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Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra

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Abstract

Crop raiding can reduce farmers' tolerance towards wildlife. Despite higher human population densities in rural areas, and more rapid conversion of forest to farmland, much less is known about crop raiding in Asia than in Africa. Over 14 months, we identified perceived and actual crop pests, and their patterns of crop raiding from farmland in and around Kerinci Seblat National Park, Sumatra. Farmers named either the wild boar *Sus scrofa* (80%) or the pig-tailed macaque *Macaca nemestrina* (20%) as the two most destructive crop pests. From 5125 crop raids by 11 species of mammal, most raids were indeed made by the wild boar (56%) and the pig-tailed macaque (19%). For all species combined, temporal crop raiding peaks were positively correlated with periods of high rainfall. Spatially, most crop raids occurred nearest to the forest edge and the local guarding strategies used were ineffective. However, raids by wild boars were more extensive than raids by pig-tailed macaques, which caused much greater crop damage (73%) than wild boars (26%), contrary to farmers' perceptions. Our research suggests that alternative mitigation strategies need to be trialed over dry and rainy seasons to identify the most effective strategies and that guarding effort should be increased during the rainy seasons and tailored towards specific crop raiding species based on their unique spatial patterns.

Introduction

Crop damage caused by raiding wildlife is a prevalent form of human–wildlife conflict along protected area boundaries (Naughton-Treves, 1998). The individual economic losses suffered from crop raiding can be relatively high in developing countries, because farmers are poor and rarely compensated for their losses (Sekhar, 1998; Rao *et al*., 2002). Such losses can make communities antagonistic and intolerant towards wildlife, which can result in retribution killing of problem species as well as undermining and impeding conservation strategies (Nyhus, Tilson & Sumianto, 2000). However, in order to mitigate this form of human–wildlife conflict more effectively, it is first necessary to understand the temporal and spatial factors that predict crop raiding, and the effectiveness of current guarding strategies (Sitati *et al*., 2003; Sitati, Walpole & Leader-Williams, 2005). It is also necessary to identify correctly those species that cause the greatest amounts of crop damage, because farmers' perceptions of the most notorious crop pests may be influenced by factors other than crop damage (Naughton-Treves, 1997; Siex & Struhsaker, 1999).

To date, most research on crop damage by wildlife has been conducted in Africa (Hoare, 1999*a*; Naughton-Treves, Rose & Treves, 1999; Hill, Osborn & Plumptre, 2002; Sitati *et al*., 2003). Apart from studies of crop raiding by Asian elephants (Sukumar, 1989; Nyhus *et al*., 2000), crop raiding by wildlife has been little studied in Asia (Sekhar, 1998; Rao *et al*., 2002), particularly outside India. Yet, rural human population densities tend to be higher, and clearance of forest for agriculture is more extensive, in Asia than in Africa (Achard *et al*., 2002). In turn, both these factors are likely to lead to escalating incidents of crop raiding in the future. Furthermore, case-specific studies are needed from farmland bordering different habitat types, with different potential crop pests, as these may also influence crop raiding patterns and, therefore, the appropriate mitigation strategies (Chiyo *et al*., 2005; Sitati *et al*., 2005). Such studies offer an important insight into the capacity of wildlife to use agroforest landscapes, which will become increasingly common in Asia (Nyhus & Tilson, 2004).

The situation around Kerinci Seblat National Park (KSNP), on Sumatra, Indonesia, illustrates the problem well: it is a large protected area with extensive tracts of forest that has been extensively converted around its edges, and also inside its borders, to farmland by low-income subsistence farmers. Furthermore, these farmers have strong perceptions of those species that cause most damage, which are often targeted through retribution killings (Linkie *et al*., 2003; Martyr & Nugraha, 2004).

In this paper, we aim to identify perceived and actual crop raiding patterns by mammals >5 kg, by investigating (1) farmers' perceptions of wildlife as crop pests, (2) temporal patterns of crop raiding by species and by crop type, (3) spatial patterns of crop raiding by species, (4) extent of crop destruction by species and (5) perceived versus actual patterns of crop raiding.

