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Spatial distribution of display sites of Grey Peacock-pheasant in relation to micro-habitat and predators during the breeding season

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Abstract

Background: The destruction and fragmentation of forest in Southeast Asia is accelerating biodiversity loss, resulting in a range of management and conservation actions. For some species, a detailed understanding of microhabitat selection is critical for this, especially in the breeding season.

Methods: To understand the factors that explain how specific habitats are used by the Grey Peacock-pheasant (*Polyplectron bicalcaratum*) in the breeding season, we used camera trapping and microhabitat sampling to assess the microhabitat selection of males. We also looked at their interaction with predators in an area of 1200 m × 1200 m at the Huai Kha Khaeng Wildlife Sanctuary, Thailand, between January and May 2013.

Results: We show that display scrapes are situated on flatter open areas with small saplings and some vines, typified by low horizontal understory density. We hypothesise that this allows a trade-off between courtship display and the avoidance of predators. Our study showed that the position of Grey Peacock-pheasant display scrapes regularly overlapped with predators within the same microhabitat. We hypothesise that the species' behavioural responses to temporal variation in predation risk allows them to avoid most predators.

Conclusions: Particular microhabitats are required for Grey Peacock-pheasant display. They avoid predators at these places by being active when predators are not.

Keywords: Huai Kha Khaeng Wildlife Sanctuary, Display scrape, Species accumulation, Predator-prey, *Polyplectron bicalcaratum*

Background

Tropical rainforest cover in Southeast Asia decreased by an estimated 14.5% between 1995 and 2010 (Miettinen et al. 2011) with rates of loss predicted to continue at ca. 1% per year (Laurance 1999; Achard et al. 2002). This massive and rapid habitat change is having serious effects on the richness and abundance of forest-dependent taxa (Sodhi et al. 2010; Gillespie et al. 2015). We know little

about the ecological or behavioural impacts on many species however, because basic ecological knowledge about many species in the region is seriously lacking. For example, little is known about the processes that shape spatial distribution of courtship display sites of individuals within Southeast Asian forest. Although it has been suggested that ecological resources and conspecifics play crucial roles in shaping male and female display distribution (Brown and Orians 1970), information on spatial patterns remains scarce for many animal groups and, therefore, understanding what might drive observed display site distribution in degrading habitat is far from clear.

Solitary breeding males of some bird species display at or around fixed points during the breeding period and this makes them conspicuous and, therefore, more

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detectable, than is the case with other species. This includes species in this region such as the Malaysian Peacock-pheasant (*Polyplectron malacense*) (McGowan 1994) and Great Argus (*Argusianus argus*) (Davison 1981).

Knowledge of spatial patterns and the factors driving them remain incomplete and there appears to have been little research in this area over the last two decades. The development of technological and analytical approaches now provides the opportunity to both gather new data and to obtain greater ecological insights from those data. For example, knowledge of the identities of other species that occur at such fixed display areas allows more robust assessment of animal communities and thus is important in understanding ecological patterns in an area (Nichols et al. 1998). Documenting the occurrence of predators and understanding predation risk for conspicuous displaying males would be a significant step towards this.

Information on the spatial distribution of male display sites and its drivers may well have importance in ensuring that predictions of consequences for species of anthropogenic change are more realistic than would otherwise be the case (Fletcher et al. 2012). At a time when loss and disruption of habitat is increasing, and particular species are targeted for hunting, this information could be very timely in allowing us to understand the wider consequences of such change. For example, loss of specific microhabitats may prevent males from exhibiting appropriate display behaviour, e.g. the Black Grouse (*Lyrurus tetrix*) (Patthey et al. 2012) and the Lesser Prairie-chicken (*Tympanuchus pallidicinctus*) (Larsson et al. 2013). Furthermore, knowledge of the relationship between microhabitat use and predation risk may allow insights into variation in survival (DeCesare et al. 2014).

