The application of camera traps to the study of Galliformes in southern Sumatra, Indonesia

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ABSTRACT

Many forest Galliformes are secretive and difficult to survey, so we assessed the potential use of camera traps in the study galliform species at Bukit Barisan Selatan National Park, Lampung, Indonesia. We used CAM-TRACKER© camera trap data from one intensively surveyed study area and 10 sample plots located throughout the park. Camera traps were able to detect five species of pheasants and one partridge. The Sumatran peacock pheasant *Polyplectron chalcurum* and Salvadori's pheasant *Lophura inornata* were restricted to forests with open understorey at higher elevations in the park, whereas great argus pheasants *Argusianus argus* were widespread in lowland areas having streams, open understorey and low human disturbance. In the study area, using great argus pheasant as an example, 29% of the deployed cameras were able to detect the species. The analysis program CAPTURE was used to fit various models including M_h; the detection probability was then estimated. In addition, the data also demonstrated that great argus pheasant reached the peak of activity at approximately one hour after sunrise. The application of camera traps seems promising for the study of several aspects of the biology of elusive Galliformes.

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INTRODUCTION

The estimation of abundance is fundamental to conservation efforts for most species and a large number of techniques for quantifying abundance have been developed to contend with a large diversity of habitats and species behaviour (Carroll & Conroy, 2001). However, there are still many limitations to population estimation, particularly when dealing with secretive species. Most methods require that a species be detectable by capture, by visual observation or by calls. In the dense understorey vegetation of tropical rainforests, galliform species may be less easy to detect due to the limited visibility, their secretive and cryptic behaviour and they use calls that are sometimes difficult to locate.

Methods such as line transects and point counts are required to meet several assumptions; (a) animals on transect lines or points are always detected; (b) animals are detected at their initial location; and (c) distances are estimated correctly (Burnham *et al.*, 1980; Buckland *et al.*, 1993). Meeting these assumptions can be critical especially when it comes to detectability. Species behaviour and habitat type have a strong influence on detection

(Bibby *et al*., 2000). Variations between observers may also influence detectability (Cunningham *et al*., 1999). Acuity, which includes visual and auditory, as well as alertness, experience, and knowledge of birds might have some influence on biasing the detection (Verner, 1985). Anderson *et al*. (1979) suggested that line transect sampling is well suited to ring-necked pheasant *Phasianus colchicus* and sage grouse *Centrocercus urophasianus* because these species inhabit open areas where flushing is feasible. However, the methods should be modified when applied to great argus pheasant and other rainforest pheasant due to the dense habitat type which lower detection probability (Winarni 2002).

Recently, biologists have made progress in censusing secretive animals by using camera trap sampling to monitor the populations of large mammals (Karanth 1995). Camera traps has been used to monitor levels of wildlife and human traffic in Sumatran rainforests (Griffiths & van Schaik, 1993), estimate tiger abundance in India (Karanth & Nichols, 1998) and Indonesia (O'Brien *et al*., 2003), evaluate the impact of deforestation on large mammals (Kinnaird *et al*., 2003) and monitor corridor use by predators in California (Hilty & Merelender, 2004). In 1999, the Wildlife Conservation Society-Indonesia Program began a program of assessing the abundance of Sumatran tiger *Panthera tigris sumatranus* in Bukit Barisan National Park. As a by product, their results demonstrated that camera traps may be a useful tool to obtain abundance data on tiger prey, including mousedeer *Tragulus* spp., wild pigs *Sus* spp., macaques *Macaca* spp., and also great argus pheasant (O'Brien *et al.,* 2003). Kinnaird *et al.* (2003) combined camera trap data with GIS to assess the core area for key large mammal species and the implications of deforestation. Despite the growth in the use of camera traps in mammal study, none has been attempted for pheasants.

In this paper, we assess the application of camera trap sampling to detect pheasants, to estimate their relative abundance using the great argus pheasant as a study case, and to determine habitat preference of pheasants in Bukit Barisan Selatan National Park, Sumatra, Indonesia.

