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RESEARCH ARTICLE

Buton Macaques (*Macaca ochreata brunnescens*): Crops, Conflict, and Behavior on Farms

NANCY E.C. PRISTON[1]*, REBECCA M. WYPER[2], AND PHYLLIS C. LEE[2]
[1]*Department of Anthropology and Geography, Oxford Brookes University, Oxford, United Kingdom*
[2]*Behaviour and Evolution Research Group, School of Natural Sciences, University of Stirling, Stirling, United Kingdom*

One consequence of anthropogenic habitat alteration is that many nonhuman primates are forced into conflict interactions with humans and their livelihood activities, especially through crop raiding. These problems are particularly acute for the endemic and threatened Buton Island macaque (*Macaca ochreata brunnescens*), in southeast Sulawesi, Indonesia. Our study investigated the crop raiding behavior of this species over time. Foods eaten and the behavioral repertoire exhibited by macaques during crop raiding at and inside farm perimeters were observed over a period of 8 years (2002–2009). Storage organ crops (e.g. sweet potato) were abundant and most frequently raided by macaques. Individual macaques were most commonly observed to raid close (0–10 m) to farm perimeters. Activities such as feeding, resting, moving, and social interaction varied significantly as a function of penetration distance into the farm, but only marginally between age-sex classes. The annual average raid frequency per farm decreased over the latter years of the study period, raising questions about changes in macaque foraging and ranging behavior over time and their response to farm management and mitigation strategies. Am. J. Primatol. 73:1–8, 2011. © 2011 Wiley Periodicals, Inc.

Key words: ethnoprimatology; crop raiding; Indonesia; macaque conservation; endemic species

INTRODUCTION

Indonesia is one of the world's richest natural environments harboring a vast diversity of both plant and animal species [Mittermeier et al., 1999], much of which remains poorly documented. Nearly two thirds of Indonesia is covered by tropical rainforest, owing to high rainfall and year-round humidity [Whitten et al., 2002]. Sulawesi is one of five main islands of Indonesia, measuring 189,216 km^2. It is mountainous and home to 127 indigenous mammals, 61% of which are endemic [Whitten et al., 2002]. Approximately 80% of these endemic species are in danger of extinction [IUCN, 2008]. This study took place on Buton Island, a remote island off the southeast coast of mainland Sulawesi (Fig. 1). Little is known of the biology and ecology of Buton Island, which has prompted recent interest in the area [Priston, 2005].

Of the 19 species of macaque, seven species or subspecies are endemic to Sulawesi [Fooden, 1969, 1980; Groves, 2001], a greater proportion than on any comparable land area [Reed et al., 1997]. The Buton macaque (*Macaca ochreata brunnescens*) is found in the lowland and hill forests [MacKinnon, 1986] of Buton and Muna islands. *M.o. brunnescens* populations are declining throughout their range, primarily because of widespread habitat loss [Rosenbaum et al., 1998]. Total population estimates are $<40{,}000$ individuals (20 individuals/km^2) [Manullang & Supriatna, 2008], and the Buton macaque is classified as ''Vulnerable'' [IUCN Red List, 2008]. Large-scale habitat destruction across Buton from logging and farming has reduced the area of potentially viable habitats available to Buton macaques [Priston, 2005]. The rate of deforestation in the study area is approximately 10% per annum and increasing year by year [Priston, 2009].

Predicting the behavioral responses and survival of this threatened endemic species in the context of its human-dominated environment is a major conservation concern. Such interconnections between humans and nonhuman primates fall under the relatively new approach of Ethnoprimatology [Sponsel, 1997], the goals of which are to understand the dynamic ecosystems within which humans and primates coexist [Fuentes & Wolfe, 2002]. Such information is essential if we are to predict how *M.o. brunnescens* populations will adapt (if at all) to

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*Correspondence to: Nancy E.C. Priston, Department of Anthropology and Geography, Oxford Brookes University, Gipsy Lane, Oxford OX3 0BP, UK. E-mail: nancy@cantab.net

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their continually changing environment and increasing overlap in resource use with humans. Detailed studies of *M.o. brunnescens* are also of great importance to local communities in their attempts to manage and mitigate damage to their subsistence farming activities. Previous research on Buton's macaques has focused mainly on socioeconomic factors associated with crop damage [Priston, 2005; Riley & Priston, 2010], and ecological modeling of the crop damage caused by macaques [Priston, 2005, 2009; Priston & Underdown, 2009]. Studies on the behavior and activities of monkeys in specific crop raiding contexts are relatively scarce [but see Maples et al., 1976; Strum, 2010; Warren, 2003; Warren et al., 2007]. Here, we report on the behavior of Buton macaques during crop raiding in subsistence farming communities over the 8-year period of our study.

