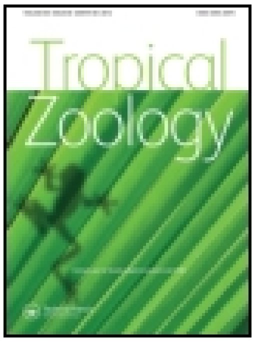

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Benefit of camera trapping for surveying the critically endangered Bawean deer *Axis kuhlii* (Temminck, 1836)

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Despite being one of the rarest deer in the world, the critically endangered Bawean deer *Axis kuhlii* has received little conservation attention. Fauna monitoring is usually limited by lack of resource; therefore, the choice of a relevant methodology is fundamental to maximize the cost–benefit ratio. We compared the performance and cost of three direct and indirect methods to survey Bawean deer in protected areas of Bawean Island. Camera trapping provided a high number of records of Bawean deer (118 for 5500 camera days) and ascertained identifications of several other species. The number of photographs increased with the dry season. Transect sampling was time-consuming in the field for a poor result (two records for 19.200 h). Faecal pellet group count was more successful (80 pellet groups for 9.600 h of fieldwork). Camera traps are expensive to buy, but they lighten the field work and provide much data for further analyses.

Keywords: Cervidae; camera trapping; transect sampling; faecal pellet group count; cost

Introduction

Bawean deer, *Axis kuhlii* (Temminck, 1836), is categorized as critically endangered (CR) on the IUCN red list (Semiadi et al. 2013), and listed in Appendix I of CITES (2009); besides, this taxon is one of the 25 priority species legally protected by Indonesian Government. This species is endemic of the 200 km^2 Bawean Island where it ranges over a very small area restricted to the Bawean Island Nature Reserve and Wildlife Sanctuary (BINR-WS), and a peninsula on the north-west side of the island (Tanjung Cina; Lachenmeir and Melisch 1996; Grubb 2005). Vulnerable to human activities, it persists only at low density; this makes the Bawean deer to be one of the rarest and the most isolated deer in the world (Semiadi et al. 2013). However, this deer received little conservation attention, mainly because it is uncommon, rarely seen and locally compete for conservation interest with more charismatic species such as Sumatran tiger *Panthera tigris sumatrae* Pocock, 1929 or Javan rhinoceros *Rhinoceros sondaicus sondaicus* Desmarest, 1822.

The Bawean Island is under conservation regimes and considered pristine but has not been adequately surveyed. The lack of long-term studies results in incomplete knowledge of the population and even the distribution of Bawean deer. However, some studies of Bawean deer documented population trends using different methods: faecal count (Blouch and Atmosoedirdjo 1978; Blouch 1980; LIPI and IPB 1999; Semiadi 2004; Semiadi and

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Pudyatmoko pers. com.; BBKSDA East Java 2009), footprints (UGM and BBKSDA East Java 2003), call counts (BBKSDA East Java 2009) and camera trap survey (UGM and BBKSDA East Java 2004). The last method, conducted within three weeks, did not show any evidence of Bawean deer.

Some other studies focused on habitat and ecology of Bawean deer (Blouch and Atmosoedirdjo 1978, 1987; Semiadi and Pudyatmoko pers. com.), using mainly indirect surveys. Direct observation of the species in its natural habitat was reported difficult, probably due to its ecology. Blouch and Atmosoedirdjo (1978, 1987) found that Bawean deer are primarily nocturnal, active intermittently through the night, very shy and typically solitary, although pairs can be sometimes recorded. Moreover, they avoid contact with humans, spending the day in forests on steep slopes which are inaccessible to loggers.

The selection of a method for monitoring mammals can influence the accuracy and comprehensiveness of research outcomes (Garden et al. 2007). Exploring the balance between positive and negative characteristics of all suitable methods in relation to specific survey constraints is crucial in order to ascertain the use of the most beneficial technique. In tropical rainforests, surveying populations of terrestrial medium- and large-sized mammals using classical sampling methods is particularly challenging (Thompson 2004; De Souza-Martins et al. 2007). Among observational techniques, transect sampling is efficient and relatively inexpensive for surveying many natural populations (Anderson et al. 1979; Burnham et al. 1980; Buckland et al. 1993; Rudran et al. 1996). In practice, this method requires some assumptions that are binding for estimating populations, the animals must be detected with certainty at their initial locations, and distance from the observer must be measured accurately (for details see Buckland et al. 1993). These assumptions are difficult to meet for species with low detection rate, either they are rare and/or elusive when they are nocturnal and live in tropical rainforest with dense vegetation (Griffiths and Van Schaik 1993; Duckworth et al. 2006). Indeed, Gopalaswamy et al. (2012) showed that visual detection was very low for ungulate species living in tropical forests where it is also difficult to capture animals. So, surveys of mammals such as deer were most often implemented by indirect methods (Mandujano and Gallina 1995; Villarreal-Espino 2006; López-Téllez et al. 2007; Koster and Hart 2008; Corona et al. 2010; Camargo-Sanabria and Mandujano 2011; Mandujano et al. 2013; Ramos-Robles et al. 2013). Identification of footprints is the oldest indirect method (Bider 1968), but it requires a strong field knowledge. Identification and count of faeces initiated by Bennett et al. (1940) is easy to use and avoids the subjectivity of the observer, in the absence of similar species (see Acevedo et al. 2010; Alves et al. 2013). However, this method becomes inaccurate when animal behaviour and variations of environmental factors influence deposit and decay of faeces.