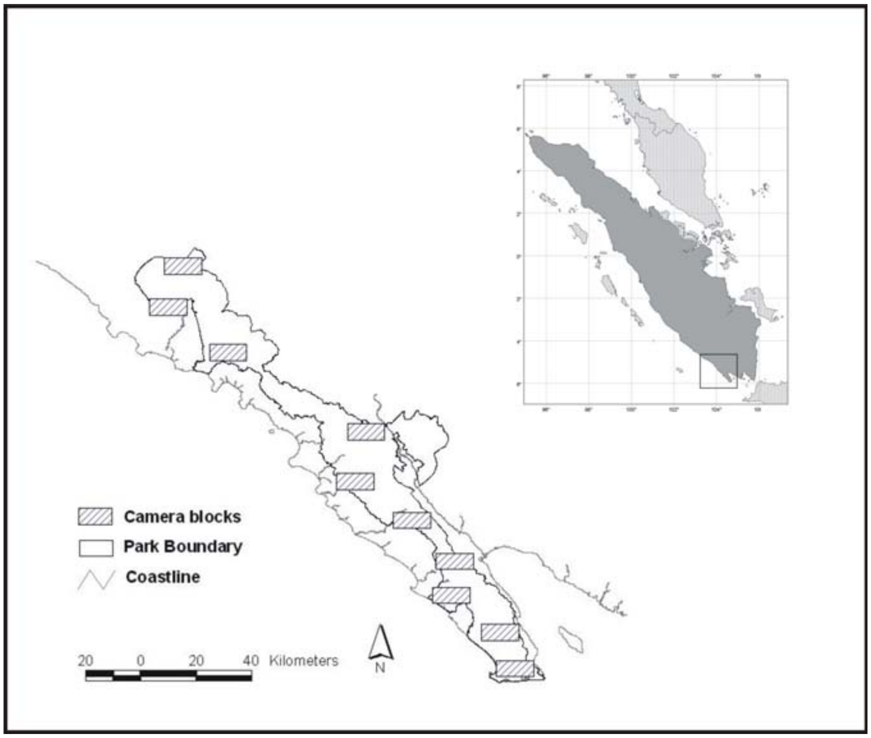
METHODS AND STUDY AREA

Study area

This research was conducted throughout the Bukit Barisan Selatan National Park (BBSNP), Sumatra during 1999-2003 and at Way Canguk Research Station in Southern area of BBSNP. The park is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien & Kinnaird, 1996). BBSNP contains some of the largest tracts of lowland rain forest remaining in Sumatra and functions as the primary watershed for southwest Sumatra (O'Brien & Kinnaird, 1996; Kinnaird *et al*., 2003).

The Way Canguk Research Station (5°39'S, 104°24'E), is located in the south western part of the park (Figure 1). The station is located in lowland forest and has a high diversity of wildlife including a number of endangered mammals, such as Sumatran tiger *Panthera tigris sumatranus*, Sumatran elephant *Elephas maximus*, Sumatran rhino *Dicerorhinus sumatrensis*, and 187 species of birds including three species of Phasianidae (Winarni, 1999). The study area encompassed a 900 ha forest within a larger forest matrix with a grid of trails at 200 m intervals. The study area is bisected by the Canguk River and the two sections are referred to as North and South sides. The North and South sides contains six 2 km and 12 2.2 km transects. The study area contains a mosaic of lowland habitat types, including primary forest (50%), lightly disturbed forest (27%), and previously burned forest (23%). The latter category resulted from fires during 1992-93 and during a drought in 1997 (O'Brien *et al.*, 1998; Kinnaird & O'Brien, 1998).

Figure 1. Camera trapping blocks within Bukit Barisan Selatan National Park, Sumatra.