METHODS

Study Site

This study was conducted on Buton (longitude 123° 12′ E–122° 33′ E and latitude 5° 44′ S–4° 21′ S; Fig. 1). The island is approximately 4,520 km^2 and is dominated by moist, deciduous, lowland forest on limestone karst [Whitten et al., 2002]. The human population is approximately 450,000, with a population density of ~30 people per km^2 [Whitten et al., 2002] and consisting mainly of native Butonese Muslims [Priston, 2009; Whitten et al., 2002]. The traditional economy is based on ''slash and burn'' subsistence agriculture and fishing [Whitten et al., 2002]. The main agricultural products are sweet potato (*Ipomoea batatas*), maize (*Zea mays*), and cassava (*Manihot esculenta*), along with a variety of fruits (especially jackfruit (*Artocarpus heterophyllus*) and papaya (*Carica papaya*)).

Research for this study was conducted around the small farming village of Kawelli in the Kapontori district of Central Buton. The village is approximately 5 km from the Kakenauwe Nature Reserve (810 ha) and Lambusango wildlife and hunting reserve (28,500 ha) [Priston, 2009]. Within the protected forests of central Buton, a small Buton macaque population has been censused at 3,752 individuals [Priston, 2005]. At the beginning of this study (2002), there were six known troops of macaques living in the forests surrounding Kawelli; by 2009, only two troops remained.

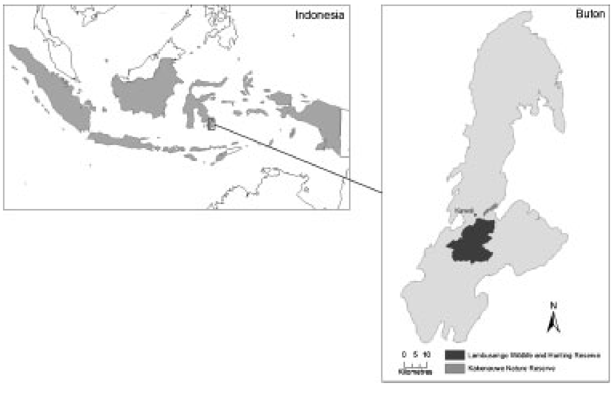

Fig. 1. Location of the study area.

Farm Descriptions

Between five and nine farms were chosen in any year for focal farm surveys (Table I). Twenty-six farms from the village of Kawelli were monitored for 809 hr during the entire research period. The focal farms were selected on the basis of crops grown, distance to forest, and local geography. Farms differed in the amount and type of crops available, with sweet potato generally being the most abundant crop overall. In many cases, the same farms were studied in two or more seasons. However, owing to differences from year to year in crop type grown, crop coverage, and in the amount and type of forested perimeter, focal farms studied in successive years were treated as independent.

Farm boundaries (usually marked by fences) were mapped using GPS UTM points, and proximity of the farm edge to the forest was measured. The farm boundaries were classed as forested perimeters with suitable trees for the macaques to use (including plantations) or as scrubland of <100 m separating the farm from the forest. Both forested and non-forested perimeter area can influence the probability of raiding [Hill, 2000]. Crops grown and percentage cover of each crop type were estimated for each farm. The presence or absence of active deterrents, natural (e.g. rivers), or man-made (e.g. fences and traps) were also recorded.

Focal Farm Surveys

A total of 11 different observers recorded macaque behavior on farms during the study period. All methods and behavioral definitions were standardized between observers based on work carried out by the first author from 1998 to 2002 [Priston, 2005]. Observers were trained by NECP for a minimum of five consecutive days during raids. Data were compared between observers and a new observer was considered reliable when $>80\%$ concordance was reached. Focal farms were observed daily from 0630 hr until 1600 hr each day for a period of 6–10 weeks during the months of June–August, between 2002 and 2009 (Table I). Each farm was observed from a discrete viewing point (usually the farmer's watch hut or suitable shelter within the farm) and all instances of crop raiding by monkeys were recorded. Instantaneous scan sampling at 2-min intervals was used to record macaque behavior on the farm or at the farm boundary [Altmann, 1974; Martin & Bateson,