The Grey Peacock-pheasant is a sedentary and loud calling ground-dwelling bird that inhabits dense forest over hilly terrain (Johnsgard 1999). Males create and maintain a particular area for display and courtship behaviour, similar to that described for the Great Argus (Davison 1981) and the Malaysian Peacock-pheasant (Davison 1983a). These display scrapes are small patches of the forest floor from which all fallen leaves and vegetation are removed, so that bare earth is exposed. Males are thought to call mainly from these display scrapes during the breeding season (Baker 1930) and calls have been interpreted as a challenge call to other males and an attraction call to females (Johnsgard 1999). Grey Peacock-pheasant's global conservation status is Least Concern (IUCN 2017), although Grey Peacock-pheasant's population trend is decreasing (IUCN 2017), recent analysis of their available habitat is only 16% (Savini T unpublished data) of that reported by IUCN Red List of Threatened Species (IUCN 2017), and also in Thailand,

it is classified as protected wildlife under the Wildlife Preservation and Protection Act of 1992 (Wildlife Preservation and Protection Act 1992). This suggests that the status of the species is especially of concern in its South-east Asian range, probably as a result of widespread habitat loss and fragmentation, combined with indiscriminate widespread illegal hunting. Here we: (1) describe the spatial distribution of Grey Peacock-pheasant, (2) assess the microhabitat use of Grey Peacock-pheasant, (3) assess the occurrence of ground-dwelling bird and mammal species at display scrapes and elsewhere in the study area, and (4) ask if Grey Peacock-pheasant display scrapes were sited in areas with relatively few potential predators.