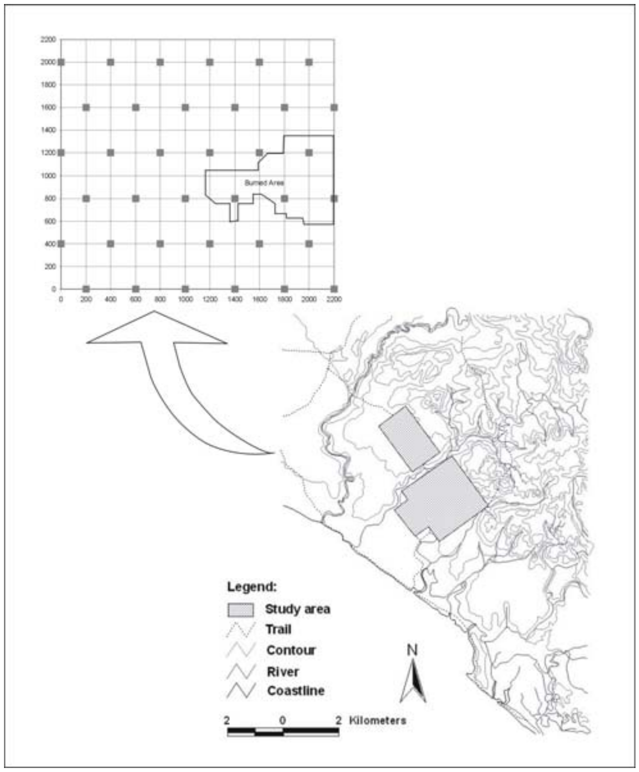
Camera Trapping

Camera trapping data were provided by the Sumatran Tiger Conservation Project of the Wildlife Conservation Society-Indonesia Program. We selected 10 sampling blocks at approximately 10 km intervals throughout the length of the park. Cameras were dispersed in 20 km^2 sampling blocks. Blocks were oriented from the edge of the park boundary towards the centre; within each block we assigned at random one camera per km^2 based on UTM coordinates. We used passive infrared camera traps (CamTrack South Inc., Watkinsville, GA 30677) that were set on animal trails. Camera traps were set to record 24 h per day and were deployed for approximately 30 days per block. Motion sensors triggered the cameras and photos were imprinted with date and time of exposure. During 1998-2003 we conducted three to four sampling periods in each block.

We identified each photographed animal to species, recorded time and date of the photograph, and rated each image as a dependent or independent event. We defined independent events as; (a) consecutive photographs of different individuals of the same or different species; (b) consecutive photographs of individuals of the same species taken more than 0.5 h apart; and (c) non-consecutive photos of individuals of the same species (O'Brien *et al*., 2003). Then, relative abundance indices were calculated using the independent event of pictures per 100 trap days. Data collected from across the park were used to examine the distribution, the abundance and habitat preference of pheasant species.

In addition, cameras were also placed in the southern study area of Way Canguk Research Station. Cameras were assigned at a density of one camera per 16 ha throughout the study area resulting in each transect trail being assigned three cameras (Figure 2). Cameras were placed on locations assumed to be animal trails and were mounted on a tree at approximately 0.6 m above the ground. Three different periods of sampling were conducted during 1999–2000, with intervals of approximately six months between each sample.

Figure 2. Distribution of camera traps (indicated by squares) throughout the Way Canguk South Study Area, BBSNP, Sumatra, Indonesia.



Great argus pheasant data from the camera trapping at Way Canguk was used to assess camera trapping performance and the species' activity period. The program CAPTURE was used to estimate camera trap capture probability among the three sampling periods. Due to the limitations in distinguishing great argus pheasant as individual, capture history (Otis *et al.*, 1978; White *et al*., 1982) was based on whether the camera trap detected any great argus pheasant. Program CAPTURE (Otis *et al.*, 1978; White *et al*., 1982) offers several estimators to model the capture probability; Model M_0 for constant capture probability, Model M_b allows variation in behavioural response of the animal captured, and M_t permits time heterogeneity. In addition, CAPTURE also offers estimators that include two sources of variation in capture probability, M_{bh} (behaviour and time), M_{th} (time and heterogeneity), and M_{tb} (time and behaviour).

Line transect sampling on great argus pheasant using 100 m fixed width was also conducted in Way Canguk. Each month, a pair of observers walked at 2.2 km transect in the morning between 0630 and 0930 h and recorded visual and auditory encounters of great argus pheasant. Observers recorded the number of animals, sighting distance, and sighting angle. Only line transect data from the south side were used in this analysis.

The detection rate of observations using encounters on line-transect and captures in camera trap were calculated for each transect. To test the relationship between the line-transect detection rate and camera trap detection rate, linear regression was used. To assess the relationship of relative abundance generated from camera traps and density estimates from line-transects, data were pooled for each transect for three-month periods that were centred on the month of camera trapping. Post-stratification estimation in DISTANCE 4 was used to calculate the density for each transect, and linear regression to determine the relationship.

Habitat structure

At each camera locations, a circular plot of 10 m radius was established around the camera. Data was collected within each plot on vegetation structure, such as, canopy cover, understorey density, presence of streams, number of trees and diameter of trees with diameter at breast height (DBH) $\geq$ 10 cm. Data was also collected on human disturbance by counting the number of cut trees, natural disturbance, and the presence-absence of wild ginger, lianas, bamboos, and herbs.