Materials and methods

Study area

The study was conducted in a conglomerate of villages known as Air Dikit, bordering the southern end of the 13 300 km^2 UNESCO World Heritage Site KSNP, in Bengkulu province (2°56′–2°64′S, 101°43′–101°51′E). Air Dikit has an altitudinal range from 100 to 300 m above sea level that supports a western lowland forest type among the most threatened habitats in Indonesia (Laumonier, 1994; Holmes, 2001). In Air Dikit, there are still small patches of degraded forest outside KSNP, but the landscape is dominated by a farmland mosaic. Air Dikit comprises a single main village with several diffuse villages, comprising a Muslim transmigrant community of Javanese descent. This community moved in the late 1990s from the adjacent south Sumatra province, either through a government-sponsored programme or spontaneously.

A total of 56 farms, which were between one and four years old, lay within 2 km of the forest edge within Air Dikit. Over 14 months, actual and perceived crop raiding patterns were recorded on 50 farms, after six farmers dropped out. To avoid raising expectations, farmers were informed from the outset that this was an academic, not a Department of Forestry or a conservation NGO, project from which no financial benefits or compensation would accrue. Of the 50 farms, 40% were previously inside KSNP. However, after the KSNP boundary was refined by the KS-Integrated Conservation and Development Project in 2002 (World Bank, 2003), 56% of these 50 farms were situated inside KSNP.

Socio-economic backgrounds of farmers, farmland profiles and perceived crop pests

On each of the 50 farms, family size, ages and education levels of respondents, and the main types of subsistence and commercial crops grown were recorded. Semi-structured interviews were individually administered in Indonesian to the household heads (all male) of each farm to learn their perceptions on which factors most limit their agricultural success, how these factors could be overcome and their ranking of the two crop pests that worse affected them.

For each farm, we recorded guarding intensity as the cumulative number of guarding measures used, including fences, guard dogs, noisemakers, guard huts, guns and fires. The boundary of each farm was mapped with the owner, using Garmin 12 global position system (GPS) units (Garmin Corp., Ulathe, KA, USA). These data were imported into ArcView v.3.2 GIS software package (ESRI Inc., Redlands, CA, USA) and constructed as a single farmland data layer, in which each farm was assigned a unique identity number and its area and perimeter length were calculated.

For each farm, the mean value for the physical features (proximity to forest edge, proximity to rivers, elevation, slope, perimeter, and farm size:farm perimeter) was extracted. Forest cover data were derived from on-screen digitizing of a radiometrically and geometrically corrected 2002 Landsat 7 ETM+ satellite image (path/row, 162/062). The river data were obtained from 1:50 000 maps produced by the Indonesian National Coordination Agency for Surveys (1985). The digital elevation model data were obtained from the Shuttle Radar Topography Mission and used to produce the slope layer (Rabus *et al.*, 2003). All spatial data layers were converted into a raster format within ArcView and geo-referenced using the UTM 47 s coordinate system within the WGS84 datum. Finally, rainfall data for the farmland region over the study period were obtained from the district rainfall station managed by the Meteorological and Geophysical Agency of Indonesia.

Crop raiding data collection

Temporal and spatial patterns of crop raiding incidents were monitored on the 50 farms from November 2001 to December 2002. Participating farmers were trained to use a calendar to record daily crop raiding incidents by each species and the crop type damaged during an initial 1-month pilot study in October 2001. The calendar was then edited using farmers' comments to improve its ease of use and encourage their active involvement in compiling data using the resulting 14-month calendar. One column allowed for daily entries of crop raiding incidents by nine mammals >5 kg: wild boar *Sus scrofa*, sambar *Cervus unicolor*, red muntjac *Muntiacus muntjak*, mouse deer (*Tragulus* sp.), porcupine *Hystrix brachyura*, pig-tailed macaque *Macaca nemestrina*, long-tailed macaque *Macaca fascicularis*, banded langur *Presbytis melalophos* and sunbear *Helarctos malayanus*. Another column allowed daily entries of raids by other species.

To avoid over-reporting of crop damage by farmers (Siex & Struhsaker, 1999) and to maintain consistency in the accuracy and quality of the data collected, three to four enumerators visited each farm every 2 days throughout the 14 months to check the calendars and verify any conflicting reports with the farmers by visiting the crops to check the damage and identify secondary signs, including prints, bite marks, faeces and hair, associated with the culprit species. This reduced problems with misreporting of any species that had only passed through the farmland without crop raiding (Sitati *et al.*, 2003).

