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Original Investigation

Free-ranging livestock influence species richness, occupancy, and daily behaviour of wild mammalian species in Baluran National Park, Indonesia

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ABSTRACT

In some developing countries, human activities in protected areas threaten wildlife populations and their habitats. This study was conducted to understand the influences of free-range livestock on the wild mammalian population in Baluran National Park, Indonesia. There were 3852 and 1156 cows and goats, respectively, and livestock occupied an area of approximately 55.96 km^2. The species richness and probability of occupancy in areas with and without livestock were assessed, and the spatial co-occurrence and overlap of daily activity patterns among mammalian species and livestock were measured. A total of 39 camera traps were installed from August 2015 to January 2016, collecting 23,021 independent photographs. In areas with livestock, the number of mammal species (eight) was lower than in areas without livestock (11 species). The most affected species were the large herbivores *Bubalus bubalis* and *Bos javanicus*, and a large carnivore *Panthera pardus*, all of which were absent in areas with livestock. Regardless of the feeding guild, the probability of occupancy of almost all species declined in areas with livestock, except the medium herbivores *Paradoxurus hermaphroditus* and *Hystrix javanica* that showed a higher probability of occupancy. The species whose probability of occupancy declined were the carnivores *Cuon alpinus* and *Prionailurus bengalensis*; the herbivores *Rusa timorensis*, *Tracypithecus auratus* and *Muntiacus muntjak*; and the omnivore *Sus scrofa*. In the presence of livestock, *R. timorensis* and *S. scrofa* changed their activities from diurnal to nocturnal. Livestock affected most wild mammals in several ways, including by reducing the species richness, lessening the probability of occupancy and changing the daily activity patterns of many animals. This research recommends a significant reduction in the size of the range area for domestic livestock.

Introduction

Land use changes, such as clearing forest for agriculture use and settlement, are considered some of the most severe drivers causing substantial declines in the biodiversity of the tropical and temperate forest biomes. The loss of forest cover will result in the extinction of local plant species and associated animals (Sala et al., 2000). The Indonesian rainforest is considered one of the largest hotspots in the world, after Madagascar and the Philippines, based on the evaluation of five key factors: number of endemics and endemic species/area ratios for both plants and vertebrates, and habitat loss (Myers et al., 2000).

To safeguard plant and animal diversity and unique ecosystems, the Indonesian Government dedicated approximately 22.2 Mha of forestland as protected areas with varying categories according to the International Union Conservation for Nature (IUCN) (Ministry of Environment and Forestry of Indonesia, 2014). Protected areas are an important policy tool used for the conservation of biodiversity and maintenance of ecosystem services. Additionally, protected areas are central elements and a cornerstone of the effective climate change adaptation strategy and generate new investment and employment opportunities (Mackey et al., 2008; Secretariat of the Convention on Biological Diversity, 2008; Gray et al., 2016).

However, many protected areas in Indonesia do not fulfil the ecological criteria and are subject to a range of social and economic pressures (Kanowski, 2001). For example, although at a slower rate than in non-protected areas, illegal logging and forest conversion still occurs, especially after the economic crisis and national reformation in 1999 (Curran et al., 2004; Hollenbach, 2005; Gaveau et al., 2007; Gaveau et al., 2009; Brun et al., 2015). Interestingly, studies from Bolivia, Costa Rica, Indonesia and Thailand found that a more strictly managed protected area does not necessarily mean more protected (Ferraro et al., 2013). A study on deforestation in Indonesia from 2000 to 2012 showed that protected areas of IA and

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V were likely to experience higher deforestation rates than other categories (Brun et al., 2015).

Since 1980, the paradigm of protected area management has shifted from top-down protection to bottom-up and participative management that accommodates the aspiration of the local people. Management has moved beyond biodiversity conservation as the sole goal to integration with local economic development and has begun to consider protected areas as a means to alleviate poverty (Pelser et al., 2013; Gurney et al., 2014). According to this paradigm, the success of protected area management depends on the ability of the manager to integrate the biodiversity conservation goals with the socio-economic issues and promote greater compliance of the local community activities with the protected area goals (Andrade and Rhodes, 2012).

Baluran National Park has been subjected to human settlement and agricultural activities that need to be evaluated to determine whether they still comply with the conservation goals of the park. Pasture and settlement began in 1975, when the government granted a license to a private enterprise (PT. Gunung Gumitir) for planting trees for pulp industry in parts of the Baluran Wildlife Sanctuary (Wianti, 2014). The license expired in 2000, but PT. Gunung Gumitir employees continue to occupy the park, using it for settlement, crop planting and grazing for their livestock.

The goal of this study is to evaluate the influence of livestock on the park ecosystem by using the mammalian community as an ecological indicator. The sensitivity of wild mammals to agricultural practice varies, some species are intolerant to human presence while others can adapt to some degree (Nanni, 2015; Ramesh and Downs, 2015). Previous studies on the interaction between livestock and the wild animal population have had mixed results. Claims and counter claims about the level of competition between wildlife and livestock have caused controversies that triggered intensive discussion among conservationists (Butt and Turner, 2012). While some scholars have stated that livestock competes with wildlife for food and space (Averbeck et al., 2009; Low et al., 2009), others have reported that livestock can coexist and do not compete with wildlife (Porras et al., 2016; Sitters et al., 2009). Other studies have even presented that livestock facilitates and improves the performance of wildlife through improvement of grazing quality (Gordon, 1988).