Methods

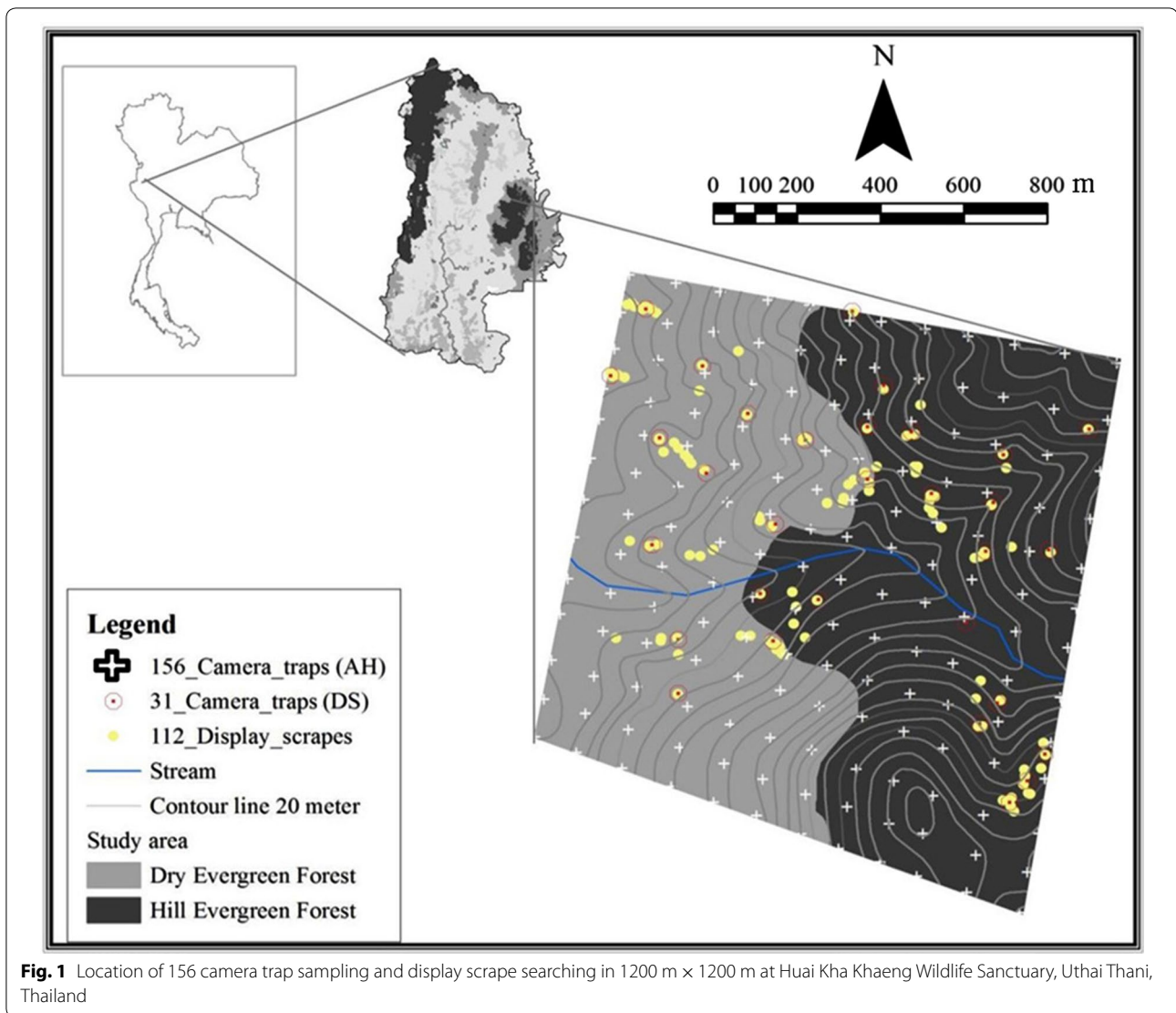
Study site

This study was conducted at Huai Kha Khaeng Wildlife Sanctuary (15°00'–15°48'N, 98°89'–99°27'E, Fig. 1), which was declared a protected area in 1972. It covers an area of 2780 km² at the eastern edge of the Western Forest Complex in Western Thailand. It is part of the Thanon Thong Chai Mountain Complex that lies in the Tenasserim Range along the Thailand-Myanmar border. Our study site covers 1200 m × 1200 m of rugged ridges and narrow valleys at 700–1500 m in hill evergreen and dry evergreen forest, near the Khao Nang Rum Research Station in the south-eastern part of the sanctuary. The study site has three seasons: the wet season (May to October) with the temperature ranging between 6 and 38 °C, the dry season (November to April) when the temperature ranges between 10 and 29 °C, and during this dry season, there is a short cold and dry winter (December and January). The average annual rainfall is 1552 mm with the maximum rainfall in October (370 mm) (National Parks Wildlife and Plant Conservation Department 2014).

Field methods

We assessed the microhabitat selection of Grey Peacock-pheasant by comparing the topography, vegetation structure, and food availability between: (1) used locations versus available locations, (2) display scrapes versus available locations, and (3) used locations versus display scrapes during the breeding season. Display scrapes are the areas cleared by breeding males where they vocalize and display. Camera traps were also used to compare animal species composition between display scrapes and random camera trap locations in the study site, and to assess whether there was a co-occurrence between highest ranking potential predators and Grey Peacock-pheasant at those sites. Fieldwork was conducted during the 2013 breeding season (January–May).

We identified 'used' and 'available' locations of Grey Peacock-pheasant in the breeding season at



156 camera trap locations throughout the study area over a 100 m × 100 m grid covering a total area of 1200 m × 1200 m. A Geographic Information System (ESRI 2008) was used to generate a 100 m² grid that was overlaid on a map of the study area (1.44 km²). Then, for used locations, the camera trap locations were used to produce a further 156 locations, 48 of which were used by the species; for available locations, the centroid of each 100 m × 100 m grid was located to produce 132 locations across all available microhabitats.

We set up 156 camera trap locations across the study area as follows, a total of 39 camera traps were set 100 m apart in three parallel lines running north–south (13 cameras per line) 400 m apart for 30 consecutive days. They were then shifted 100 m eastwards for the following 30 days and so on. The entire study area was, therefore,

covered in four blocks between January and May 2013 (Fig. 1). We used Scout Guard, SG565F-8M, a digital scouting camera with an incandescent flash that can be triggered by any movement in front of a passive infrared sensor. The camera traps were programmed to record video 24 h per day in camera mode (depending upon light availability) with three pictures/trigger and a time delay for activation of one second apart. Each video or photograph was date and time stamped. Camera traps were attached to a suitable tree at a height of 40–50 cm above the ground and with an angle of depression of 5–10°.

We searched intensively for display scrapes throughout the study area between January and the end of April 2013. We did this by dividing the study site into six subplots of 400 m × 600 m. Four observers searched each subplot and were spread 100 m apart to ensure even search effort

across each subplot. The size of all display scrapes was measured (width \times length) and its position recorded on the Universal Transverse Mercator coordinate system (X , Y). We checked to see if each display scrape was used in the following (year 2014) breeding season.

We measured microhabitat variables in circular plots that were centred on the 48 used locations, 112 display scrapes and 132 available locations across the study area. For each plot 12 variables were recorded. Within each 10 m radius we recorded the number and diameter at breast height (DBH) of trees (DBH \geq 4.5 cm), number of vines, and horizontal understory density. Within each 5 m radius, we recorded the number of saplings (DBH \leq 4.5 cm, height $>$ 1.30 m) and within each 1 m radius, we recorded the number of seedlings (height $<$ 1.30 m.), number of soil invertebrates (i.e. insects, worms), and number of fallen fruits. In addition, at each plot we also measured canopy cover, slope, aspect and elevation. These habitat characteristics reflect the openness of the habitat (and conversely the availability of cover), the availability of food (Grey Peacock-pheasants feed on both insects and fruit) and the characteristics of the site that might promote calling by males (e.g. slope of the site, elevation and canopy cover).