To obtain information on the extent of crop destruction by the different species, a random subset of the 50 farms was selected each week over a 5-month period from November 2001 to March 2002. On these farms, the extent of the area damaged was measured directly in square metres (m^2). For each crop raiding incident, the age of the crop was recorded, based on its stage of maturity, using the following categories: seedling, partially grown or fully grown (Hoare, 1999*b*).

Data analyses

The farmland profile data and crop raiding data (frequency and amount of destruction) for wildlife species, both collectively and individually, were imported into SPSS v.11 software (SPSS Inc., Chicago, IL, USA). The continuous data were logarithmically transformed to reduce the likelihood of extreme results having a disproportionate influence on the overall dataset.

To identify the perceived crop pests, the percentage of farmers that ranked each wildlife species as either the first or second worst pest was calculated. Next, to enable comparative analyses of crop raiding patterns between months with unequal numbers of days, we calculated the average number of crop raids per day, referred to hereafter as 'monthly crop raiding frequency'. Spearman's rank correlation coefficient (r_s) was used to determine whether there was a relationship between monthly rainfall patterns, either directly or with a 1-month lag period, and monthly crop raiding frequency, for all wildlife species individually and combined. Spearman's rank correlation coefficient was also used to examine possible relationships between crop types eaten each month and monthly rainfall patterns.

To investigate spatial patterns of crop raiding, the number of crop raids on each farm was calculated over 14 months. A stepwise multiple linear regression analysis was then used to determine which combination of spatial factors best explained spatial crop raiding frequency for all wildlife species combined, and for the most frequent crop raiding species individually. The factors included in the analysis were based on previous studies (Naughton-Treves, 1998; Sitati *et al.*, 2005) and comprised mean proximity to forest edge and to rivers, elevation, slope, farm size, farm perimeter, farm size:farm perimeter and guarding measures. The performance of the model was evaluated by calculating the r^2 value, and the presence of spatial autocorrelation in the model was tested by calculating Moran's I statistic using Crime-Stat v.1.1 (N. Levine and Associates, Annadale, VA, USA). Correlation coefficients were used to test for problems with collinearity (correlations between independent variables).

A Mann–Whitney U-test was performed to determine if there was any difference in the extent of crop damage between the two most prolific crop raiding species. Finally, the relationship between each farmer's perceptions of the main crop pests and the species that were recorded as crop raiding most frequently on their farm over 14 months was determined by performing an independent-samples t-test.

Results

Socio-economic backgrounds of farmers, farmland profiles and perceived crop pests

The socio-economic backgrounds of farmers differed little across participating farms. The mean family size for each household was 3.8 ± 1.8 (SD) people, with a mean age of 22.5 ± 14.1 years. Most farmers (71%) had attained a primary school education level, but only 29% had achieved higher. The average farm size and perimeter length was $3900\,m^2 \pm 2300$ and $890\,m \pm 315$, respectively. Farm size was not correlated with distance to forest edge ($n = 50$, $r_s = 0.26$, $P = 0.07$). Farmers grew their crops for subsistence (56%) and commercial (44%) purposes. Among the subsistence crops edible to wildlife species, all farmers grew rice and cassava for their main crops, while banana, chili, maize, papaya, eggplant and water spinach were among the other subsistence crops. The main commercial crops grown were coffee (62%), patchouli (18%) or a combination of both (20%) crops, which are unpalatable to most mammal species.

Most farmers thought that cutting down the forest would increase flooding (94%), soil erosion (88%) and attacks from insect crop pests (66%). However, farmers thought that other factors were more detrimental to their livelihoods, and that agricultural success was limited by (1) wildlife crop raiding (90%), (2) a decrease in market prices for cash crops (43%) and (3) a long distance to the nearest market (37%). Most farmers (70%) were generally unsure about how they could overcome wildlife crop raiding, while no farmer stated retribution killings as a control measure. Some farmers (30%) thought that guarding their farms might reduce crop raiding. However, no farms were fenced and only a minority of farmers employed some form of crop protection (30%), of which the main strategies were use of a guard dog (24%) or a gun (6%).