Livestock in Baluran National Park is essential to sustain the livelihood of the local people and for the economic development of the region. However, there is little understanding of the interaction between wild mammals and the livestock. A better understanding of what the impacts are and which animals are most affected by the occurrence of livestock will improve the management strategies. This research proposed multiple hypotheses. First, species richness of mammals will be lower in the AOL (Area Occupied by Settlement and Livestock) than in the ANOL (Area Not Occupied by Livestock). Second, the probability of occupancy and the abundance of wild mammalian species in the AOL will be lower, but the magnitude of the impact of livestock will vary among the mammalian species. Third, the spatial occurrence of wild mammals is negatively associated with the occurrence of livestock. Finally, the daily activity patterns of wild mammals in the AOL will change with the presence of livestock.

Material and methods

Study area

Baluran National Park is 250 km^2 and located in East Java Province, Indonesia. The area is classified as climate type AW according to the Köppen Climate Classification. The rainfall ranges from 797 mm to 3500 mm year^{-1} with an average of 1500 mm year^{-1}. Climate data indicate that the rainy season is very short and normally occurs from December to February. Therefore, the lack of water is the most important limiting factor for vegetation in the area. The largest part of the foot and the slopes of Baluran Mountain is covered by dense, dry forest. The forest continuously extends into the lowland area, which is dominated by savannah interspersed with small forests along the galleries, on top of hills and in humid areas.

Data collection

I conducted a census to collect data on the number of human inhabitants and their livestock by conducting house calls. To map the distribution of the livestock, the movement of each herd was followed for one month to determine the location as well as the extent of the area used by the livestock. The point coordinates of the routes of livestock were identified using a handled Global Positioning System (GPS) receiver (Garmin 72H). Based on these data, a map of the grazing area was produced using Map Source, DNR GPS and SAGA GIS (Conrad et al., 2015).

To collect data on species abundance of wildlife, passive infrared digital camera traps (model: Bushnell Trophycam HD Max) were installed from August 2015 to January 2016. The survey areas were representative of the range of used and unused area by livestock. Each camera trap station was considered one sampling unit. A total of 39 camera trap units were used, 16 camera traps were installed in the AOL and 23 camera traps in the ANOL. Camera stations were separated by an average distance of 1.4 km to promote spatial independence among detections (Moreira-Arce et al., 2015). In all survey areas, cameras were positioned approximately 50–150 cm above the ground. The cameras were active 24 h a day, set with an interval of 2 s between exposures and were adjusted to take three photographic captures per shoot. Cameras were programmed to record the time and date of every image.

Data analysis

Species richness

The rarefaction method was used to determine if the expected species richness of ANOL and AOL differed for a common number of individuals (Gotelli and Chao, 2013). The number of species in the ANOL, which had a larger sample, was rarefied to the total number of species in the AOL (with a smaller sample). The **EstimateS 9.1.0** software was used to calculate the expected number of species (Colwell et al., 2012).

Abundance distribution

The abundance distribution of species in ANOL and AOL was measured using the Evenness Index (Pielou, 1969). The value is constrained between 0 and 1.0, with 1.0 representing a situation in which all species are equally abundant. The formula for the Evenness Index is as follows:

$$E = \acute{H}/H_{max} = \acute{H}/\ln S \tag{1}$$

where: $\acute{H}$ is the Shannon Index of Diversity and S is the total number of species.

The Index of Relative Abundance (RAI) was calculated as the number of independent photographs of a species by all cameras (A_i) divided by the total independent captures of all species during the study period (N), and then multiplied by 100 (Liu et al., 2013).