We assessed animal species occurrence at display scrapes between February and May 2013 by setting one to three camera traps at each display scrape, depending on the size of display scrape and the amount of vegetation cover. Multiple detections from one scrape at the same time were treated as a single detection. In some cases there were several display scrapes in a cluster and so cameras were set so as to maximize the likelihood of capturing individuals present given the configuration of the scrapes. Overall, camera traps were set at 31 display scrapes between 20 and 45 days (Fig. 1).

Data analysis

Microhabitat variables measured at used locations, available locations and display scrapes were compared using an independent Mann–Whitney U test for non-normally distributed data. Variables that differed significantly ($p < 0.05$) were retained for analysis as reduced and fitted variables in General Linear Models (GLMs). We tested for multicollinearity among independent variables using Pearson's correlation matrix and we did not allow independent variables with high correlation coefficients ($|r| \geq 0.70$) in the same model. We standardised the value of each variable with a z -score transformation, so that each variable has mean of 0 and standard deviation of 1 (Knopff et al. 2014).

This produced a list of 12 variables. We then created a model in R 3.2.1. (R Core Team 2015) that combines variables as efficiently as possible to explain the microhabitat

selection difference between: (1) used locations and available locations, (2) display scrapes and available locations, and (3) display scrapes and used locations. We did this in three steps as follows.

Step 1: We conducted binary logistic regression modelling utilising a binomial GLM and then used the information theoretic approach based on Akaike's Information Criteria (AIC), Akaike difference (Δ AIC) and Akaike weight (w_i) (Burnham and Anderson 2002) to select candidate models, which had Δ AIC between 0 and 2, indicating that there is strong support for the model (Burnham and Anderson 2002). This indicates that the candidate model explains much of the variation in microhabitat selection of used locations and display scrapes.

Step 2: We looked at how much of the variation in the pattern was explained by the candidate models and identified the top model, which was the one that explained most variation in the microhabitat at the two types of sites where Grey Peacock-pheasants were recorded (i.e. used location, display scrapes). We used the package AICcmodavg 2.3-2 to calculate the Akaike model weights for all candidate models (Mazerolle 2015). For the top model the Akaike model weight was less than 0.90, indicating that it was not the single best model in the set (Burnham and Anderson 2002) and so we used model averaging for the final model selection.

Step 3: We then interpreted the average model in terms of microhabitat variables. We performed model averaging for microhabitat selection at used locations and display scrapes. The Hosmer–Lemeshow test was used to test for model fit and we used package pROC R package version 1.8 (Robin et al. 2015) to calculate for the area under the Receiver Operator Curve (ROC) to measure the accuracy of model.

We compared the species composition of the large vertebrate assemblage at display scrapes with that in available habitat across the study site by identifying photographs from camera traps. Photographs that were not clear enough to permit identification to species level were excluded from our analysis. Photographs had to be taken more than 1 h apart to be considered independent events, so as to avoid double counting of individual animals lingering in front of the camera (Mugerwa et al. 2012). We used the camera trapping rate as an index of abundance. Camera trapping rate was defined as the ratio of independent photographs of each species to the number of trap days (number of 24 h periods that the cameras were deployed) and multiplied by 100. We then used the mean trapping rate as a measure of the Relative Abundance Index (RAI) of each species across the study area following (Rovero and Marshall 2009). We used tools inside the community ecology package (Vegan) R package

version 2.3-2 (Oksanen et al. 2015) for describing the animal community at display scrapes and at other camera trap locations by using: (1) Species Accumulation Curve (Specaccum) to compare animal species richness between display scrapes and random camera trap locations, (2) Non-metric Multidimensional Scaling (NMDS) for measuring animal community (species and abundance) dissimilarities between display scrapes and random camera trap locations, (3) Analysis of Similarities (ANOSIM) to test statistically whether there was among group difference in species and abundance between display scrapes and random camera trap locations, and (4) Similarity Percentages (SIMPER) for discriminating animal community between display scrapes and random camera trap locations by using Bray–Curtis dissimilarities.