Temporal patterns of crop raiding by wildlife

Over 14 months, farmers compiled a total of 5125 daily records of crop raiding by 11 mammalian species, comprising wild boar (56%), pig-tailed macaque (19%), red muntjac (7%), porcupine (6%), sambar (5%), banded langur (4%), civet (1%) and long-tailed macaque (1%), with sunbear, tapir and mouse deer (<1%). Wild boar and pig-tailed macaque were responsible for most (75%) crop raiding incidents and for all farms combined; these raids comprised an average of 206.1 and 69.8 daily incidents/month for wild boar and pig-tailed macaque, respectively. The crop raiding patterns for all species combined and the main crop pests individually were strongly seasonal, and most crop raiding incidents occurred from November to December in both 2001 and 2002 (Fig. 1).

There was a positive correlation between crop raiding patterns among those mammal species responsible for more than 5% of the total crop raiding incidents combined and rainfall (Table 1). However, there was an even stronger correlation between crop raids by pig-tailed macaque and rainfall that incorporated a 1-month lag period.

Temporal patterns of crop raiding by crop type

A total of 19 different crop types was damaged by mammal species during this study. Porcupine and red muntjac

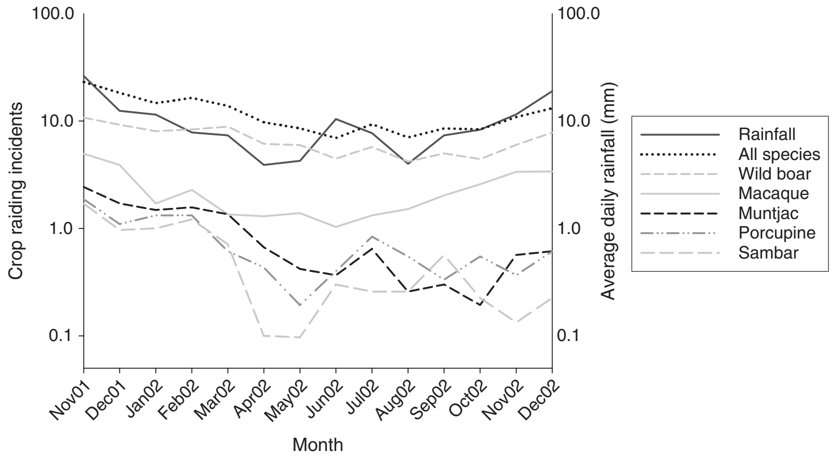

Figure 1 Temporal crop raiding patterns for all mammal species combined and the main crop pest individually (i.e. responsible for more than 5% of the total crop raiding incidents) in Air Dikit. Wild boar, *Sus scrofa*; porcupine, *Hystrix brachyura*; sambar, *Cervus unicolor*.

Table 1 Patterns of monthly crop raiding by wildlife and monthly rainfall for all mammal species combined and for the main crop pests individually in Air Dikit ($n=14$), based on Spearman's rank correlation coefficient (r_s)

	Without 1 month lag		With 1 month lag	
Species	r_s	P	r_s	P
All species combined	0.78	<0.01	0.52	0.06
Wild boar *Sus scrofa*	0.62	0.02	0.44	0.11
Pig-tailed macaque *Macaca nemestrina*	0.54	0.06	0.72	<0.01
Red muntjac *Muntiacus muntjak*	0.72	0.01	0.43	0.13
Porcupine *Hystrix brachyura*	0.89	<0.01	0.53	0.05

showed similar raiding patterns for chili bushes and green beans, as did pig-tailed macaque and wild boar for rice (Table 2).

Of the different crop types eaten by all wildlife species combined, only the frequency of raiding on rice crop and chili crop (with a 1-month lag period) showed a relationship with rainfall, with more raids during months with greater rainfall (Table 3).