TABLE I. Farm Plots Included in the Focal Farm Observations, Showing the Years That Each was Sampled, the Perimeter Distance, Total Area, and Mean Number of Raids Experienced Per Year

Farm	Years in sample	Perimeter (m)	Area (m^2)	Mean *N* raids
Aco	2009	244	3,881	0
Agis	2007, 2008	363	4,839	3
Asrun	2009	222	2,565	0
Darmin	2003, 2004, 2005	443	8,997	24
Dauer	2004	338	8,559	43
Farlan	2007, 2008, 2009	370	6,379	9
Fayuni	2007, 2008	407	9,973	6
Gustor	2009	343	3,875	1
Igi	2009	373	5,472	4
Ishak	2007	338	5,988	6
Jonaidin	2003, 2004, 2005	306	4,663	8
La Adu	2007	384	4,033	1
La Bau	2003	470	13,641	11
La Bau	2005, 2007, 2008	441	12,054	7
La Damaridi	2003, 2005	483	9,305	24
La Dauer	2007	384	8,559	2
La Hamili	2009	150	2,357	2
La Husuna	2002, 2003, 2004, 2005	406	9,056	7
La Igi	2008	373	5,472	7
La Musrifa	2002, 2003, 2005	358	7,527	0
La Niju	2009	237	3,017	0
La Ruhuni	2002, 2003, 2004, 2005	505	15,657	23
La Ruhuni 2	2002	220	3,000	16
La Sahili	2002, 2003, 2005	197	2,323	0
La Samusi	2009	483	14,035	0
La Tole	2002, 2003	364	6,375	7
La Tole	2005, 2007	353	6,865	6
La Tole	2008	306	4,835	7
La Tuni	2007, 2008	403	6,164	2
Sukri	2004	217	2,405	6
Unnamed	2002	421	7,950	2

Where these varied from year to year, farms are repeated. All farms had fences as basic crop-raiding deterrence, but human and dog activity on farms varied on any day.

1993]. Behaviors analyzed here were classified as feeding on either natural foods or on crops (with crop type recorded), moving, resting, vigilance (defined as stationary alert scanning of the environment), and social interactions (grooming, play, aggression, contact), or ''other'' (e.g. copulations, vocalizations) [see Priston, 2005].

Raiding bouts consisted of the entry to a focal farm by one, several, or all individuals of a troop. As soon as macaques were visible, individuals (by age-sex class) were recorded as either ''in'' (within the farm boundaries) and potentially raiding, or outside the focal farm. Once raiding, the 2-min scans commenced. If they were raiding an adjacent farm during ''out'' recordings, their behavior was noted as eating crops elsewhere but was not included in the calculations of time spent raiding the focal farm. A raid event was defined as any incursion into the focal farm or focal farm's fence by any member of the troop followed by an exit of all raiders. A raiding bout was calculated when the first macaque was observed in the vicinity of the focal farm until the last macaque was out of sight for 30 min. It was assumed that after 30 min of no sightings the troop had moved on. Duration of raids was based only on time visible on focal farms. Farmers, on those occasions that they were present, were encouraged to continue with their normal activities and not to allow macaques to raid for the purpose of our study. Chasing or actively deterring macaques was seen on 43 occasions during intensive observations in 2002–2003, suggesting that our presence did not hinder farmers from carrying out normal farm protection activities [Priston, 2005].

Data Analysis

The data set combines observations from the 11 researchers over seven field seasons (June–August). Owing to logistical constraints on observer presence, this data set is lacking continuous sequences and has a 1-year gap (2006). As such, no time sequences could be assessed, although variance among years could be explored. Furthermore, we are unable to make seasonal comparisons, as observations all took place during the same period in each sampled year. However, seasonality in crop planting, ripening, and harvesting is not marked on Buton [Priston, 2005]. We are currently in the process of assessing availability and phenology of natural foods.

Individuals in this study were categorized into age-sex classes as follows: infants (dependent on mothers, under about 2 years), juveniles (weaned and not yet sexually mature, under 4 years), subadults (smaller than full adults, not yet reproducing), and adults (adult female, 6–9 kg; adult male, 12–17 kg) [following Priston, 2005]. Exact ages are unknown.