Techniques using remote triggered photographic camera units have become popular in the last decade (Burton et al. 2015). The method is efficient for inventories, especially for cryptic and elusive animals in tropical rainforest (Tobler et al. 2008; Rovero et al. 2014), as well as for population studies of species when individuals can be individually recognized by marks, e.g. white-tailed deer *Odocoileus virginianus* Zimmermann, 1780 (Soria-Díaz and Monroy-Vilchis 2015), Indian mouse deer *Moschiola indica* (Gray, 1852) (Kumbhar et al. 2013), or not, e.g. Reeves' muntjac *Muntiacus reevesi* (Ogilby, 1839) and Chinese water deer *Hydropotes inermis* Swinhoe, 1870 (Rowcliffe et al. 2008).

Despite the variety of field techniques that can be used for surveying terrestrial mammals such as Bawean deer, the efficiency of the method could also be related to the available budget and human involvement. In addition to establishing clear objectives, wildlife research must deal with reality of budget and time frame, the trade-off among these constraints must be considered and even tested, including extending the time and resources needed to complete the assigned task (Witmer 2005).

Thus, to support monitoring and conservation tools for Bawean deer, we evaluated the efficiency of three survey methods, camera trapping, transect sampling and faecal pellet group count, both in terms of seasonal detection (1) and of financial and human costs (2). We hypothesize that camera trapping provides valuable results and present the best trade-off between cost, effort and results.

Materials and methods

Study area

The Bawean Island (Indonesia) is a quite isolated island in Java Sea (5°40’–5°50′S; 112°3′–112°36′E, Figure 1). Based on the classification of Schmidt and Ferguson (1951), climate is categorized as type C (Semiadi 2004). Rainfall is mostly abundant during the north-west monsoon lasting from the end of October until April, and reaches ca. 2.500 mm on the southern coast. Temperature conditions are almost uniform throughout the year, the average of maximum temperature is 32 °C and minimum temperature is 22 °C (Semiadi 2004).

The centre of the island is mountainous with peaks at 400 to 630 m in altitude, and is mainly covered by evergreen tropical forests (4700 ha, ca 23% of the island), including teak (*Tectona grandis*) plantations. The remaining natural forests are confined to the steep sides and top of the higher hills and mountains. Coastal low hills are separated by broad valleys, they are primarily cultivated lands. A mosaic of grassland, shrub, open and closed forest with understory are found in the study area.

Sampling design

Study sites were selected on the basis of previous results regarding the presence/absence of Bawean deer in Bawean Island (Blouch and Atmosoedirdjo 1978; Semiadi 2004; BBKSDA East Java 2009) and by conducting interviews with local people. Over 100 interviewed people, only 13% reported records of Bawean deer for 2012–2014, and 87% told that they have not seen any deer or sign for many years or that Bawean deer do not exist in the area. Most records since 2012 originated from the north-west and south-west parts of the island, in the Bawean Island Nature Reserve and Wildlife Sanctuary (BINR-WS), and in Tanjung Cina, a peninsula (ca. 950 m × 300 m) where there is no resident human population on the north-west side of the island cut off from the main island by high tide. Therefore, surveys focused on the wildlife sanctuary (ca. 3832 ha) and nature reserve (ca. 725 ha), and additionally on Tanjung Cina.