Spatial patterns of crop raiding

All participating farms experienced crop raiding by mammals (Fig 2a). Farms closest to the forest edge were most frequently raided by wild boar, pig-tailed macaque and porcupine individually and by all species combined (Table 4; Fig. 2a–d), while other physical factors or guarding measures had no effect. The respective regression models for wild boar, pig-tailed macaque and porcupine individually and by all species combined were not affected by spatial autocorrelation (Moran's $I = 0.01, -0.03, -0.01$ and -0.02, respectively; all $P > 0.05$). The spatial patterns of crop raids showed that pig-tailed macaque raids were not as widespread as wild boar raids (Fig. 2b and c).

Crop destruction by the main crop pests

Over the 5 months from November 2001 to March 2002, the damage caused during a total of 346 crop raiding forays encompassed a total crop area of 1421.0 m^2. The mean damage per foray was 4.1 m^2 for all mammal species combined. Wild boar and pig-tailed macaque were responsible for 99% of the damage (Table 5). Pig-tailed macaque caused significantly more damage (73%) than wild boar (26%) when crop raiding ($n = 310$, $Z = -4.97$, $U = 3116$, $P < 0.01$). Of these 346 crop raiding forays, pig-tailed macaque raided 13% of the forays but caused 73% of the total damage, whereas wild boar raided 76% of the forays but caused only 26% of the total damage. Overall, each problem species differed in their preference for crop maturity. Pig-tailed macaque pre-dominantly ate fully grown crops, which partly explains their greater destructiveness, while wild boar were the least selective, and ate crops at all stages of maturity.

Perceived versus actual crop pests

The majority (80%) of farmers named wild boar as the crop pest that worse affected them, while the remaining (20%) farmers named pig-tailed macaque. Farmers who named wild boar were not found to be from farmland that was raided more frequently by this species ($F = 2.10$, $P = 0.15$).

Discussion

This study represents an important first step in the mitigation of crop raiding by wildlife, because it is based on an explicit understanding of the actual crop pests and their spatio-temporal patterns of crop raiding. This study quantified perceived and actual patterns of crop raiding by different mammal species in and around KSNP, Sumatra. The most frequent crop raiders among 11 recorded species of mammal were wild boar and pig-tailed macaque. Most farmers around the Air Dikit study area thought that crop raiding was the greatest limitation to their agricultural

Table 2 Frequency of raids by main mammal crop pests combined and by the main crop pests individually in Air Dikit

Species	Number of crop species eaten more than once	Frequency of raids on main crop species (%)		
		1	2	3
All species combined	19	Rice (25%)	Cassava (19%)	Chili (14%)
Wild boar *Sus scrofa*	16	Cassava (31%)	Rice (30%)	Sugar cane (9%)
Pig-tailed macaque *Macaca nemestrina*	12	Rice (33%)	Papaya (24%)	Banana (20%)
Red muntjac *Muntiacus muntjak*	6	Chili (69%)	Green beans (12%)	Rice (9%)
Porcupine *Hystrix brachyura*	9	Chili (45%)	Squash (21%)	Green beans (12%)

Table 3 Patterns of monthly crop raiding by crop type and monthly rainfall for all mammal species combined and for the main crop pests individually in Air Dikit ($n=14$), based on Spearman's rank correlation coefficient (r_s)

	Without 1 month lag		With 1 month lag	
Crop type	r_s	*P*	r_s	*P*
Rice	0.74	<0.01	0.52	0.07
Cassava	0.13	0.67	0.41	0.16
Chili	0.28	0.34	0.69	0.01
Sugar cane	−0.07	0.81	0.14	0.65
Papaya	0.14	0.64	0.07	0.82
Banana	0.06	0.85	−0.15	0.63
Green beans	−0.15	0.61	−0.14	0.66
Squash	0.05	0.87	0.43	0.14

success, but most did not know how to mitigate this threat, and the limited range of guarding strategies used proved to be ineffective at reducing crop raiding. This study was not able to assess fully the socio-economic consequences of the observed patterns of crop raiding, which remains an important gap in much research on human–wildlife conflict, even where the topic has been more widely researched (Conover, 2002). However, determining the spatio-temporal patterns of crop raiding (Sitati *et al*., 2003) has proven sufficient in some areas of Africa to establish trials for mitigating crop raiding (Sitati & Walpole, 2006).