The data used in analyses were limited to variables shown to be reliable over time. Data were mostly categorical and non-normal, with an uneven distribution of age-sex classes and observations. Frequencies were significantly skewed, and did not transform to a normal distribution. Thus, analyses rely primarily on nonparametric statistics and are descriptive. Data were coded and entered into SPSS versions 17 and 18 for analysis. Significance was set to $P<0.05$, two tailed. Where data were normally distributed, we used parametric correlation tests. Activities, food types eaten, and macaque location within farms are expressed as percentages of each observer's summed scan observations for each age-sex class in each year. The use of these annual age-sex class percentages takes into account variation in the number of individuals in each age-sex class and differences in the total observation time among the observers and years.

We compared behaviors between four age-sex classes (excluding infants) on the farm at four categories of distance from the boundary and out of farm using Kruskal–Wallis nonparametric ANOVA. Since behavior categories were mutually exclusive, we nested behavior within location for these tests. We also used Kruskal–Wallis tests on crop type eaten by each age sex class. In overall comparisons of activities on farm and off farm, we used a Mann–Whitney U test for each behavior. In post hoc pairwise comparisons to assess differences between age-sex classes, we used a Bonferroni correction, and set $P<0.01$ to account for a saturated model with no degrees of freedom between the four age-classes. Owing to a high number of zero observations of rare behavior, we present results for activities as means with error bars in figures.

This research adhered to the ASP ethical guidelines for the treatment of nonhuman primates, was approved by institutional ethics committees (Oxford Brookes University and University of Stirling, UK) and complied with Indonesia's laws for foreign researchers.

RESULTS

Raid Characteristics

We analyzed a total of 54,549 scan samples in 455 raid events on 26 focal farms over the seven field seasons. Crop raiding behavior was observed on all focal farms, although not in every year. Each focal farm experienced different annual frequencies of raiding, ranging from 0 to 43 raids. The average yearly farm raiding frequency increased from 2003 to 2004 and then gradually decreased until 2009 (Fig. 2).

The average number of macaques present (per farm per year) during a single raiding event varied from 2 to 16 individuals of any age-sex class (median = 8.0, IQR = 4.0–11.0). The numbers involved in the raid appeared to depend on the type of food being raided, with some food species potentially inducing more large-group feeding bouts than other foods (see below).

Macaques raided in bouts of various lengths, intermittently throughout the day with no clear diurnal pattern. Average raid duration varied considerably between years and between farms from 1 min to 1 hr4 min for a single raid event or entry to the farm. The greater the mean number of monkeys present in raids, the longer was the mean raid duration (Pearson $r = 0.414$, $N = 50$ raided farms, $P = 0.03$) (Fig. 3).

Individual macaques were most commonly observed to raid at less than 10 m from the farm boundary (Fig. 4). Individuals were observed in 19% of all scans in bordering trees or grounds during a raid event, where some individuals retreated to consume their stolen crop. Very rarely did macaques penetrate further than 20 m into the farm (5% of raid scans), especially in farms where human activity or presence was noted. On average, for 75% of raids ($N = 455$), no human deterrence or patrolling of the farm was observed. Shouting alone was the most common deterrence (33%), with chasing or throwing stones seen in only 8% of raids.

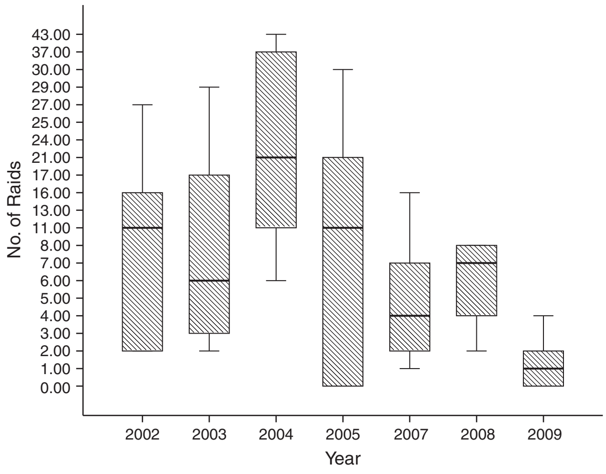

Fig. 2. Median, IQ range, and 95% confidence limits of frequencies of macaque raids in each study year for all 56 focal farms combined.