The BINR-WS area was divided into 20 4 km^2 grids using a Geographic Information System (ArcGIS 10.2.2). From March to November 2014, 20 units of Bushnell Trophy Cam HD Max digital cameras working on passive infrared motion/heat sensors were installed, one per grid. These were set at one-minute video mode with one-minute interval and one-minute video per trigger. Before installation, we collected evidence of the presence of Bawean deer throughout the grid, either footprints, faeces, food remains or antler rubbing on trees. Because our goal was to monitor Bawean deer in the whole area of BINR-WS and to obtain as many photographs as possible in each grid, camera traps were deployed in the most promising locations of each grid and when a camera did not capture any animal (zero presence) after two or three checking visits, we changed its location in the same grid. Consequently, 75 locations of camera trapping were sampled during the study.

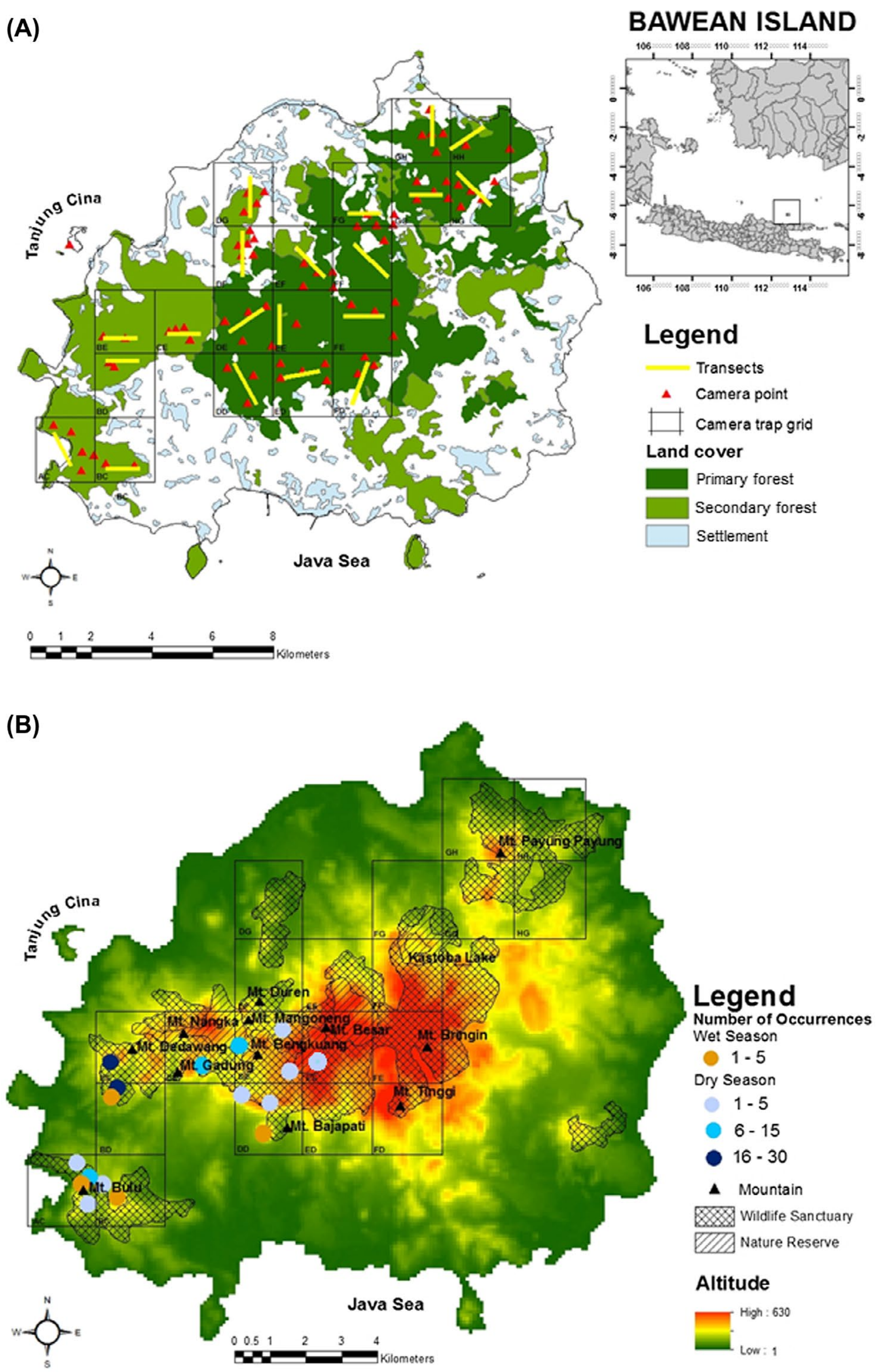

Figure 1. Camera trapping and transect sampling in the Bawean Island Nature Reserve and Wildlife Sanctuary (BINR-WS), Indonesia, (a) sampling sites within a 4 km^2 grid (n = 75) and map of forests, (b) Bawean deer presence (118 photographs for 14 camera sites) and map of altitude (up to 630 m).