In the tropics, the temporal relationship between crop raiding, rainfall and forest fruiting patterns is complex and poorly understood (Chiyo *et al*., 2005). However, this study found strong seasonality in the temporal patterns of crop raiding for all crop pests combined and for the main pests individually. Crops were most vulnerable to raiding during the rainy season. As with elephant crop raiding patterns in southern Sumatra (Nyhus *et al*., 2000), the main crop staple of rice was raided more often in Air Dikit during the wetter months, when the crop was ripe. In contrast, cassava crops do not ripen seasonally and were raided throughout the year without any relation to rainfall patterns, as also shown in southern Sumatra (Nyhus *et al*., 2000). This would suggest that crop raiding patterns in Sumatra may be determined by the seasonal ripening of nutritious crops rather than by a scarcity of forest fruit food sources at particular seasons (Sukumar, 1989; Chiyo *et al*., 2005), but experiments would be needed to prove which explanation is correct.

Spatial patterns of crop raiding in the tropics are less complex and more clearly understood. While Hill (1997) found that the factors best explaining spatial patterns of crop raiding varied between different wildlife species in Uganda, most other studies have found that proximity to forest edge, or probable surrogates, is the single most important explanatory factor (Jhala, 1993; Studsrød & Wegge, 1995; Sekhar, 1998; Hill, 2000; Saj, Sicotte & Paterson, 2001). In Air Dikit, crop raiding was also mostly confined to farmland closest to the forest edge, probably because of the barrier created by the agricultural landscape (Hoare & du Toit, 1999) and the crop pests' need for a forest refuge. However, mapping the crop raiding patterns revealed that wild boar raids were more extensive than pig-tailed macaque raids.

The patterns of crop raiding by pig-tailed macaques appear similar to those of African elephants in that they were not widespread and inflicted relatively large losses on farmers (Sitati *et al*., 2003). Being a frugivore, pig-tailed macaques predominantly raided mature fruit crops (papaya and banana). Crop raids on mature rice crops, which were grown in all farms, may have allowed pig-tailed macaques to increase their foraging efficiency by reducing the amount of time spent travelling to different food sources. In contrast to pig-tailed macaque crop raiding patterns, wild boars entered farms more frequently to raid crops, but caused significantly less damage, both per foray and overall. This was probably due to the wild boar's catholic diet, as reflected by its targeting crops at all stages of maturity. If this study had included crop raiding by small animals (birds, rodents and insects) then crop raiding would probably have been much more extensive and destructive (Naughton-Treves & Treves, 2005).

Farmers' perceptions of the damage caused by different crop pest species could include metrics such as economic value (e.g. average quality of the crop damaged and time invested in cultivating the crop) and opportunity costs (e.g. children not attending school to guard family farms instead), as well as the frequency and extent of raiding and maturity of crop damage measured in this study. Therefore farmers' perceptions of damage and our measure of the extent of damage may not be strictly comparable. Nevertheless, it is interesting to note that the farmers in Air Dikit perceived the wild boar to be the crop pest that worse affected them, but this did not correspond with the observed patterns of crop damage on their farm. The