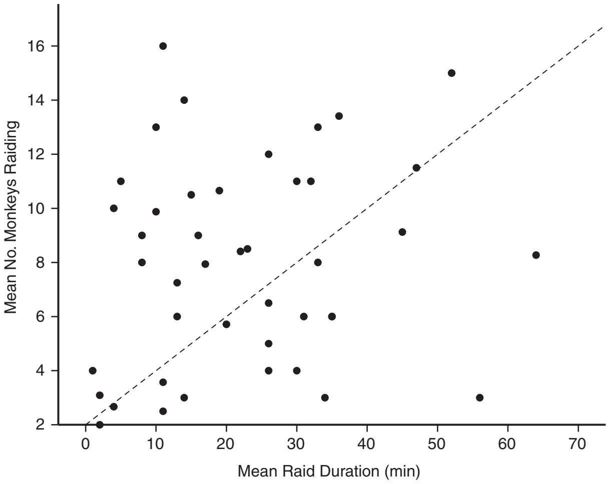

Fig. 3. Mean number of macaques present during a raid plotted against mean raid duration for focal farms ($N = 50$) across all years, with regression line. Farms without raids in any year were excluded.

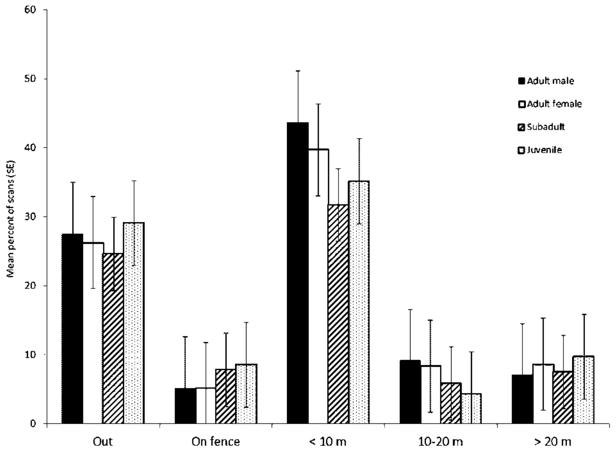

Fig. 4. Mean (±1SE) of the percentage of scans where individuals from each age-sex class were seen at different penetration distances into the farm from the farm boundary during raid events (N events = 4,350).

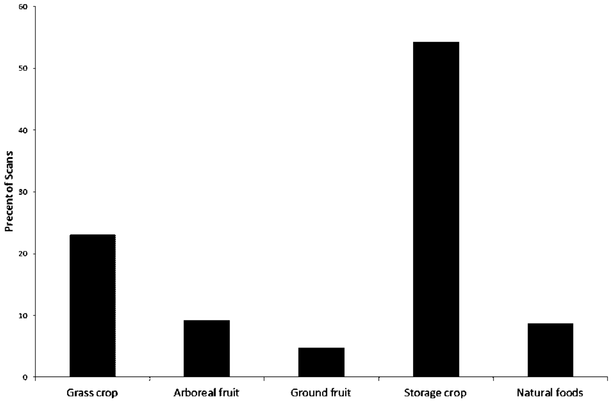

Fig. 5. Percent of feeding scans on farms where macaques were eating each major type of crop food ($N = 4{,}169$).

Raided Crop Types

Macaques were observed feeding on a variety of farm crops and wild foods with a total of 32 different food species over all years. These 32 food items were classified as arboreal fruits, ground fruits, grass crops, storage crops, or natural foods. Although fruit ripeness was not assessed quantitatively in this study, fruits eaten generally appeared to be ripe and available for macaques. The most common crops taken by macaques were sweet potatoes and other storage organs (Fig. 5). Some natural foods (insects, leaves and flowers) were available in the vicinity of the farms and these were occasionally targeted during raids. There were no significant differences among the age-sex classes in the percent of scans exploiting different crop types (Kruskal–Wallis ANOVA: grass crop $\chi^2 = 0.21$, df = 3, $P = 0.976$; arboreal fruit $\chi^2 = 5.34$, df = 3, $P = 0.148$; ground fruit $\chi^2 = 0.26$, df = 3, $P = 0.968$; storage crop $\chi^2 = 1.5$, df = 3, $P = 0.683$).