To record both small and large animals, cameras were set up at 30–50 cm above the ground. Species recorded by camera trapping and transect sampling were identified using Suyanto et al. (2002) for mammals, MacKinnon et al. (1993) for birds, Iskandar (2002) for squamates and amphibians. Cameras were checked once every 21–28 days, including replacing battery and memory card, and even the camera trap in case of malfunction. To compare the efficiency with other methods, we used only data collected during the same two months in both seasons: wet 1 = February–March; wet 2 = April–May; dry 1 = June–July; dry 2 = August–September. We counted the number of exposed photographs for Bawean deer and other species. Photographs with more than one individual in the frame were counted as one for each species.

Within each grid, we also defined one transect line 1–1.5 km long (Figure 1). Each transect has been walked four or six times in April–May and June–July 2014, according to five 3-h periods: period I (morning) from 06:00 to 09:00; period II (midday) from 11:00 to 14:00; period III (evening) from 16:00 to 19:00; period IV (night) from 21:00 to 24:00 (using night-vision thermal imaging binoculars); and period V (early morning) from 02:00 to 05:00. This sampling design achieved a total of 20 transects. All wild animal sightings, tracks and signs were recorded simultaneously.

Within each grid, next to each camera trap location, we also sampled four permanent square plots (7 m × 7 m), evenly spaced 10 m, for performing faecal pellet group count according to previous studies (e.g. Acevedo et al. 2010; Alves et al. 2013). A total of 300 square plots (4 plots per location × 75 camera-traps point location) were surveyed in February-March 2014 (wet season) and August–September 2014 (dry season). We used the faecal accumulation rate by recording the monthly deposit of pellets after the initial removal of all pellets present in the plot. This method is appropriate for rapid surveys and when it is quite difficult to find a new group of faecal pellets in the field (St-Laurent and Ferron 2008; Acevedo et al. 2010; Camargo-Sanabria and Mandujano 2011).

Surveys were carried out by two people to reduce observer bias, the surveyor himself and a ranger who has been working on wildlife in protected areas of Bawean Island for more than 10 years.

Data analyses

From camera-trapping data, we computed seasonal relative abundance indices (RAIc) for Bawean deer according to Carbone et al. (2001):

$$\mathrm{RAIc} = \frac{\text{sum of all independent photographs} \times 100}{\text{total number of camera days}}$$

To reduce the bias caused by multiple detections of the same species, data were considered independent if photographs were taken more than 0.5 h apart (O'Brien et al. 2003). We also computed relative abundance indices (RAIt) per season for transect sampling data as:

$$\mathrm{RAIt} = \frac{\text{total number of sighted individuals} \times 100}{\text{number of transects} \times \text{repetitions}}$$

Faecal pellet indices were expressed following Forsyth (2005). We compared the seasonal results and methods within seasons using chi-square tests in SPSS version 20 (IBM, Armonk, NY, USA).

In addition, we evaluated the cost of each method for a 30-day survey (as this is the maximum time interval to replace memory card and batteries of camera traps) and for a 4-month survey (the duration of the study for transect sampling and faecal pellet group count). For camera trapping, we considered 7 days per month of researcher's work, 3 days to set up camera traps, 4 days to interpret photographs and compile data, and 3 days of field assistant to help setting up and checking or removing cameras. Transect sampling and faecal pellet group count required 48 days and 52 days of researcher's work, respectively, as the researcher was needed every day in the field to correctly identify the wild animals and faeces of Bawean deer, and 8 days of field assistant for both methods, to prepare transects and square plots. The cost of each method included additional fixed and variable expenses. Fixed expenses were those which did not change throughout the project, i.e. computer, global positioning system set, compass, etc. As they were identical for the three methods, they were discarded of the calculations. Variable expenses included: camera traps, batteries and memory cards for camera trapping; range finder and binocular (diurnal and night vision) for transect sampling; peg and meter roll for faecal pellet group count. Vehicle cost (rent and fuel) as well as daily allowance for researcher and field assistant were calculated on the basis of field days for each method. All costs were converted from the local currency (real) to American dollar (average exchange rate of April–July 2014: Rp 10.000 ≈ US$ 0.8).

Results

Overall, we accumulated a total of 132.000 h of camera trapping (5500 trap days), 19.200 h of transect sampling and 9.600 h of faecal pellet group count. During the whole study, we recorded 27 genera and 28 species of wild animals and humans. The identification at species level within the genus *Sus* was only possible through camera trapping.