$$RAI = \frac{A_i}{N} x100 (i = 1 - 11) \tag{2}$$

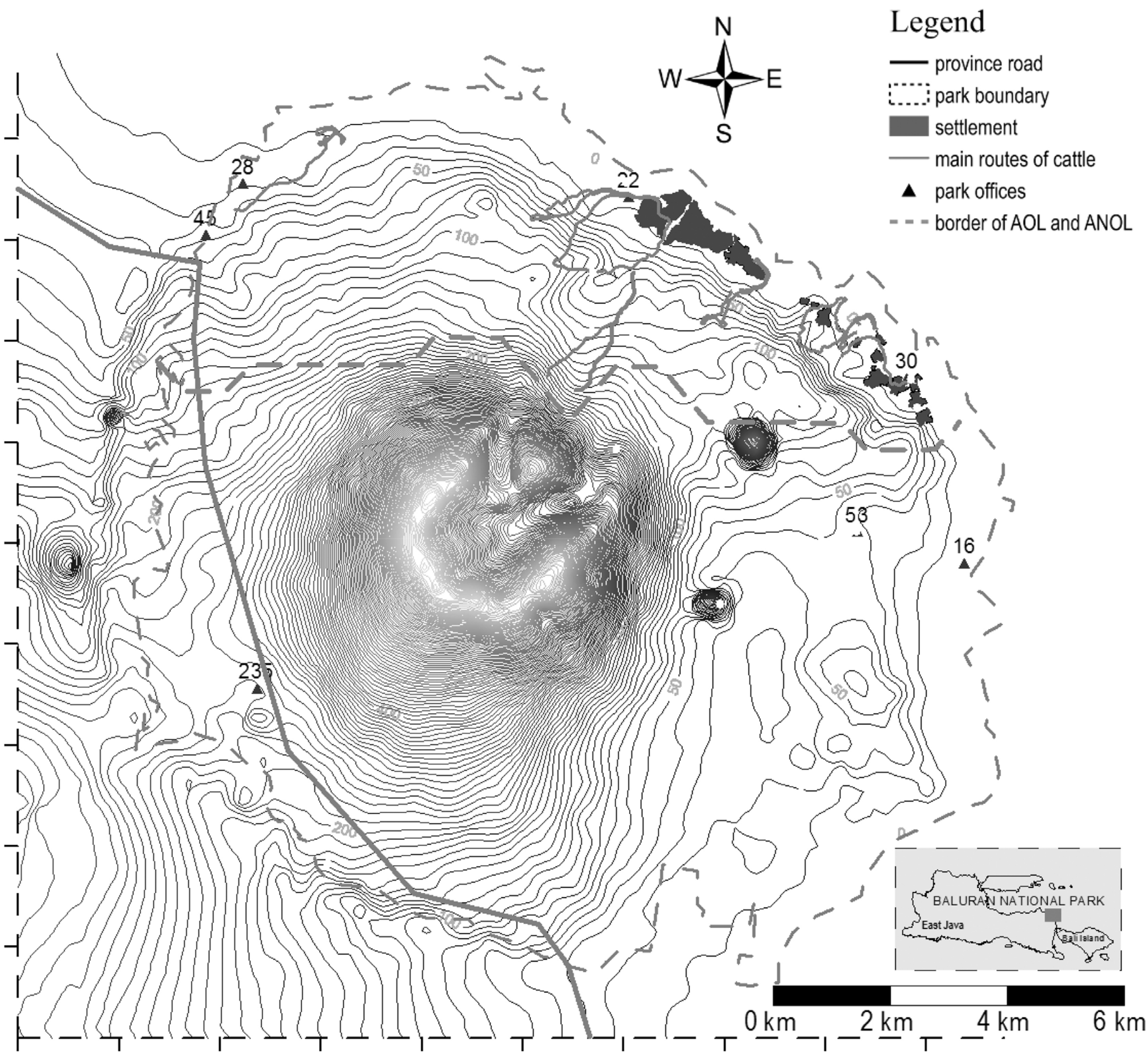

Fig. 1. The geographic location of Baluran National Park. The shaded black areas are settlement and agriculture areas. The black lines are the main routes of livestock movement. The area within the dashed lines is the AOL. The numbers signify altitude.

Species occupancy

Sites with higher occupancy estimates were interpreted as preferred by a species, as sites preferred by a species are more likely to be occupied than those sites not preferred by a species (Sunarto et al., 2012). To estimate the site occupancy rate, the occupancy model of a single-season was applied to the data (MacKenzie et al., 2006). This model uses data from repeated records of whether or not the animals were detected during the survey period. This record is termed as the detection history, which is specific for each site and each species and is then converted into a mathematical statement. Data of a species at a single site can take the form of a detection history, such as: $h_i = 0101010$, to describe the seven repeated observations, where sequences of '1' indicate the presence of a mammal species, while sequences of '0' indicate the non-detection of mammals in a day (Henschel and Ray, 2003). Photographs that were recorded within thirty minutes of a previous photograph at the same site were excluded from the data set due to concerns about the lack of independence (Ridout and Linkie, 2009). The probability of occupancy (ψ) was estimated using an occupancy model, which produces estimates that are robust to "false absences" and spatial and temporal variation in detection probability (MacKenzie et al., 2006). The data were analysed using the **PRESENCE 11.1** software (Mackenzie and Royle, 2005).

Spatial Co-occurrence

The pattern of spatial co-occurrence of wildlife and livestock is analysed with the probabilistic species co-occurrence model. The substantial advantage of this model as a statistical method is that it eliminates one major source of Type I and II errors in the analysis of species co-occurrence patterns (Veech, 2013). The association of two species is considered negative when $P(lt) \leq \alpha$ (where $P(lt) = \$p\_lt$ and $\alpha = 0.05$) and positive when $P(gt) \leq \alpha$ (where $P(gt) = \$p\_gt$ and $\alpha = 0.05$) (Griffith et al., 2016). The R package, **cooccur** (Griffith et al., 2016) was used to determine the spatial co-occurrence pattern of wild mammalian and livestock.

Temporal overlap of daily activity patterns

For quantifying the overlap of daily activity patterns between a pair of species, a two-step procedure developed by Ridout and Linkie (2009) is applied. The first step consists of pooling the data for all sites, then investigating the diel (24-h cycles) activity pattern of each species using a Kernel Density Estimation (KDE) on circular data with a smoothing parameter (c) of 1.00. The patterns of daily animal activity were classified into four categories: diurnal, nocturnal, crepuscular and cathemeral (Foster et al., 2013).

The second step consists of measuring the coefficient of overlap (Δ) between the two probability distributions of a species pair, whose value ranges from 0 (no overlap) to 1 (complete overlap). There are three alternative methods of estimating Δ, i.e., Δ_1, Δ_4 and Δ_5. In this study, Δ_1 and Δ_4 are applied, which are appropriate for small ($n < 50$) and large samples ($n > 50$), respectively (Meredith and Ridout, 2014). The 95% confidence intervals were obtained as percentile intervals from 10,000 bootstrap samples. The R package **overlap** (Meredith and Ridout, 2014) was used to fit kernel density functions, estimate the coefficient of overlap, and calculate bootstrap estimates of the confidence intervals.