Behavior When Raiding

Feeding and moving were the most frequent behaviors exhibited during farm raids (31 and 37%, respectively). Vigilance represented little of the behavior exhibited by the macaques both in (1.9%) and out (2.5%) of the farm and was less frequent when inside the farm; the macaques appeared to be relatively relaxed during successful crop raiding events since time spent resting (20%) and in social (9%) interaction while raiding was high.

Significant differences were found for resting, social behavior, and vigilance when macaques were on the farm by comparison with when they were out of the farm (Mann–Whitney U: Rest $Z = -3.74$; $P < 0.001$; Social $Z = -3.20$, $P = 0.001$; Vigilance $Z = -3.1$, $P = 0.002$; all $N_1 = 36$, $N_2 = 124$). Feeding and moving did not differ when inside the farm by comparison with the surrounding areas (Feed: $Z = -0.77$, $P = 0.44$; Move: $Z = -1.2$, $P = 0.23$; Fig. 4).

No significant differences were found among the age-sex classes in the percent of time spent in major behaviors (Kruskal–Wallis: feed: $\chi^2 = 2.05$, $P = 0.562$; move $\chi^2 = 0.18$, $P = 0.98$; rest $\chi^2 = 0.46$, $P = 0.927$: all df = 3). However, vigilance and ‘‘other’’ behaviors did differ significantly among the age-sex classes ($\chi^2 = 16.84$, $P = 0.001$; $\chi^2 = 8.63$, $P = 0.035$). Adult males exhibited significantly higher frequencies of vigilance by comparison with juveniles (Mann–Whitney $Z = 3.9$, $N_1 = 40$, $N_2 = 40$, $P < 0.001$) and adolescents ($Z = -2.7$, $P = 0.008$). Primarily, adult members of the troop performed ‘‘other’’ behavior such as alarm calling and copulations. Subadults and juveniles very rarely exhibited these behaviors, while play (included in social behavior) was more common among the immatures.

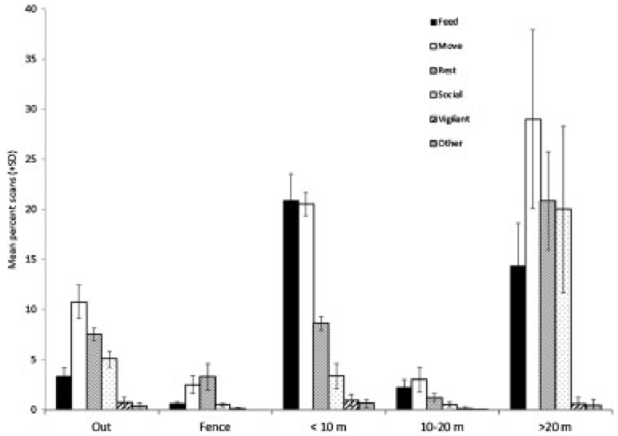

Fig. 6. Mean (±SD) of age-sex class percentage of scans (*N* = 12,913) in each behavior which were made at each location relative to the farm boundary.

Although there were few differences in activities among the age-sex classes, behaviors for all age-classes combined differed significantly as a function of penetration distance into the farm (Feed: $\chi^2 = 64.4$, Rest: $\chi^2 = 55.3$, Move: $\chi^2 = 31.7$; Social: $\chi^2 = 41.3$; Vigilant $\chi^2 = 29.5$; Other: $\chi^2 = 31.5$; all df = 4, $P < 0.001$). At the farm boundary or fence, resting behavior was frequent while movement along the farm perimeter via a fence was also common (Fig. 6). Most feeding behavior was exhibited 0–10 m into the farm. Movement within this part of the farm was also high. As the macaques penetrated further into the farm, resting and social behavior became less frequent. However, at penetration distances of >20 m which were associated with significantly longer raid durations, social and resting behavior were frequently observed. There was no statistically significant difference among age-sex classes in the percent of scans spent at each distance into the farm (Kruskal–Wallis ANOVA: surrounding areas $\chi^2 = 0.58$, $P = 0.901$; fence $\chi^2 = 0.093$, $P = 0.993$; 0–10 m $\chi^2 = 1.08$, $P = 0.782$; 10–20 m $\chi^2 = 3.125$, $P = 0.373$; >20 m $\chi^2 = 1.006$, $P = 0.800$, all df = 3).