We assessed whether there was a co-occurrence between the most commonly detected potential predators and Grey Peacock-pheasant at the display scrapes in four steps, as follows:

Step 1: We determined potential predators based on our knowledge of predator feeding and hunting behaviour, including the overlapping activity periods of Grey Peacock-pheasant and predators in an area (Fig. 4).

Step 2: Photographs of these potential predators were pooled into two groups according to where they were taken, ‘display scrape’ or ‘random camera trap locations’.

Step 3: We considered the frequency of camera trapping of potential predators to determine the most commonly photographed potential predators for analysis of co-occurrence of predators and Grey Peacock-pheasant.

Step 4: The co-occurrence of the potential predators and Grey Peacock-pheasant was interpreted in terms of occupancy and detection of both (i.e. peacock-pheasants and predators) at display scrapes following (Richmond et al. 2010; Magle et al. 2014) by using two species single season interaction in Presence Program 6.1 (Mackenzie et al. 2004; Donovan and Hines 2007).

Results

Dispersion of Grey Peacock-pheasant

Display scrapes

We found 112 display scrapes (Fig. 1) with a mean size of 0.57 ± 0.018 (SE) m \times 0.90 ± 0.037 m. Each male created and maintained more than one display scrape (mean = 3.92 ± 0.52 , $n = 27$ individuals) and these were aggregated into clusters. The mean distance between display scrapes in a cluster was 35.26 ± 3.66 m ($n = 77$ clusters), 95% CI and the mean diameter of a cluster of scrapes was 106.3 ± 14.40 m (95% CI (80, 135)). Display scrapes were maintained in the same general area in both

years and 20.72% of individual scrapes used in 2013 were reused in the following breeding season (2014).

Used locations

Grey Peacock-pheasant was detected at 48 locations of the 156 where camera traps were set between January and May 2013.

Microhabitat selection

Microhabitat characteristics

The microhabitat of the used locations showed some differences from the available locations. Mann–Whitney U test showed that six of 12 independent variables were significantly different and lower than in the available locations with tree basal area, density of saplings, density of fruits (Mann–Whitney U test $p < 0.001$, Table 1) and slope, percent of tree canopy, density of insects (Mann–Whitney U test $p < 0.05$, Table 1).

Nine microhabitat characteristics differed significantly between display scrapes and available locations. Display scrapes were sited in areas that were significantly flatter, with open canopy, lower horizontal understory density, smaller trees at higher density, higher density of vines, higher density of saplings, lower density of insects and fallen fruits (Mann–Whitney U test, $p < 0.001$, $p < 0.05$, Table 1).

The microhabitat at display scrapes differed from used locations, with eight of the 12 variables differing significantly between the two: slope (less than at used locations), percent of horizontal understory density (less than used locations), density of trees (higher than used locations), density of fruit on the ground (higher than used locations) (Mann–Whitney U test, $p < 0.001$). Most display scrapes were facing west whereas used locations were facing southwest, elevation was lower than in the used locations, density of saplings was higher than in the used locations and density of insects was lower than in the used locations (all Mann–Whitney U test $p < 0.05$ Table 1).

Microhabitat selection at used locations of Grey Peacock-pheasant in breeding season

Seven microhabitat selection models were considered as candidate models for the used locations as they showed a $\Delta AIC_c < 2$ and low model support weight variation (w_i between 0.23 and 0.09, see Table 2 for details). The microhabitat independent variables highlighted by those seven models are tree basal area, slope, percent of tree canopy closure, elevation, horizontal understory density, density of saplings, density of insects, density of fruits, density of trees and aspect (Table 2). Averaging the seven candidate models in the final microhabitat selection model for used location resulted in a negative trend with the basal area

Table 1 Comparison of habitat variable measured on Grey Peacock-pheasant used locations ($n = 48$ locations), display scrapes ($n = 112$ locations), and available location ($n = 132$ locations)