Results

There was a total of 303 households made up of 921 people living in the settlement. The size of the AOL was approximately 55.96 km^2, approximately one-fifth (22%) of the total terrestrial area of the park. A part of the AOL (2.61 km^2) was used as a settlement area and agriculture land. There was a total of 3852 cows, and 2170 (56%) of the cows were owned by the inhabitants of the settlement area, and 1682 (44%) were owned by people living outside. There was a total of 1156 goats, all owned by the local inhabitants. The majority of cows, 3510 (91%), and goats, 731 (63.2%), were free range. The remaining 342 cows (9%) and 425 (26.8%) goats were kept in captivity. The location of the AOL and the route of livestock movement in the national park were presented in Fig. 1.

Species richness

Total sampling effort was 1562 camera days: 512 in AOL and 1050 in ANOL. The mean effort of each camera/sampling unit was 32 days in AOL and 46.65 in ANOL. In total, 23,021 independent photographs were captured during the study, 6336 (27.5%) of which were in the AOL, and 16,685 (72.5%) were in the ANOL. A total of eight species were observed in the AOL, which was lower than in the ANOL (11 species). The species that occurred in the study area were *B. javanicus*, *B. bubalis*, *P. pardus*, *R. timorensis, S. scrofa*, *M. muntjak*, *C. alpinus*, *T. auratus*, *H. javanica*, *P. bengalensis* and *P. hermaphroditus*. Among them, two species were classified as Endangered by the IUCN Red List Species (*B. javanicus* and *C. alpinus*) and three were Vulnerable (*T. auratus*, *P. pardus* and *R. timorensis*). Three large mammal species were absent in the AOL, namely *B. javanicus*, *B. bubalis* and *P. pardus*. The result of the rarefaction analysis showed that the expected number of species in the ANOL (10 species) was larger than in the AOL (eight species) (Fig. 2).

Abundance of wild mammals

The abundance of wild mammals in the ANOL (16.95 ± 1.38 (SE) independent photographs day^{-1}) was higher than in the AOL (12.8 ± 1.40 (SE) independent photographs day^{-1}). In the AOL, the three species with the largest RAI were *R. timorensis* (70.54) and two livestock species, *Bos taurus* (16.26) and *Capra aegragus* (6.77), whereas in the ANOL, they were *R. timorensis* (74.6), *B. bubalis* (20.45) and *B. javanicus* (3.20) (Table 1). The abundance distribution of the mammalian community in Baluran National Park was extremely unequal (E = 0.20 in the AOL and 0.31 in the ANOL). The mammal community was dominated by a single species, namely *R. timorensis*. This species was most photographed and occurred in 27 of the 39 sites (69%).

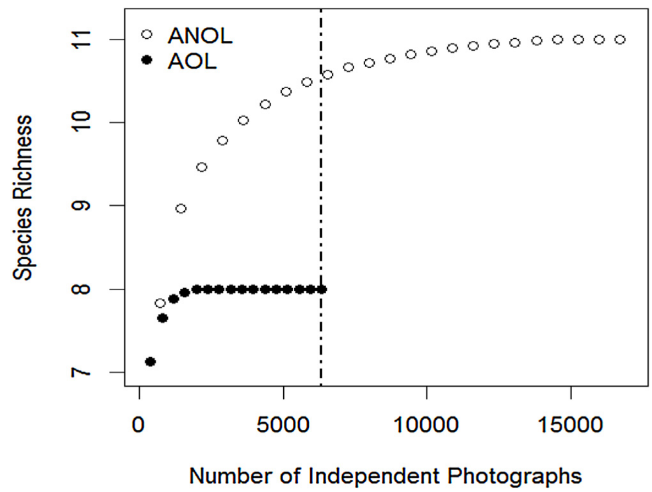

Fig. 2. Standardized comparison of species richness for the AOL and the ANOL. The dashed and dotted vertical line illustrates a species richness comparison standardized to 6336 individuals. The ANOL contains 10 species, and the AOL contains 8 species.

Probability of occupancy

The proportion of occupied sites (Ψ) of most animals decreased in the AOL. Three species (*B. javanicus, B. bubalis and P. pardus*) have a zero probability of occupancy in the AOL, while they possessed a relatively high probability of occupancy in the ANOL. In the AOL, the probability of occupancy of *R. timorensis* declined from 0.77 to 0.56, *T. auratus* declined from 0.40 to 0.33, *M. muntjak* declined from 0.54 to 0.25, *C. alpinus* declined from 0.36 to 0.21, *S. scrofa* declined from 0.35 to 0.07, and *P. bengalensis* declined from 0.32 to 0.21. Only *H. javanica* (0.04–0.70) and *P. hermaphroditus* (0.12–0.42) showed an increase of Ψ in the AOL (Table 1).

Spatial co-occurrence

The probabilistic analysis found mostly random co-occurrence patterns between livestock and wild mammalian species. Thereby, the occurrence of the majority of wild mammals (seven species) was not influenced by the presence of livestock. Only one species, *B. javanicus*, was negatively associated with livestock, and one species (*H. javanica*) was positively associated (Table 2). The examination of the co-occurrence between *S. scrofa* and *P. bengalensis* and livestock was excluded from the analysis because the values of the expected co-occurrence of these pairs were less than 1 (Veech, 2013; Griffith et al., 2016).