Salvadori's pheasant, crested fireback, and great argus pheasant habitat preference was investigated using forward-step binary logistic regressions based on presence-absence data of these species (SPSS Inc., 1999). Other species were not analysed due to low sample sizes.

RESULTS

Park-wide distribution and abundance

From the camera trap surveys six species of Galliformes were recorded during 1998-2003, great argus pheasant *Argusianus argus*, Sumatran peacock-pheasant *Polyplectron chalcurum*, Salvadori's pheasant *Lophura inornata*, crested fireback *Lophura ignita*, red junglefowl *Gallus gallus* and crested partridge *Rollulus rouloul*. Four species were recorded in the Northern block (Sumatran peacock-pheasant, salvadori's pheasant, crested partridge, great argus pheasant), four species in the Middle block (salvadori's pheasant, crested partridge, great argus pheasant, crested fireback) and two species in the Southern block (great argus pheasant, red junglefowl). Great argus pheasant occurred in all blocks, but was never recorded at sites with Sumatran peacock-pheasant (Table 1).

Table 1. Galliformes captured by camera traps in Bukit Barisan Selatan National Park, Indonesia, 1998-2003.

Species	Number of photographs	Number of independent events	Number of locations
Crested partridge	5	5	5
Crested fireback	1	1	1
Great argus pheasant	496	466	11
Red junglefowl	3	3	2
Salvadori's pheasant	16	12	2
Sumatran peacock-pheasant	6	5	1

Based on the data collected during 1999-2003, the relative abundance of great argus pheasant was highest in the Middle block and lowest in the North block (Table 2). Relative abundance decreased over time within all sections, although it was more stable between 2002-2003 in the southern section (Table 2).

Other galliform species were less abundant and were not recorded by all camera traps. Crested partridge was captured in the North and Middle of the park. The camera traps captured only one independent event of a crested fireback. Red junglefowl was found only in the South of the park. Salvadori's pheasant was captured in the North and Middle, and Sumatran peacock-pheasant was found only in the North (Table 2).

Table 2. Relative abundance of Galliformes captured by camera traps in the North, Middle and South sections of Bukit Barisan Selatan National Park, Indonesia 1999-2003. The values represent the number of independent events per 100 trap-days. NS = no survey.

Species	North				Middle				South			
	99/00	01	02	03	99/00	01	02	03	99/00	01	02	03
Crested partridge	0.20	NS	-	-	0.09	0.04	-	0.05	-	-	-	-
Crested fireback	-	NS	-	-	0.03	-	-	-	-	-	-	-
Great argus pheasant	1.20	NS	0.79	0.19	3.84	2.85	1.81	1.11	2.05	1.70	0.62	0.62
Red junglefowl	-	NS	-	-	-	-	-	-	-	0.15	-	0.05
Salvadori's pheasant	0.26	NS	0.09	0.26	0.09	0.12	-	0.05	-	-	-	-
Sumatran peacock-pheasant	0.33	NS	-	0.09	-	-	-	-	-	-	-	-

Habitat preference

Sumatran peacock-pheasant was restricted to higher elevations sites (χ^2_1 = 14.56, p = 0.005) and was associated with open understorey (χ^2_2 = 19.40, p < 0.001; Table 3). The model correctly classified 98.8% of both data. The occurrence of Salvadori's pheasant was significantly associated with higher elevations (χ^2_1 = 16.11, p < 0.001), but less sensitive to understorey conditions (Table 3). Logistic regression correctly predicted 97.9% of Salvadori's pheasant observations. The occurrence of great argus pheasants was significantly associated with the presence of streams (χ^2_1 = 7.42, p = 0.006), low levels of human disturbance (χ^2_4 = 17.01, p = 0.002), open understorey (χ^2_5 = 23.35, p < 0.001), few rattans (χ^2_7 = 39.10, p < 0.001), and few palms (χ^2_8 = 43.31, p < 0.001). The model correctly classified 81.1% of the great argus pheasant data.

Table 3. Habitat variables (mean ± s.d.) associated with salvadori's pheasant, great argus pheasant, and Sumatran peacock- pheasant recorded at camera-trap location.