Variable	Variable description	Median			Mann U test		
		Used location	Display scrape	Available location	1 ^a	2 ^b	3 ^c
Slp	Slope (°)	21.50	15	24.00	0.003	<0.001	0.001
Asp	Aspect (°)	248	265	270	0.15	0.40	0.05
Ele	Elevation (m)	906.50	852	879	0.23	0.18	0.03
TreeCCS	Tree canopy closure (%)	91.50	91	93	0.02	0.03	0.96
VertD	Vertical dense (%)	76	28.50	72.00	0.09	<0.001	<0.001
BA	Tree basal area (m ²)	0.77	0.77	2.45	<0.001	<0.001	0.49
DENTR	Density of trees (number of trees/m ²) (DBH \geq 4.5 cm, height > 1.30 m)	0.08	0.10	0.08	0.81	<0.001	<0.001
DENSPL	Density of sapling (number of saplings/m ²) (DBH \leq 4.5 cm, height > 1.30 m)	0.23	0.27	0.23	<0.001	0.002	0.02
DENS DL	Density of seedlings (number of seedlings/m ²) (height < 1.30 m)	3.02	3.18	3.18	0.63	0.75	0.69
DENVI	Density of vines (number of vines/m ²)	0.008	0.01	0.006	0.06	<0.001	0.07
DENINS	Density of insects (number of insects/m ²)	10.03	6.37	13.69	0.005	<0.001	0.04
DENFRU	Density of fruits (number of fruits/m ²)	3.66	15.92	25.80	<0.001	0.03	<0.001

1^a: p value between used locations versus available locations

2^b: p value between display scrape locations versus available locations

3^c: p value between used locations versus scrape locations of Grey Peacock-pheasant

Table 2 Ranking microhabitat candidate model for used location in breeding season and display scrape location scrape

Model	K	AIC_c	ΔAIC_c	w_i	LL	ROC
Used candidate model						
BA + Slp + TreeCCS + Ele	5	145.92	0	0.23	-67.79	0.8887
BA + Slp + TreeCCS + Ele + VertD	6	146.28	0.36	0.20	-66.90	0.8919
BA + Slp + TreeCCS + Ele + DENSPL	6	146.83	0.91	0.15	-67.17	0.8892
BA + Slp + TreeCCS + Ele + DENINS	6	147.20	1.28	0.12	-67.36	0.8867
BA + Slp + TreeCCS + Ele + DENFRU	6	147.40	1.48	0.11	-67.46	0.8928
BA + Slp + TreeCCS + Ele + DENTR	6	147.63	1.71	0.10	-67.57	0.8886
BA + Slp + TreeCCS + Ele + Asp	6	147.93	2.0	0.09	-67.72	0.8810
Null.model	1	210.80				
Display scrape candidate model						
VertD + Slp + BA + DENINS	5	85.43	0	0.55	-37.59	0.9855
VertD + Slp + BA + DENSPL	5	85.86	0.43	0.45	-37.80	0.9851
VertD + Slp + BA + TreeCCS	5	87.99	2.55		-37.87	0.9848
Null.model	1	338.60				

Based on K = number of model parameter, Akaike's information criterion (AIC_c), ΔAIC_c = AIC for a given model minus AIC for the top model. w_i = Akaike model weight, and LL is the log-likelihood. Competitive model ($\Delta AIC_c < 2$), ROC = Receiver operating curve to indicating the true positive

of tree ($p < 0.001$), slope ($p = 0.006$), and a positive trend with percent of tree canopy closure ($p = 0.021$), elevation ($p = 0.038$), while horizontal understory density, density of saplings, density of insects, density of fruits, density of trees and aspect were not important ($p = 0.189$, 0.257, 0.365, 0.471, 0.705, 0.715, respectively) (see Table 3 for details; Hosmer–Lemeshow test, $\lambda^2 = 10.68$, $df = 8$, $p = 0.22$).

Microhabitat selection at display scrapes of Grey Peacock-pheasant

Two models were considered as candidate models for explaining the microhabitat at display scrapes, as they showed a $\Delta AIC_c < 2$ and low model support weight variation (w_i between 0.55 and 0.45, see Table 2 for details). The independent microhabitat variables highlighted by those two models were horizontal understory density,

Table 3 Results from averaging model fitted to model selection for used location in breeding season and display scrape of Grey Peacock-pheasant