Daily activity pattern

In respect to their daily behaviour patterns, animals were found to respond differently to the presence of livestock. First, two species changed their behaviour from mainly diurnal to nocturnal, i.e., *R. timorensis* and *S. scrofa* (Fig. 3 & 3). Second, *P. hermaphroditus*, *H. javanica*, and *P. bengalensis* were nocturnal both in the ANOL and the AOL (Fig. 3, 3 & 3). Third, *T. auratus* was diurnal both in the AOL and the ANOL (Fig. 3.3). Finally, *M. muntjak* has shown activity during the night and day with two peaks of activity in the morning and at dusk both in the AOL and the ANOL. This pattern was similar to the pattern of *C. alpinus,* which was a cathemeral animal both in

Table 1
Comparison of the frequency of animal captures per 100 days (the number of days that a species was captured by photographs within a 100-day time frame), number of independent captures, relative abundance, naïve occupancy, and probability of occupancy of 11 wild mammalian species between the area occupied by livestock (AOL) and the area not occupied by livestock (ANOL) in Baluran National Park, East Java, Indonesia.

No.	Species	Frequency/ 100 day		No. of independent captures		Relative abundance index		Naïve occupancy		Probability of occupancy Ψ±SE	
		AOL	ANOL	AOL	ANOL	AOL	ANOL	AOL	ANOL	AOL	ANOL
1	*R. timorensis*	36.91	25.05	5806	12467	70.54	74.72	0.56	0.74	0.56 ± 0.12	0.77 ± 0.09
2	*T. auratus*	2.54	0.95	188	51	2.28	0.31	0.25	0.22	0.33 ± 0.15	0.40 ± 0.17
3	*M. muntjak*	6.25	3.62	156	104	1.90	0.62	0.25	0.43	0.25 ± 0.11	0.54 ± 0.13
4	*P. hermaphroditus*	4.49	0.76	88	9	1.07	0.05	0.38	0.17	0.42 ± 0.14	0.12 ± 0.12
5	*C. alpinus*	2.15	2.00	40	44	0.49	0.26	0.19	0.22	0.21 ± 0.11	0.36 ± 0.16
6	*H. javanica*	4.69	1.24	35	27	0.43	0.16	0.44	0.04	0.70 ± 0.22	0.04 ± 0.04
7	*S. scrofa*	0.78	0.38	12	7	0.15	0.04	0.06	0.13	0.07 ± 0.07	0.35 ± 0.29
8	*P. bengalensis*	1.76	0.48	11	2	0.13	0.01	0.19	0.13	0.21 ± 0.11	0.32 ± 0.21
9	*P. pardus*	0.00	2.00	0.00	28	0.00	0.17	0.00	0.39	0.00	0.59 ± 0.17
10	*B. bubalis*	0.00	13.71	0.00	3412	0.00	20.45	0.00	0.30	0.00	0.30 ± 0.10
11	*B. javanicus*	0.00	5.24	0.00	534	0.00	3.20	0.00	0.43	0.00	0.48 ± 0.11
12	*B. taurus*	6.05	0.00	1338	0.00	16.26	0.00	0.56	0.00	0.56 ± 0.12	0.00
13	*C. aegragus*	26.56	0.00	557	0.00	6.77	0.00	0.13	0.00	0.13 ± 0.09	0.00

Table 2
The pattern of spatial co-occurrence between wild mammals and livestock.

No.	Species	No. of occurrence	Obs. Co-occurrence	Exp. Co-occurrence	P(lt)	P(gt)
1	*R. timorensis*	27	5	6.2	0.27	0.92
2	*T. auratus*	13	4	3.0	0.88	0.34
3	*M. muntjak*	14	3	3.2	0.59	0.71
4	*P. hermaphroditus*	10	4	2.3	0.97	0.15
5	*C. alpinus*	12	4	2.8	0.92	0.27
6	*H. javanica*	8	5	1.8	1.00	0.01**
7	*P. pardus*	9	0	2.1	0.07	1.00
8	*B. bubalis*	7	0	1.6	0.13	1.00
9	*B. javanicus*	10	0	2.3	0.05*	1.00

Note: 1. The number of sites with livestock occurrence is nine, 2. P(lt) and P(gt) express the probabilities that the two species would co-occur less (P(lt)) than or greater (P(gt)) than the observed value, respectively. They can be interpreted as *p*-values. Significant p-values have been indicated by an asterisk "*" and "**".

the AOL and the ANOL (Fig. 3.7). The species that were only present in the AOL, *P. pardus* and *B. javanicus,* were mainly nocturnal (Fig. 3 and 3), and *B. bubalis* was mainly cathemeral (Fig. 3.11).