Through camera trapping, a total of 5406 photographs were exposed (270.3 per camera trap), showing 2961 wild and 25 domestic mammals (54.77% and 0.46%, respectively), 130 humans (2.40%), 1 bird (0.02%), 9 squamates (0.17%) and 1 insect (0.02%; Table 1). A large number of photographs (42.29%) did not show any animal. Fourteen species were detected, the most frequent species was the long-tailed macaque *Macaca fascicularis* (n = 2013 photographs) and was the only species photographed at all sites. This primate was followed by wild boar *Sus scrofa* (n = 708), humans (n = 130), Bawean deer (n = 118) and Javan warty pig *Sus verrucosus* (n = 85). The other species, including feral domestic dog *Canis lupus familiaris,* were photographed less than 30 times (Figure 2), and 9 species were photographed less than 15 times. The number of photographs showing animals was lower in the wet season than in the dry season (n = 913 vs. 2199; χ^2=287.168; df = 1; $p < 0.001$). For Bawean deer, the number of photographs was also lower in the wet season (n = 6 vs. 112; χ^2=42.373; df = 1; $p < 0.001$). RAIc were 0.41 and 3.93 for the wet and dry seasons, respectively. After the initial period of installation, the number of photographs increased from the end of the wet season (April), peaked in the middle of the dry season (August) and declined later to reach low values at the beginning of the next wet season (November; Figure 3).

Through transect sampling, a total of 21 species and 721 individuals were detected: mammals (n = 261; 36.20%) and humans (n = 44; 6.10%), birds (n = 326; 45.21%), squamates (n = 12; 1.66%) and insects (n = 78; 10.81%). Animals were less detected in the wet season than in the dry season (n = 110 vs. 287; χ^2=45.038; df = 1; $p < 0.001$). Bawean deer were sighted only twice along the 108 km walked during the dry season (Table 2). On five occasions during transect sampling, we recorded vocalizations of deer; however, individuals were difficult to find because of dense vegetation.

Through faecal pellet group count, we could identify faeces belonging to long-tailed macaque, wild pigs (wild boar and Javan warty pig) and Bawean deer (Table 2). The number of deer pellet groups was not significantly higher during the dry season (χ^2 = 1.563;

Table 1. Species recorded by camera trapping in wet and dry seasons within each 4 km^2 grid of the Bawean Island Nature Reserve and Wildlife Sanctuary, Indonesia. References of grids are given in Figure 1.

Species	Grid	Number of photographs	
		Wet	Dry
Mammalia			
Primates			
Cercopithecidae			
Long-tailed macaque *Macaca fascicularis* (Raffles, 1821)	AC BC BD BE DD DF DG ED EE EF FD FE FF FG GG GH HG HH	491	1522
Hominidae			
Human *Homo sapiens*	AC BC BD DD DF DG ED EE EF FD FE FF FG GG GH HG HH	62	68
Artiodactyla			
Suidae			
Wild boar *Sus scrofa* Linnaeus, 1758	BD BE DD DF DG ED EE EF FD FE FF FG GG GH HG HH	195	513
Javan warty pig *Sus verrucosus* Müller, 1840	AC BC BD BE DD DE DG ED EF FE FD FG GG HH	38	47
Cervidae			
Bawean deer *Axis kuhlii*	AC BC BD BE CE DD DE EE	6	112
Carnivora			
Canidae			
Feral dog *Canis lupus familiaris* Linnaeus, 1758	BE DD DF DG ED EF FE FF FG GG GH HG	15	9
Viverridae			
Common palm civet *Paradoxurus hermaphroditus* Pallas, 1777	HG FD FG GG	0	7
Felidae			
Domestic cat *Felis catus* Linnaeus, 1758	HH	0	1

(*Continued*)

Table 1. (*Continued*).

Species	Grid	Number of photographs	
		Wet	Dry
Rodentia			
Muridae			
Tanezumi rat *Rattus tanezumi* Temminck, 1844	BC BD BE EF FF HG GH	7	5
Hystricidae			
Malayan porcupine *Hystrix brachyura* Linnaeus, 1758	DF	1	0
Chiroptera			
Pteropodidae			
Lesser short-nosed fruit bat *Cynopterus brachyotis* (Müller, 1838)	BC	0	2
Aves			
Accipitriformes			
Accipitridae			
Crested serpent eagle *Spilornis cheela* Latham, 1790	FF	0	1
Reptilia			
Squamata			
Varanidae			
Monitor lizard *Varanus salvator* (Laurenti, 1768)	AC DD DF FF FE	2	6
Scincidae			
East Indian brown mabuya *Eutropis multifasciata* (Kuhl, 1820)	ED	0	1
Insecta			
Lepidoptera			
Papilionidae			
Great Mormon *Papilio memnon* Linnaeus, 1758	ED	0	1