Habitat structure	Salvadori's pheasant	Great argus pheasant	Sumatran peacock-pheasant
Altitude (m)	952.44 ± 229.51	409.34 ± 224.97	1079.80 ± 213.31
Human disturbance (counts)	0.89 ± 0.33	0.60 ± 0.54	0.20 ± 0.45
Presence of stream (counts)	0.56 ± 0.53	0.70 ± 0.46	0.20 ± 0.45
Number of trees (counts)	16.50 ± 7.84	16.67 ± 8.04	20.70 ± 7.80
Under-storey (counts)	5.25 ± 3.09	5.91 ± 3.05	3.95 ± 3.01
Presence of liana (counts)	1.00	1.00	1.00
Presence of bamboo (counts)	0.11 ± 0.33	0.06 ± 0.24	0.00
Presence of rattan (counts)	1.00	0.98 ± 0.16	0.80 ± 0.45
Presence of palm (counts)	0.67 ± 0.50	0.27 ± 0.45	0.40 ± 0.55
Wild ginger (counts)	0.89 ± 0.33	0.79 ± 0.41	1.00
Average DBH of trees (m)	24.80 ± 8.02	25.01 ± 6.83	26.16 ± 6.86

Camera trap performance in Way Canguk

Camera trapping detected great argus pheasants at an average of 29% of the trap locations during three sampling periods (Table 3). Great argus pheasant were not detected on the day the camera was set, but first detection was most often <10 days after setting the camera (Table 4). First capture was significantly different ($F = 13.23$, $p = 0.006$) with a Duncan post-hoc test showing that the first stage (1-10 days) was significantly different to the second (11-20 days) and third (21-30) stage of camera deployment.

Table 4. Great argus pheasant capture rate, from cameras set during three different sampling periods and during the days following the initial setting of the camera, in Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia, 1999 & 2000.

Sample	Date deployed	Number of cameras	% detection of cameras	Time of first capture (days)			
				0	1-10	11-20	21-30
1	Apr-May 99	39	23.08%	0	5	1	2
2	Sep-Oct 99	35	28.57%	0	6	3	1
3	Jun-Jul 00	32	34.38%	0	7	0	3

Analyses of capture histories based on the detectability of camera traps, identified M_h (heterogeneity between each detection) as the most appropriate model (Model value = 0.62). Although the analysis identified M_0 (constant capture probability), M_{th} (time-heterogeneity), and M_{tbh} (time-behavior-heterogeneity) as appropriate model, M_0 was not considered robust to violation of the assumption that there is no variation in capture probability. The other models, M_{th} and M_{tbh} are rarely used since there are no estimators associated with these models (*Otis et al*., 1978). Under the M_h model, capture probability was quite high (average $\hat{p} = 0.7037$). In this case, heterogeneity of individuals should be considered as variations in detection at each location, since capture histories were based on detection of great argus pheasant, not on the individual itself.

Relative abundance and density estimate of great argus pheasant in each transect at Way Canguk are given in Table 5. Numbers of great argus pheasant detected by camera traps showed a positive relationship with detection rate from line-transect surveys ($R^2 = 0.09$, $F_{1, 34} = 3.24$, $p = 0.08$; Figure 3). In addition, relative abundance (RAI) of great argus pheasant generated by camera traps showed a significant relationship with estimated density of great argus pheasant generated by line-transects ($R^2 = 0.53$, $F_{34} = 38.28$, $p < 0.001$; Figure 4).

Table 5. Relative abundance (independent events per 100 trap-days) for camera traps and density estimates (individual per km^2) from line transect surveys of great argus pheasant at Way Canguk, Indonesia.

Transect	Camera	Line transect	Camera	Line transect	Camera	Line transect
A	1.00	0.01	4.23	0.03	2.54	0.06
C	2.00	0.07	0.85	0.04	10.18	1.00
E	4.00	0.03	1.69	0.01	5.09	0.02
G	2.00	0.01	2.54	0.05	5.09	0.06
I	2.00	0.01	1.69	0.03	1.67	0.04
K	0.33	0.08	1.69	0.03	2.54	0.09
M	1.00	0.00	3.39	0.02	2.54	0.20
O	0.00	0.00	0.85	0.00	5.67	0.00
Q	1.00	0.00	3.81	0.09	0.00	0.00
S	0.00	0.00	2.54	0.00	0.00	0.00
U	0.00	0.00	1.69	0.00	0.00	0.00
W	0.00	0.00	2.54	0.00	0.00	0.00

Figure 3. The relationship between the detection rate of great argus pheasant recorded by camera traps and line-transects (y = 0.2502x - 0.0111).