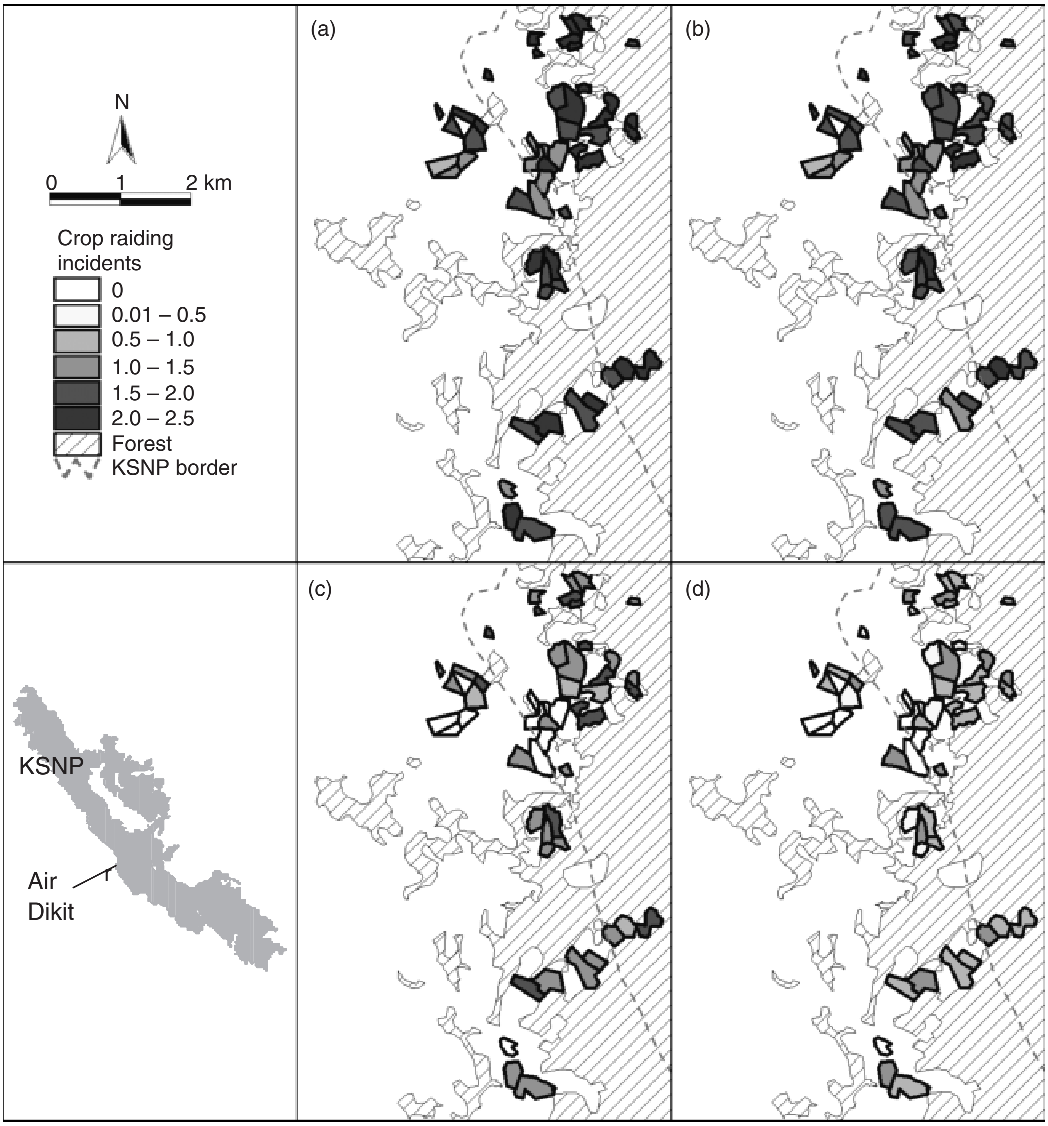

Figure 2 Log_{10} crop raiding frequency for (a) all wildlife species combined, (b) wild boar *Sus scrofa*, (c) pig-tailed macaque *Macaca nemestrina* and (d) porcupine *Hystrix brachyura* in Air Dikit at the redefined border of Kerinci Seblat National Park (KSNP; inset).

difference in the perceived and the recorded crop pests illustrates a need to investigate community perceptions associated with crop damage (Siex & Struhsaker, 1999). In comparison with the pig-tailed macaque, the propensity of the wild boar to raid crops more frequently and to raid more staple crops may have led farmers to describe wild boar as the worst crop pest in Air Dikit, despite the fact that pig-tailed macaques caused more damage overall. In contrast, research from Uganda found that olive baboons *Papio cynocephalus*, which caused the most cumulative damage, were considered by farmers as worse crop pests than red-tailed monkeys *Cercopithecus ascanius*, which raided most frequently (Naughton-Treves, 1997). Wild boars may also have received a disproportionate amount of the blame for crop damage because they were more conspicuous as a consequence of their frequent and widespread raiding. Similarly in Zanzibar, negative attitudes toward red colobus monkeys *Procolobus kirkii* may have been linked to farmers wrongly accusing these monkeys of damaging bananas, which was actually caused by the smaller and less conspicuous Sykes monkeys *Cercopithecus mitis* that often intermingle with red colobus monkeys. The farmers' main complaint was on the negative impact of red colobus monkey coconut consumption, but this species actually foraged on immature coconuts, which were actually associated with higher harvests, possibly due to a pruning effect (Siex & Struhsaker, 1999).