Figure 2. Main mammal species photographed by camera traps in Bawean Island Nature Reserve and Wildlife Sanctuary (BINR-WS), Indonesia. Images are sorted from left to right based on the number of photographs from the largest to the smallest (1) long-tailed macaque *Macaca fascicularis*, (2) wild boar *Sus scrofa*, (3) human *Homo sapiens*, (4) Bawean deer *Axis kuhlii*, (5) Javan warty pig *Sus verrucosus*, (6) feral dog *Canis lupus familiaris.*

df = 1; $p > 0.05$). Three locations of Bawean deer around Mt. Duren and Mt. Bajapati were only recorded by this method.

The detection of Bawean deer was significantly higher using camera trapping than faecal pellet group count during the wet season ($\chi^2 = 40.500$; df = 1; $p < 0.001$) but not during the dry season ($\chi^2 = 0.417$; df = 1; $p > 0.05$). Records of deer were too scarce with transect sampling for computing statistical analysis.

The daily costs of variable expenses estimated for a 30-day survey and the 4-month survey were, respectively, US$ 145 and US$ 52 for camera trapping, US$ 233 and US$ 165 for transect sampling and US$ 150 and US$ 143 for faecal pellet group count (Table 3). For a quite similar result, the later method is much more time-consuming both for

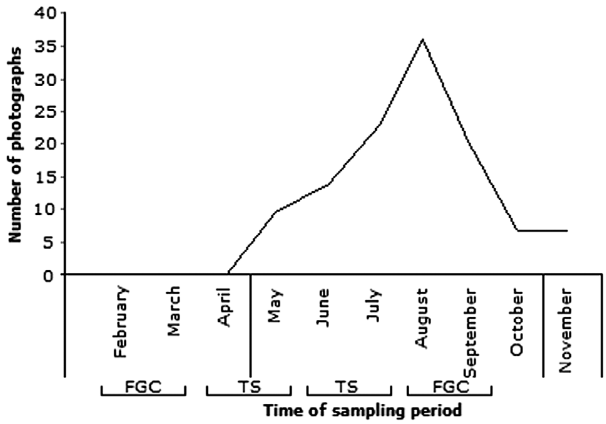

Figure 3. Monthly number of photographs taken by camera traps set for surveying Bawean deer in the Bawean Island Nature Reserve and Wildlife Sanctuary (BINR-WS), Indonesia, and sampling periods for faecal pellet group count (FGC) and transect sampling (TS).

Table 2. Relative abundance of Bawean deer in wet and dry seasons by three survey methods at Bawean Island Nature Reserve and Wildlife Sanctuary, Indonesia. RAIc and RAIt: Relative abundance index for camera trapping and transect sampling, respectively. FPI: Faecal pellet index.

	Camera trapping		Transect sampling		Faecal pellet group count	
Period of survey	Number of photographs	RAIc	Number of sightings	RAIt	Number of pellet groups	FPI
Wet 1 (February–March)	0	0	–	–	31	0.14
Wet 2 (April–May)	10	0.82	0	0	–	–
Dry 1 (June–July)	37	3.03	2	1.67	–	–
Dry 2 (August–September)	59	4.84	–	–	49	0.23

researcher and field assistant than camera trapping (52 + 32 days vs. 16 + 12 days for the 4-month survey).

Discussion

Comparative efficiency of camera trapping

Although camera traps were used for the second time in Bawean Island, we recorded the first automatic photographs of Bawean deer. In 2004, the study using camera traps by the Faculty of Forestry, University of Gadjah Mada, failed in obtaining any photographic evidence of the species (UGM and BBKSDA East Java 2004). This absence of detection of Bawean deer might result from: the smaller number of cameras, a worse camera location and a shorter duration of study. Indeed we used a double number of cameras and chose carefully their location, moving them within the same grid when they did not detect any animal after 41–61 days. Si et al. (2014) showed that moving cameras frequently gives

Table 3. Estimated costs (in US$) of variable expenses for three methods used for surveying Bawean deer in Bawean Island Nature Reserve and Wildlife Sanctuary, Indonesia, considering a 30-day survey and a 4-month survey.