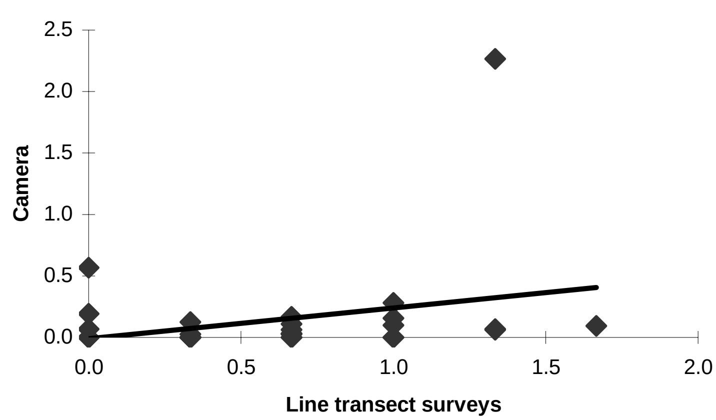
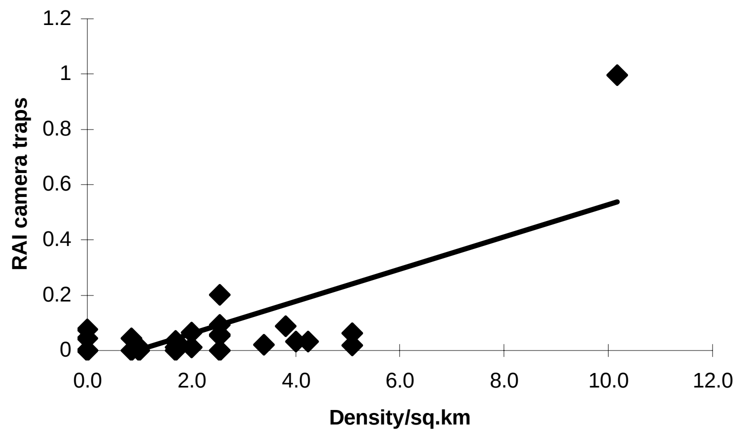


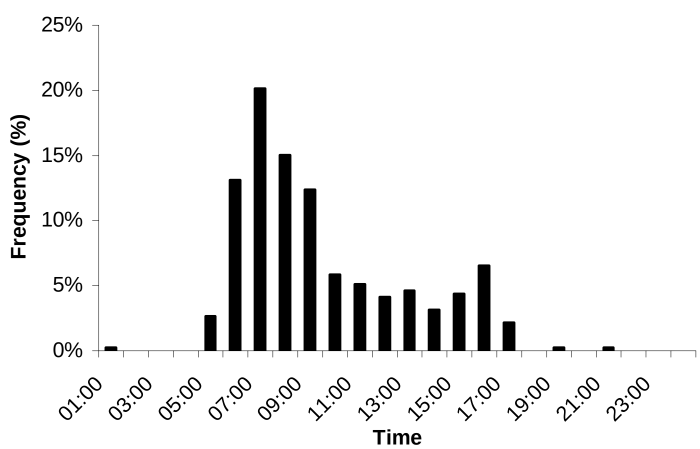
Figure 4. The relationship between Relative Abundance Indices (RAI) of great argus pheasant from camera traps and estimated density from line transect surveys at Way Canguk, Indonesia (y = 0.0581x - 0.055).



Activity Period

The majority of great argus pheasant camera trap photos were taken about one hour after sunrise and declined gradually during the day. However, there was a slight increase in activity at approximately two hours before sunset (Figure 5). Approximately 83.50% of the independent events were obtained during daylight hours (0600-1800) with the rest (16.50%) being obtained after daylight. The camera data suggest that great argus pheasant are strictly diurnal.

Figure 5. Distribution of great argus pheasant photographs captured throughout the day at Bukit Barisan Selatan National Park, Sumatra 1999-2000. Sunrise is approximately 0600h and sunset approximately 1800h.



DISCUSSION

The results from this study suggest that camera traps can be used to measure Galliformes, both spatially and temporally. Comparisons between line transects and point count from the same area (Winarni *et al*., 2004) showed that line transects accounted for one species compared to camera traps, indicating that conventional methods may not generate the same detectability as camera traps. Salvadori's pheasant and crested fireback was only sighted using camera traps. Comparisons of great argus pheasant using line transect sampling revealed that auditory detection was increased as the bird move farther from the line, suggesting that at some closer distances the bird seemed able to detect the observers and, thus, tried to be less conspicuous (Winarni, 2002).

