. The reason for this is not clear. Perhaps surveillance by protected area managers creates resentment among more powerful plantation groups, or as in some cases, they have encroached upon reserved forests.

Although non-significant across regions, a higher proportion of plantations in Gudalur preferred not to state whether or not they supported wildlife conservation. Gudalur is an important region for wildlife, as it lies between major PAs, and is an important Elephant corridor connecting Mudumalai Tiger Reserve and Wynaad Wildlife Sanctuary that run through this region (Puyravaud et al. 2017). There are, however, many conflicts over forest leases and land tenure in this region (Krishnan 2009).

Land tenure insecurity is widely observed in tropical and developing regions and often overlaps with areas that have high conservation value (Bruce et al. 2010). There was a distinct land tenure system called the 'janmum' tenure in Gudalur which the Tamil Nadu State Government sought to abolish in 1969 through the "Gudalur Janmum Estates" (Abolition and Conversion into Ryotwari) Act, 1969. Litigation over implementing this Act has been dragging on, and this uncertainty has resulted in large scale encroachment of forest land (Davidar et al. 2012). Out of the 32,375ha of disputed land in the taluk that falls under janmum system of hereditary proprietary rights, 11,736ha have been identified as forests, and 6,475ha have been leased to local communities (Ravichandran 2019a). Among the remaining 14,164 unsettled hectares, 12,140ha has been encroached upon by plantations (Ravichandran 2019b).

Land tenure insecurity can create resentment towards conservation. For instance, Romañach et al. (2007) found that land "squatters" were not as positive towards the presence of carnivores when compared to those who held a title deed to communal land. Similarly, Guinness (2016) also found that land ownership significantly influenced local perceptions of crop-raiding. Hence, it is possible, this could be among the reasons for antagonism towards conservation among many plantation managers in Gudalur. Targeted education and awareness programs for the plantation community in general are thus necessary, as they can help increase support for wildlife conservation and encourage participation in ongoing conservation efforts in the region.

Our study shows that plantations provide a supplementary habitat for many endangered and iconic species. Support for conservation was high, although the ubiquitous presence of some species such as the Bonnet Macaque and Wild Boar, considered 'pests' by the respondents, caused a high proportion of damages. Overall, a few species caused most of the problems, and a few plantations suffered high costs. Mitigation attempts should, therefore, focus on these species and plantations to increase conservation support. With adequate mitigation of negative impacts, plantations can serve as a 'transition' zone for the Nilgiri Biosphere Reserve, to soften the hard boundaries between protected areas and the human-dominated mosaic, and to facilitate the movement of wildlife between reserves.

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Appendix 1. Sample questionnaire

Name of plantation
Corporate/family/others
Year of establishment
Total area of plantation
Region
Plantation crops (tick one) tea coffee cardamom rubber others
Total area (if multiple crops)
Geographical coordinates latitude longitude altitude
Presence of forests in your plantation yes/no type of forest
Area or % of forest cover
Nearest protected area to estate **Approximate distance (km)**

Wildlife		**Frequency of sightings in plantation**				
Species	**Impact ±**	**Daily**	**Weekly**	**Monthly**	**Annually**	**Not Sighted**
Asian Elephant						
Bengal Tiger						
Leopard						
Gaur						
Sloth Bear						
Wild Dog						
Wild Boar						
Bonnet Macaque						
Sambar Deer						
Muntjak						
Crested Porcupine						
Malabar Giant Squirrel						

Wildlife	Number of damage incidents in plantation					
Species	**Crop damage**	**Infrastructure damage**	**Livestock attack**	**Human attack**	**Financial loss (INR)**	**Comments**
Asian Elephant						
Bengal Tiger						
Leopard						
Gaur						
Sloth Bear						
Wild Dog						
Wild Boar						
Bonnet Macaque						
Sambar Deer						
Muntjak						
Crested Porcupine						
Malabar Giant Squirrel						

Amount spent on insect pest control per year

Do you (as a management) support wildlife conservation?
Yes/No Why?

How can you help conserve wildlife?

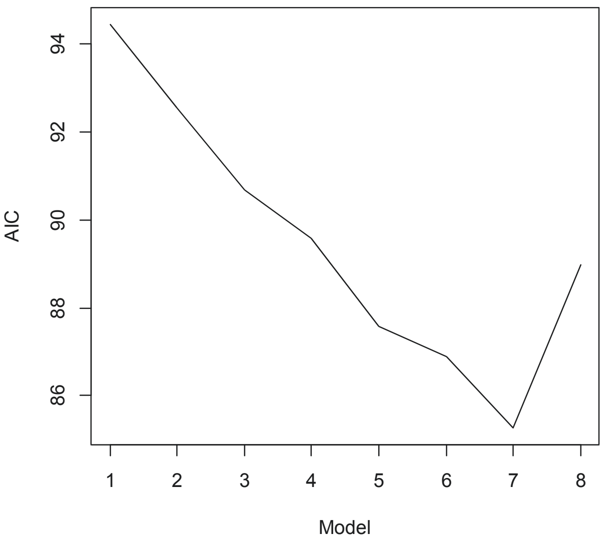
Appendix 2. General description of the 78 tea plantations surveyed across Gudalur, Kotagiri, and Coonoor taluks of Nilgiris District, India.