Temporal overlap between wild mammal and livestock

This research found high time segregation between wild mammal and livestock as presented by the low overlap of diel activity patterns (Fig. 4). Among the wild mammals, *T. auratus* and *M. muntjak* showed the highest coefficient of overlap with livestock, i.e., $\Delta_4 = 0.49$ (0.39–0.58) and $\Delta_4 = 0.40$ (0.32–0.48), respectively. The species with a coefficient of overlap below 0.1 were *H. javanica* $\Delta_1 = 0.04$ (0.004–0.078), *P. hermaphroditus* $\Delta_4 = 0.04$ (0.005–0.079), *P. bengalensis* $\Delta_1 = 0.05$ (0.00–0.14) and, *R. timorensis* $\Delta_4 = 0.06$ (0.05–0.08). The values of the coefficient of overlap between livestock and *S. scrofa* and *C. alpinus* were $\Delta_1 = 0.17$ (0.00–0.38) and $\Delta_1 = 0.19$ (0.07–0.31), respectively.

Discussion

The results of this study supported the first research hypotheses that the species richness of the mammalian community was higher in the ANOL. This difference was revealed by the absence of two large herbivores (*B. javanicus* and *B. bubalis*) and a top predator (*P. pardus*), while the dominance was more pronounced in the AOL, as indicated by the lower value of the evenness index. This finding also affirmed the second hypotheses that livestock affected the probability of occupancy and abundance of wild mammalian species at various degrees. There were three groups of animals whose responses were related to livestock, first animals whose probability of occupancy and abundance declined (*B. javanicus*, *B. bubalis*, *R. timorensis* and *P. pardus*), a second group whose probability of occupancy declined but abundance increased (*C. alpinus*, *T. auratus*, *M. muntjak*, *P. bengalensis* and *S. scrofa*). These were the animals that have higher photograph rates, but a lower number site of occurrences. This result indicated that these animals were not randomly distributed, rather they select a few places in an area with livestock for their activity. The third group contained animals whose probability of occupancy and abundance increased in the AOL, i.e., *P. hermaphroditus* and *H. javanica*. These animals benefitted from the presence of livestock.

The results suggested that all large and some medium animals were negatively affected by livestock. The large herbivores with body weights ranging from 300 to 900 kg (*B. javanicus* and *B. bubalis*) and the obligate carnivore *P. pardus* (weighing up to 90 kg) have a zero probability of occupancy in the AOL. The occupancy of the smaller herbivore *R. timorensis* (weighing up to 120 kg) also declined in the AOL, but it was still present with a relatively high probability. This finding was consistent with the theory that large animals are more intolerant than small ones to human disturbance (Blumstein, 2006; Samia et al., 2015).

In the tropical rainforest in Borneo, *B. javanicus* preferred selectively logged forest over the primary forest and did not exhibit an edge effect, as the abundance was not influenced by the distance to the habitat boundary (Brodie et al., 2015). In a drier region, such as Java and some regions in South East Asia, *B. javanicus* occurred more in semi-open habitat and semi-evergreen forest (Steinmetz, 2004). The habitat features in the AOL were similar to the habitat in the ANOL, which provide enough food and shelter to support the occurrence of *B. javanicus*. Wind and Amir (1977) reported that the settlement and grazing area were once a habitat of *B. javanicus*.

The small population of *B. bubalis* depended heavily on water and spent considerable time wallowing in the artificial mud holes. This requirement resulted in a restricted distribution (occurred