Camera traps can also be used to measure and estimate the distribution and relative abundance of many species that are not easy to observe in dense forests (Karanth & Kumar, 2002). The abundance indices derived from our camera trapping data provide information on the distribution and the abundance of different galliform species throughout the park. Bukit Barisan Selatan elevation ranges from sea level in the south to 1,800 m in the north. Great argus pheasant was common in most of the camera locations except in for one independent event in Pulau Beringin where elevation ranged between 500 and 1,300 m.

The combination of camera trap data and habitat structure information provides information on factors affecting species occurrence. Our results suggest that both Sumatran peacock-pheasant and Salvadori's pheasant are more related to elevation, whereas great argus pheasant is more related to the presence of streams, low levels of human disturbance, and more open understorey vegetation. However, refinements of methods by collecting microhabitat variables may probably depict a better bird-habitat relationship.

Analysis of our results using program CAPTURE suggests that behavioural responses did not influence the capture probability. The identification of M_h as the best model suggested that camera traps allow heterogeneity in the detection. Heterogeneity is influenced by sex and age and by accessibility to camera relative to individual home ranges (Otis *et al*., 1978; White *et al*., 1982). Since capture histories were not based on the individual itself, individuals detected by a camera might not be the same individual detected later. Although the chance of detecting the same individual is high, particularly on an area within adult male home ranges, there are always possibilities to detect females or sub-adult males wandering the area.

To generate population estimate, numbers of individuals detected must represent a constant proportion of actual numbers present across time and space (Thompson, 2002). Tropical rainforest contains dense vegetation which limits the sighting range of observers (Griffiths & van Schaik, 1993). When using methods that rely on auditory encounters, such as point counts, detectability of a species is also reduced by the limiting ability of observer in identifying birds through calls. Other factors that may influence the detectability may vary according to time of survey, weather, bird activity and their susceptibility to being counted (Bibby *et al*., 2000). By using camera traps, these limitations may be reduced since camera trap have an advantage over many constraints. There are no requirements of human presence when using camera traps (Griffiths & van Schaik 1993). By deploying for 24 h for approximately 30 days, weather and time of survey can be controlled.

However, to use camera traps data to generate transect level population estimate in a capture-recapture framework would need clear identification of individuals. The best thing we can get from camera trapping data of un-uniquely marked individuals is to calculate the index of density (Karanth & Nichols, 2002). The development of techniques such as double sampling allow us to use both more intensive and less intensive methods to estimate abundance of a species (Conroy & Carroll 2000). Although it is difficult to distinguish individual pheasant without marking birds, it might be possible to use double sampling techniques to estimate populations of great argus pheasant in areas where camera trapping is used (Winarni, 2002). Double sampling has also been used to estimate population of tiger prey species (O'Brien *et al*., 2003) and this research revealed that camera traps can be used to generate the relationship between indices based on camera traps and intensive techniques such as line transects.

Camera trap are beneficial in that they detect great argus pheasant beyond periods of peak activity, whereas conventional method like line transect surveys only detect birds during the period of survey. Great argus pheasants were photographed more frequently during daylight hours than after dark. Although great argus pheasants often performed calls during nights (N. Winarni, pers. obs.), it is confirmed that great argus pheasant are strictly diurnal. Radio telemetry data also suggested that great argus pheasants was mostly active in the morning (N. Winarni, unpub. data).

So far, there is no literature suggesting that camera traps have been utilised in any detailed galliform studies. Galliformes are distinctive for their secretive habit and some species are less conspicuous in calling (Bibby *et al*., 2000). Hence, camera traps showed potential use for the future galliform studies. The use of camera traps in BBSNP has proved that this method can provide information on rare animals such as tigers and their prey (O'Brien & Kinnaird, 2003) and this research suggested that camera traps may detect more species than direct observation. The camera trap data also showed occurrence of other galliform species such as crested partridge *Rollulus rouloul* and Sumatran peacock-pheasant *Polyplectron chalcurum*. While providing information on presence and absence, relative abundances of rare and secretive species also were revealed as well as other baseline ecological information. Hence, application of camera traps to study Southeast-Asian pheasants having similar habitat affinities is promising.

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