The few guarding measures used in Air Dikit were ineffective in reducing crop raiding, although by using them farmers presumably perceived them as having some

Table 4 Best multiple linear regression models describing the relationship between the spatial factors and $\log_{10}$ crop raiding frequency, for all crop pests combined and for the main crop pests individually in Air Dikit

Model	Coefficient (β) ± SE	d.f.	F	t	P	r^2
All species combined						
$\log_{10}$distance to forest edge	−0.59 ± 0.16	49	13.04	−3.61	< 0.01	0.21
(constant)	3.12 ± 0.35			8.95	< 0.01	
Wild boar *Sus scrofa*						
$\log_{10}$ distance to forest edge	−0.48 ± 0.13	49	13.67	−3.70	< 0.01	0.22
(constant)	2.67 ± 0.28			9.65	< 0.01	
Pig-tailed macaque *Macaca nemestrina*						
$\log_{10}$ distance to forest edge	−0.77 ± 0.24	49	10.02	−3.17	< 0.01	0.17
(constant)	2.69 ± 0.52			5.19	< 0.01	
Porcupine *Hystrix brachyura*						
$\log_{10}$ distance to forest edge	−0.49 ± 0.18	49	7.35	−2.71	< 0.01	0.13
(constant)	1.72 ± 0.38			4.47	< 0.01	

Table 5 Crop raiding frequency, amount of damage and stage of maturity consumed in selectively monitored farms in Air Dikit

			Maturity of crop eaten (%)					
Species	Number of forays	Percentage of forays	Seedling	Partially grown	Fully grown	Mean damage (m^2 ± SE)	Total damaged (m^2)	Total damage (%)
Wild boar *Sus scrofa*	266	76	19	47	34	1.4 ± 0.3	368.4	26
Pig-tailed macaque *Macaca nemestrina*	44	13	0	6	94	23.6 ± 1.3	1037.6	73
Red muntjac *Muntiacus muntjak*	16	5	14	29	57	0.3 ± 0.2	4.6	< 1
Porcupine *Hystrix brachyura*	20	6	0	40	60	0.5 ± 0.1	10.0	1

potential. Alternative guarding methods that might be trialed in conjunction with farmers include thorny shrub fences to prevent wild boar raids, or chili grease fences that have successfully excluded African elephants from maize fields (Sitati & Walpole, 2006). The destructive pig-tailed macaques present a more intractable problem, but communal guarding by farmers, which is not currently practised in Air Dikit, may minimize their crop raiding, especially during the rainy season. Trialing such alternative strategies over a subsequent 14-month period would enable an evaluation of their effectiveness in reducing crop raiding (Sitati & Walpole, 2006). More general initiatives that target all crop pests could include the planting of edible crops (e.g. rice and cassava) further from the forest edge and in areas where they could be better guarded.

Human settlements bordering protected areas in Sumatra receive no tangible legal benefits from living with destructive wildlife, either through tourism (Walpole & Thouless, 2005) or through extractive use (Leader-Williams & Hutton, 2005). However, the unsanctioned hunting of crop pests as prized game can be an effective defence strategy that can provide, at least, some direct community benefits (Naughton-Treves, 1998; Lee, 2000). Retribution killings of wildlife do occur in farmland around KSNP, as intolerant farmers set snare traps, which indiscriminately trap wildlife, including tigers (Martyr & Nugraha, 2004). However, there appears little killing, consumption or sale of crop raiding pig-tailed macaques and wild boars, both of which are considered 'unclean' by Muslim farmers.

Critically, this study highlights an enduring problem facing KSNP management, because the farms most heavily raided were illegal settlements inside the KSNP boundary (Fig. 2). While all farmers interviewed claimed not to know that their farm was inside KSNP, most (82%) farmers were unaware of restrictions on opening up new farmland (Linkie, 2003). Thus, the KSNP boundary needs to be enforced more vigorously to reduce farmland encroachment. At the same time, this needs to be coupled with improved mitigation of human–wildlife conflict to reduce farmer hostility towards wildlife, particularly of threatened species.

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