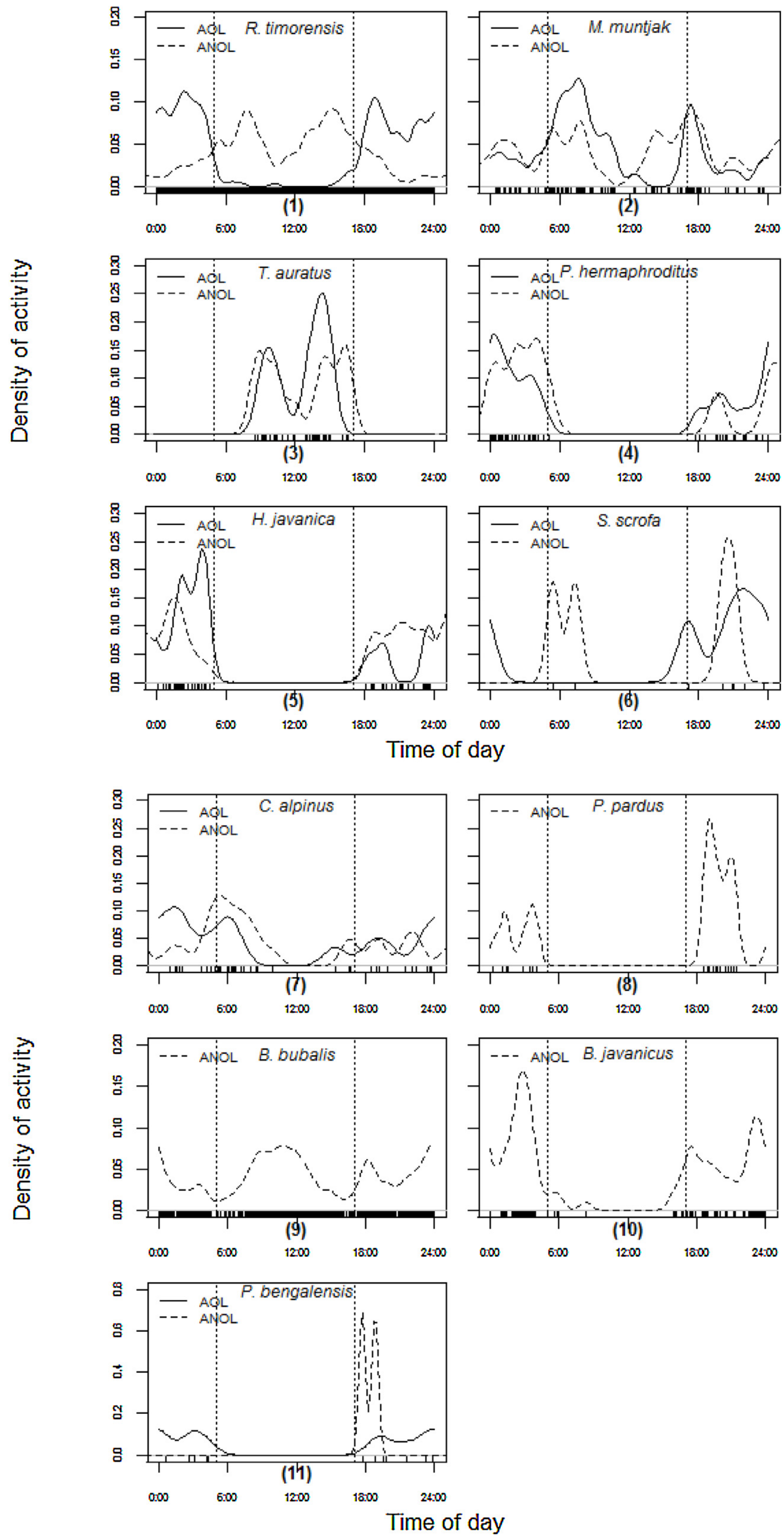

Fig. 3. Density estimates of the daily activity patterns of 11 wild mammal species detected by camera traps in the ANOL (dashed line) and the AOL (solid line). The short vertical lines above the x-axis indicate the time of individual photographs, and the vertical dashed line presents the approximate time of sunrise and sunset in the study area.

only in seven sites) in the ANOL. The habitat selection of *P. pardus* was greatly influenced by the prey catchability, which was the result of two factors, prey abundance and habitat structure characterized by a flat slope and intermediate cover (Balme et al., 2007; Simcharoen et al., 2008). *P. pardus* is well known as an obligate carnivore with a broad diet and behavioural plasticity that enables