Method	Item	Variable expenses unit value	30-day survey quantity	Total	4-month survey quantity	Total
Camera trapping	Camera traps	184	20	3680	20	3680
	Memory cards	4.8	20	9.6	20	9.6
	Batteries	0.35	160	56	640	224
	Vehicle rent and fuel	4.5	2 × 6	54	2 × 24	216
	Researcher's per diem	100	7 days	700	16 days	2800
	Field assistant's per diem	50	3 days	150	12 days	600
Total				*4649.6*		*7529.6*
Per-day cost				*155*		*61.7*
Transect sampling	Range finder	259	1	259	1	259
	Binocular monarch	330	1	330	1	330
	Night vision binocular scout	499	1	499	1	499
	Vehicle rent and fuel	4.5	2 × 12	108	2 × 48	432
	Researcher's per diem	100	12 days	1200	48 days	4800
	Field assistant's per diem	50	8 days	400	32 days	1600
Total				*2796*		*7920*
Per-day cost				*233*		*165*
Faecal pellet group count	Peg	0.4	300	120	300	120
	Meter roll	0.8	3	2.4	3	2.4
	Vehicle rent and fuel	4.5	2 × 13	117	2 × 52	468
	Researcher's per diem	100	13 days	1300	52 days	5200
	Field assistant's per diem	50	8 days	400	32 days	1600
Total				*1939.4*		*7390.4*
Per-day cost				*149.2*		*142.1*

more efficient detection and that camera traps should not be left at one site for more than ca. 40 days.

Moreover, we guess that in the previous study, which did target Bawean deer, some locations of camera traps were less relevant, as most of them were placed on river banks (e.g. Lampeci river and Tambelang river), even if the survey was conducted in the dry season. In our study, camera traps which were installed on river banks did not photograph any Bawean deer contrary to camera traps placed deeper into forests. Moreover, based on our results, it seems that Mt. Tinggi and Tanjung Putri do not host resident Bawean deer any longer. In addition, the sampling effort during the previous survey was only 200 camera days, whilst we accumulated 5.500 camera days. Computing a rarefaction analysis, Si et al. (2014) showed that a minimum of 931 camera days is needed to detect one resident species in a plot, and ca. 8700 camera days to detect all 10 resident species, including black muntjac *Muntiacus crinifrons* (Sclater, 1885) and Reeves' muntjac *M. reevesi* (Ogilby, 1839), at Gutianshan National Nature Reserve (China).

Camera trapping provided the most numerous and accurate records for mammals which could be identified at the species level, including cryptic and rare species, such as Bawean deer. Two studies comparing camera trapping to alternative monitoring methods reported the efficiency of this method to accurately identify species and detecting rare and nocturnal deer in tropical forest, pampas deer *Ozotoceros bezoarticus* (Silveira et al. 2003) and brocket deer *Mazama* sp. (Lyra-Jorge et al. 2008). The ability to collect data on rare or secretive species that are generally difficult to observe directly can lead to great improvements in understanding community composition (Azlan and Lading 2006). Time recording permits to assess the presence of different individuals of the same species along the day (Lyra-Jorge et al. 2008) and their reproductive status, mainly when a doe is mare with her fawn (Srbek-Araújo and Chiarello 2005). This information is particularly relevant for studies of population dynamics, e.g. for estimating the size and trend of a population. Transect sampling or faecal pellet group count does not allow such a differentiation particularly in dense vegetation (Staines and Ratcliffe 1987). However, for most tropical mammals, including Bawean deer, absence of physical characteristics makes it not possible to identify individuals with confidence. Relying on scars or blemishes on the body should be risky because these signs disappear after some time (Kelly et al. 2008). At last, a major advantage of camera trapping is the long duration of field work in the absence of researcher as cameras can be left for several days and weeks; moreover, any trained person is able to renew memory card and battery, and ensure that the camera trap is still operational.

On the contrary, transect sampling, which requires a heavy field work, relies on the surveyor competence for identifying species from signs and for surely estimating animal–observer distances through dense vegetation (Walsh and White 1999). Then, there could be an observer bias if data are collected by inexperienced or inadequately trained people (Azlan and Sharma 2006; Rovero et al. 2006). Following a precise path can make surveying problematic in difficult terrain, such as in many areas of BINR-WS, and clearing a pathway through dense vegetation could be a hard work and come out detrimental for data collection (Walsh and White 1999). Transect sampling efficiency also depends on weather conditions since a strong rain or wind and hot temperature condition can disturb observation or cause animals to be inactive (Stelzner 1988). Bias is not just dependent on training of researchers and favourable field conditions, but also on the diurnal activity pattern and body size of species (Roberts 2011). At last, transects can be problematic for monitoring rare species, as poor encounter rates can lead to sample sizes not large enough for data analysis (Bennun and Howell 2002). This was the case in our study as we only detected Bawean deer twice in the dry season.