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Gudalur (n=20)	1	3.44	960	61	6	3	0	100000	0
	2	2.83	943	7	0	0	0	24000	2
	3	2.84	940	7	0	0	0	0	2
	4	0.16	1257	7	3	3	10000	10000	2
	5	6.18	1939	40	8	5	0	0	1
	6	4.71	943	12	3	2	0	0	2
	7	3.29	1064	853	9	0	0	0	1
	8	1.73	941	243	7	4	0	0	2
	9	2.76	1093	61	7	3	0	123600	2
	10	1.82	1061	896	4	1	350000	3200000	1
	11	4.42	1036	648	9	0	0	160000	1
	12	0.5	1935	1457	7	2	0	100000	2
	13	0.03	1475	24	5	0	0	10000	2
	14	1.9	1230	8094	9	5	0	0	1
	15	4.99	959	1214	8	0	0	0	1
	16	3.36	960	1012	10	2	0	0	1
	17	1.89	955	360	7	3	0	0	1
	18	0.84	700	81	7	2	28000	0	2
	19	4.57	971	1214	9	4	0	0	1
	20	0.69	1156	1012	7	5	0	0	1

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Kotagiri (n=22)	21	3.43	1842	243	10	3	35000	3000000	1
	22	6.18	1939	28	4	1	0	0	2
	23	1.17	1461	61	9	2	0	0	2
	24	1.66	1924	24	7	2	0	0	0
	25	3.54	1793	27	6	4	0	0	2
	26	5.51	1980	36	7	6	0	700000	1
	27	1.4	1487	166	8	8	0	500000	1
	28	0.14	1487	29	8	6	0	216000	0
	29	6.56	2006	89	7	3	0	0	1
	30	0.17	1302	210	6	3	0	290625	2
	31	0.66	1288	625	9	6	25500	3437500	1
	32	0.52	1718	263	8	4	0	30000	1
	33	1.67	1502	202	5	2	0	0	1
	34	0.86	1415	192	10	6	0	1000000	2
	35	4.03	1966	202	8	4	0	90000	2
	36	4.62	1879	133	8	6	0	0	1
	37	3.82	1585	133	9	6	0	0	1
	38	4.55	1890	10	7	5	0	30000	1
	39	1.02	1837	250	9	5	0	236000	1
	40	0.46	1921	359	7	1	0	681681	1
	41	0.36	1538	24	6	2	5000	40000	2
	42	2.71	1792	118	6	0	0	0	1

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Coonoor (n=36)	43	2.84	1935	49	9	10	0	300000	1
	44	0.8	1688	185	8	3	0	500000	1
	45	1.78	2057	151	6	4	0	150000	1
	46	4.08	1663	134	7	2	0	0	1
	47	3.8	1649	61	8	6	0	0	2
	48	2.62	1810	20	8	2	0	0	2
	49	0.5	1005	259	7	0	0	100000	1
	50	1.08	1349	384	10	3	0	200000	1
	51	1.22	1612	61	9	4	0	0	1
	52	4.64	1756	61	2	1	0	0	0
	53	*	*	19	9	3	0	0	1
	54	2.62	1810	5	6	0	0	0	2
	55	1.45	1679	607	8	5	0	200000	1
	56	1.08	1350	1063	7	6	0	400000	1
	57	2.45	1579	18	9	5	0	270000	1
	58	4.04	1885	36	7	5	0	50000	2
	59	4.17	1840	32	7	4	0	0	2
	60	1.92	1754	50	6	1	0	0	0
	61	0.1	1867	1498	12	3	0	0	1
	62	10.04	2230	21	3	0	0	0	1
	63	1.06	1572	101	8	5	0	0	2
	64	0.49	2050	270	11	4	0	300000	1
	65	3.56	1863	101	8	4	0	0	1
	66	0.16	1599	164	9	3	0	380000	1
	67	0.4	1545	69	7	5	0	0	2
	68	1.04	1856	207	8	5	0	0	1
	69	0.7	2047	176	8	3	0	200000	1
	70	7.33	2132	147	4	3	0	0	1
	71	3.38	1727	12	9	3	0	120000	2
	72	1.5	1936	52	4	0	0	220000	1
	73	1.4	1969	48	9	4	0	0	1
	74	2.26	1624	45	8	3	0	0	1
	75	1.98	1920	70	8	2	0	500000	1
	76	0.6	1739	427	10	0	0	0	1
	77	0.86	1604	600	10	3	0	500000	1
	78	2.54	2074	47	6	1	0	0	1

* Could not obtain data
Wildlife incidents, cost of wildlife damage and insect pest control over a one-year period (January 2010 to January 2011)
Support for wildlife conservation: 0- Negative, 1- Positive and 2- No Response



Appendix 3. Change of the Akaike's information criterion (AIC) with model simplification with all variables and interactions.

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Author contributions: TK and TAP carried out the field work. PD and JPP secured funding, helped with study design, statistical analysis, preparation of study area map and editing. All authors contributed to the literature review and writing.

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