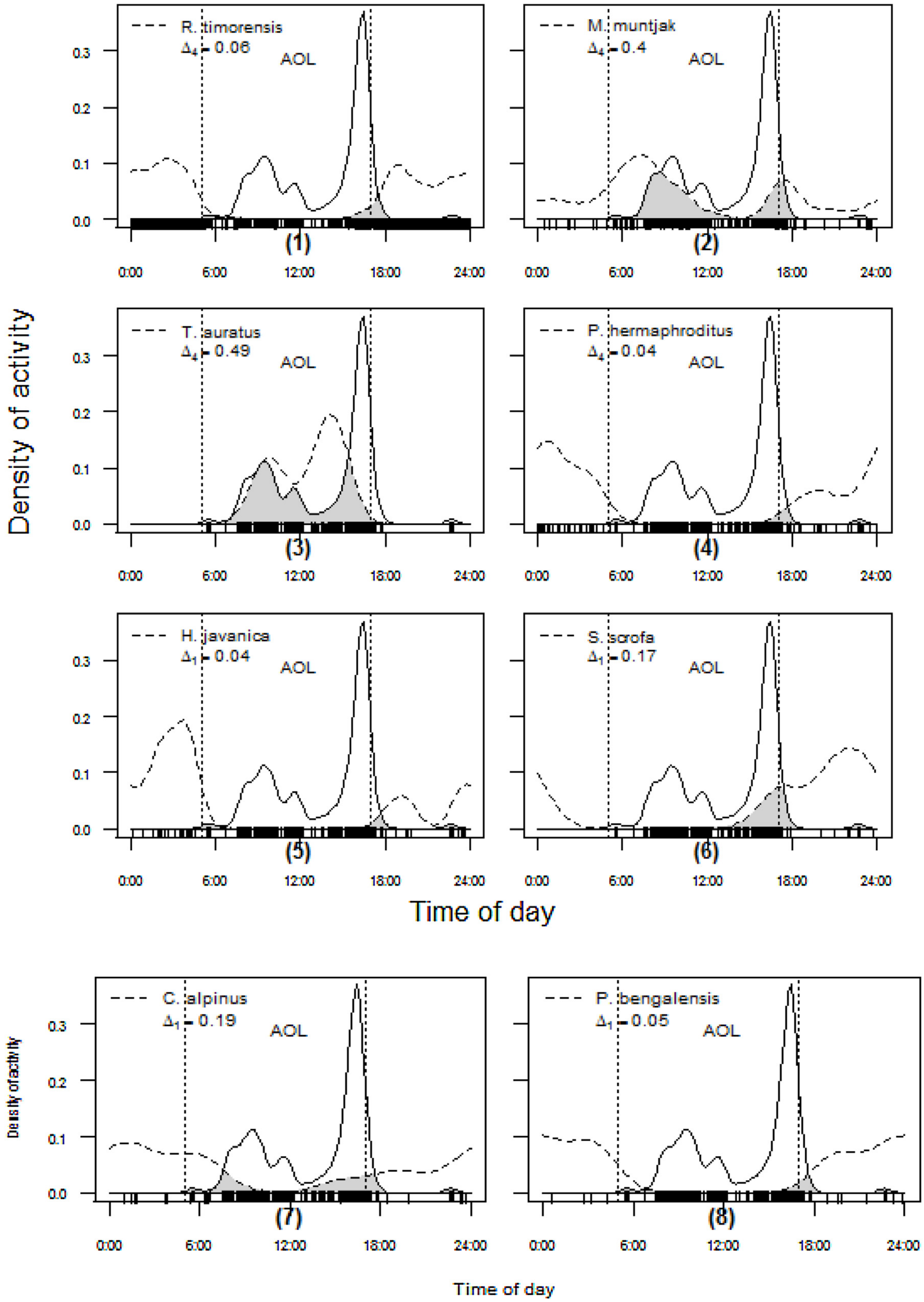

Fig. 4. Estimates of the daily activity patterns of wild mammalian species (dashed line) and livestock (solid line). The short vertical line above the x-axis indicates the photograph times of individual animals. The vertical dashed line indicates the approximate time of sunset and sunrise. The overlap coefficient is the area under the minimum of the two density estimates, as shown by the shaded area in each graphic.

them to persist in a highly human modified landscape (Athreya et al., 2013). The animal might not truly be absent in the AOL, even though it was not detected by the camera trap. In fact, an attack on a goat by the animal in the border between the ANOL and the AOL was recorded during the study period. However, the abundance of this species in the AOL was likely much lower than in the ANOL.

R. timorensis had the largest population of wild mammals and occupied the most area of the national park, except in the steep areas of Baluran Mountain. This species has been reported to have a broad diet composition, remarkable site fidelity and is known to prefer savannah or semi-open habitat over dense rainforest (De Garine-Wichatitsky, 2005; Spaggiari and De Garine-Wichatitsky, 2006). A higher probability of occupancy of *C. alpinus* in the ANOL might be correlated with the width and even distribution of its main prey species (*B. bubalis, B. javanicus*, *R. timorensis, S. scrofa and M. muntjak*) (Nurvianto et al., 2016). It has been reported that *P. bengalensis* is a generalist species that occurs in a higher abundance near the edge than in the forest interior (Azlan and Sharma, 2006; Cheyne et al., 2016).

It was difficult to obtain reliable estimates of the probability of occupancy of *P. hermaphroditus* and *H. javanica* (in the ANOL) and *S. scrofa* (in the AOL) from this research because of the small sample size. For rare species that are elusive and difficult to observe, a longer survey time is needed to obtain precise estimates. In the tropical rain forest, muntjac, pig and porcupine consistently use logged and unlogged forest with an occupancy of >0.5 (Cheyne et al., 2016). *P. hermaphroditus* and *H. javanica* were animals with high adaptability that can inhabit secondary and degraded forest (Samejima et al., 2012).

The third hypotheses of a negative association between livestock and wild mammals cannot be accepted fully, since it was only true for *B. javanicus*. However, although not statistically significant, some species showed a tendency to be negatively associated with livestock as indicated by a lower value of observed co-occurrence than expected co-occurrence. The fourth hypothesis was not rejected for *R. timorensis* and *S. scrofa* but was not true for other species. To lessen the interaction with livestock, *R. timorensis* and *S. scrofa* change their daily activities from the normal diurnal behaviour and become nocturnal. Under normal behaviour, the overlap of daily activity between *R. timorensis* and *S. scrofa* and livestock should be very high, but when they spatially co-occurred, the overlap of daily activity is very small. This change in activity patterns might be a plausible explanation of the mechanism that allows for the co-occurrence between livestock and wild mammals.

This study showed that the overlap of daily activity of most animals that spatially co-occurred with livestock is very small (below 0.20), except for *T. auratus* (0.49) and *M. muntjak* (0.40). *T. auratus* is an arboreal animal that never competes for food or space with livestock, and this animal is very rarely hunted by humans. *M. muntjak* was active during the day and night. This activity pattern overlapped substantially with livestock and with the main predator, *C. alpinus,* both in areas with or without livestock. The similarity of patterns in the daily activity of *M. muntjak* and *C. alpinus* was also reported in lowland deciduous forest in Cambodia (Gray, Prum et al., 2016).

Conclusion

This research demonstrated that livestock affected the occurrence of wild mammals in several ways, such as by reducing the species richness, displacing wild mammals from suitable habitat, lessening the probability of occupancy and changing the daily activity pattern of animals. The main reason for the establishment of Baluran National Park was to conserve the diversity of mammalian species, especially large mammals. This study showed that the animal most affected by livestock was *B. javanicus*. The population size of *B. javanicus* in the park has continuously decreased since 2002 (Pudyatmoko, 2007). It was estimated that the number of *B. javanicus* in Baluran National Park in 1970 was 150–200 individuals (Halder, 1970).

Since livestock affected most wild mammals, it should be better regulated. The area for livestock herding should be significantly reduced, i.e., agriculture and livestock husbandry should be allowed only in the settlement area, and free-range livestock should not be allowed. Considering the local socioeconomic context, it is not possible to remove people from the national park area, but it is still possible to encourage them to practice an integrated farming system that requires less agricultural area and promises higher productivity. Ecotourism could also be developed in this area. The Baluran National Park has to be managed based on imperatives for the conservation of biodiversity and socio-economic uplifting of local community.

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