Faecal pellet group count could detect the presence of only some species in Bawean Island. This result can be explained by the species rarity, their small size or the defecating behaviour of animals, inside water, buried faeces in small holes or on branches of trees (Chame 2003; Mohapatra and Panda 2014). Faecal pellet group count is probably the most limiting of the three methods. It is dependent on field conditions at sampling plots, substrate and vegetation type, and on climate that induces a great variability in faecal decay rate (Laing et al. 2003; Skarin 2007). Faecal pellet group count has been much studied in temperate areas where the technique works well in cold climates with snowy winters (Decalesta 2013); frozen pellet groups deteriorate less quickly than in warm and/or rainy climates (Tsaparis et al. 2009). One problem with faecal pellet group count in tropical forest is the accelerated decay of faeces during the wet season as a result of high rainfall levels and breakdown of pellet groups by insects and bacteria which biases the 'standing crop procedure'. Very dry conditions during the aptly called dry season may lead to a better preservation of pellet (Jachmann and Bell 1979, 1984). Pellet group counts during the dry season would give a better estimate of animal number in the area. Moreover, our results showed that this technique can be additional to camera trapping as it recorded Bawean deer in three locations where no photograph was taken.

Limitations of camera trapping

Setting cameras for a long time at the same location can induce trap-shyness behaviour, as animals may be disturbed by the flashing lights (Meek et al. 2014). In our study, detection of Bawean deer increased from the installation of cameras until ca. 6 months when animals are supposed to increasingly avoid the areas covered by cameras. The subsequent decrease at the end of the study period could be related to the new wet season.

Camera traps are equipped with active and passive infrared detection, and detect heat or movement for taking photographs. So their performance reduces during hot days, when the air temperature becomes close to the animal body temperature or can be triggered by shaken or falling leaves and rain (Swann et al. 2011), which is an important issue in the tropics. This is a reason for higher detection at night, when the air temperature is fresher than the animal body (Srbek-Araújo and Chiarello 2005). In addition, Bawean deer was more photographed and recorded by faecal pellet group count during the dry than the wet season. Rowcliffe et al. (2011) found that the effective detection distance of tropical mammals by camera traps decreases from the dry to the end of the wet season, whereas the effect of season on effective detection angle was in the opposite direction.

Two cameras have been stolen, probably by poachers who did not want to get their images recorded. The risk of camera theft is typically higher when cameras are set up near settlements or along logging roads and ridgelines. In most cases, an explanatory notice attached to each camera can alleviate theft, together with delivering information in local villages and at police officers. A padlock on the camera can also help, but ultimately if someone wants to remove the camera he will almost find a way to do so. In our case, to reduce the likelihood of theft, we set cameras far from settlements or in areas more cluttered by vegetation. In any camera-trapping surveys, it is mandatory to account for potential losses by having some additional cameras for securing the sampling design and obtaining good results (Meek et al. 2012).

Budget comparison

The cost of camera trapping is initially high, but this method automatically works during 24 h per day without interruption and cameras can be set for a long time and/or reused in other projects. In a medium-term project, the daily cost decreases with time because travel and human expenses are low. On the other hand, transect sampling and faecal pellet group count require daily field visits. For a 30-day survey, the daily cost is similar for camera trapping and the two other methods. For a 122-day survey, the daily cost is much more in favour of camera trapping with only US$ 62 per day vs. US$ 165–143 for transect sampling and faecal pellet group count, respectively. Most researchers who evaluate costs and benefits of mammal recording methods agree that more expensive methods, if more accurate, are the best for long-term studies and/or when different research groups share field equipment, and that the combination of two or more methods always result in better quality data, especially when surveying rare or secretive species (Barea-Azeón et al. 2007; Scheibe et al. 2008).

We believe, that in BINR-WS, camera trapping can provide reliable and standardized tools for the management of various mammal species, including Bawean deer. In this study, we successfully obtained the first automatic photographs of this rare, shy and elusive species which avoids contact with humans as it is supported by the absence of sighting during thousands of hours of fieldwork in BINR-WS. Moreover, camera-trapping data would be used to investigate habitat use, daily activity pattern of deer and possibly population trend with an accuracy that was not possible with previous techniques, particularly in tropical rainforest. Such knowledge is crucial for designing sound management strategies for the conservation of this species.

Disclosure statement

No potential conflict of interest was reported by the authors.

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