DISCUSSION

Characterizing raiding behavior and understanding daily activity budgets are essential from a conservation perspective [Strum, 2010], and provide information to help manage the crop raiding behavior of the macaques and thus promote tolerance on the part of the farmers [e.g. Riley & Priston, 2010]. Based on all day group follows [Priston, 2005], macaques spend less than a third of their daily activities in crop raiding (32–38%). When they do raid, members of a group tend to exhibit similar behavior. We found very few statistically significant differences among age-sex classes in either crop type eaten or in the frequencies of behaviors on farms. Since most primates raid as a group [Forthman Quick & Demment, 1988; Maples et al., 1976; Strum, 1994], they tend to be highly co-ordinated in where, when, and what they are doing within the potentially risky environment of the farm.

Led primarily by adult and subadult males, the overall behavior of these troops changed significantly as a function of penetration. Both adults and immatures devoted a larger part of their activity budget to activities such as grooming, feeding, and resting at the greatest penetration distances into the farm, and were most vigilant at the farm boundaries. Our ad libitium observations suggest that juveniles spent more time playing during ''social'' time, even when crop raiding [see also Roonwall & Mohnot, 1977: *M. mulatta* and *M. radiata*; O'Brien & Kinnaird, 1997: *M. nigra*].

Individuals may only penetrate deep into the farm and exhibit behavior such as social grooming or play if it is perceived as safe to do so because farmers were not actively engaged in deterring the macaques [e.g. Priston, 2005]. We suggest that safety in numbers during a raid event affects the nature, duration, and behavior seen. When more monkeys were present, raid duration increased. Is it that the mere presence of more individuals is causal in longer raids, or that long raids encourage more individuals to enter the farm? Cautious individuals may only risk entering the farm after a certain time has passed without deterrence [Priston, 2005]. In this sense, individual macaques may be cognitively aware that longer time spent at the raiding site means that potential risks from humans or dogs are low and thus raiding will be safe and successful.

Focal farms varied considerably in size, perimeter length, forested perimeter, number of neighboring farms, crop abundance, crop type, level of human activity, and the mix of deterrents used. There were thus marked differences among the farms in their probability of experiencing raids and in the nature of those raids. In addition, variation in raid frequency for the same farm across years could result from farm characteristics that change annually. Year by year variation in crop type, planting schedules and harvesting on the same farm suggest that raiding frequency will not be consistent over time. Those farms that expand further into the forest after a ''slash and burn'' event may experience more frequent raids in the following year [Naughton-Treves et al., 2003].

Patterns of raiding changed over the 8 years of the study. In the early years, raiding occurred at a much greater frequency than after 2007, which saw a marked decrease in the number of raids (Fig. 2). Annual variation, in addition to the between-farm variation noted above, may have been due to a number of environmental and human factors: wild fruits may have been in greater abundance during the latter years of the study, or less available during 2002/2003; the weather may have hindered monkeys from venturing out of the forest canopy cover (for example, 2007 was a particularly wet season); crop abundance may have been very poor with very little available for humans and monkeys alike associated with high rainfall. Finally, following management advice on deterrence strategies such as fencing, guarding—especially with dogs, and stratified planting of the most vulnerable crops further from the edge [Priston, 2005; Priston & Underdown, 2009], farmers' prevention strategies may have reduced monkey invasions into farms. The number of potential raiders and raiding troops declined over time due to loss of habitat and human activities. In earlier years, we can suggest that the monkeys were forced into raiding as their natural habitats were reduced due to agricultural expansion, and if the macaque population has subsequently crashed as suggested by the drop in numbers of known troops, then there will now be fewer macaques to raid and possibly less need for them to raid with reduced competition for natural foods.

Human–macaque interactions have yet to escalate into overt conflict in this area; religious and traditional views on nonhumans promote some sense of co-existence [e.g. Riley and Priston, 2010]. It is therefore vital that we help manage this rare instance of "tolerant" human–wildlife interaction before it reaches an escalated and crisis conflict situation. This long-term study confirmed earlier suggestions [Priston, 2005] that the peak distance for raiding is within 10 m of the farm boundary. Thus, systematic farm management could ensure the macaques' future and allow farmers to continue to share their forests and fields with macaques. Widespread action, such as planting buffer crops <10 m into the farm, or planting highly palatable and important subsistence crops more than 20 m from the border, along with less favored monkey crops such as chilli near the fence or forest boundary form part of the potential long-term strategies to manage and mitigate conflict and to sustain macaque-tolerant farmers.

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