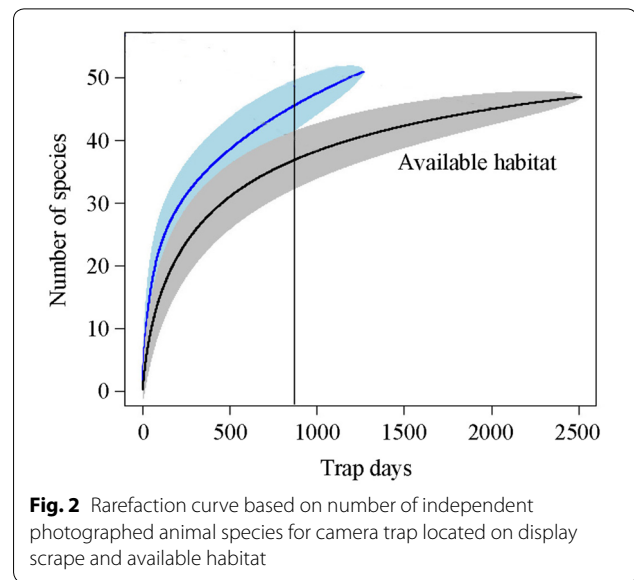
Variable	Coefficient	95% CI		p value
		Lower	Upper	
Used model selection				
Intercept	-2.789	-3.803	-1.775	<0.001
Basal area of tree	-5.177	-7.311	-3.043	<0.001
Slope	-0.676	-1.156	-0.195	0.006
Tree canopy closure (%)	0.724	0.136	1.311	0.021
Elevation	0.496	0.038	0.954	0.038
Horizontal understory density	0.071	-0.387	0.530	0.189
Density of saplings	0.048	-0.511	0.608	0.257
Density of insects	-0.026	-0.497	0.445	0.365
Density of fruits	-0.035	-0.911	0.840	0.471
Density of trees	-0.022	-1.167	1.123	0.705
Aspect	0.009	-0.541	0.560	0.715
Display scrape model selection				
Intercept	-0.611	-1.270	0.047	0.08
Horizontal understory density	-3.852	-5.124	-2.580	<0.001
Slope	-1.759	-2.542	-0.977	<0.001
Basal area of tree	-1.904	-3.198	-0.611	0.003
Density of insects	-0.910	-1.527	-0.248	0.009
Density of saplings	0.400	-1.040	1.840	0.016

slope, tree basal area, density of insect, density of sapling (Table 2).

Averaging the two candidate models, the final micro-habitat selection model of display scrape gave a significant negative effect ($p < 0.001$) with slope and horizontal understory density; a significant negative effect ($p < 0.01$) with tree basal area and density of insect; and a significant positive effect ($p < 0.05$) with density of sapling (see Table 3 for details; Hosmer–limeshow test, $\lambda^2 = 1.48$, $df = 8$, $p = 0.9929$).

Occurrence of animal species

A total of 2853 photographs were taken during 1266 trap days at 31 display scrapes, which gives a mean camera trap rate of 40.83 days/location. There were 333 photographs that were excluded either because they contained no animals (121 photographs) or because the species could not be identified (212 photographs). And a total of 1555 photographs were taken in 2515 trap days at 117 of the 156 random camera trap locations used during the study (February–May 2013 as the same period with display scrapes). We excluded 17 locations to reduce the zero detection in dataset, following the zero-adjusted approach for denuded assemblages proposed by Clarke



et al. (2006), which gives a mean of 25.15 days/location. There were twenty-eight photographs excluded either because they contained no animal (14 photographs) or because the species could not be identified (14 photographs). Altogether 63 species of animal (32 mammals, 29 birds, 2 reptiles) were photographed at both types of location (Additional file 1: Table S1). Of these animals, 51 species (26 mammals, 23 birds, 2 reptiles) were photographed at display scrapes and 48 species (29 mammals, 19 birds) at random camera trap locations, of which 36 species (23 mammals, 13 birds) were photographed at both types of location.

The confidence intervals of the rarefaction curve of animal species at display scrapes and random camera trap locations overlapped until the curve reached 800 trap-days which means the number of animal species were not significantly different (Fig. 2). At 800 trap-days, however, the confidence intervals did not overlap and the number of animal species (species richness) recorded at display scrapes (mean species richness = 39.02 ± 0.28) was higher than at random camera trap locations (mean species richness = 37.51 ± 0.19 ; $F = 1.11$, $p = 0.03$, $df = 1265, 2514$).

The animal assemblages recorded at display scrapes comprised 59.51% birds, 40.26% mammals and 0.23% reptiles. The main bird group detected was Galliformes (82.2%): Grey Peacock-pheasant (63.64 ± 10.87), Bar-backed Partridge (*Arborophila brunneopectus*) (9.35 ± 3.46), Scaly-breasted Partridge (*Arborophila chloropus*) (8.02 ± 3.78), Red Junglefowl (*Gallus gallus*) (3.26 ± 2.08) and Kalij Pheasant (*Lophura leucomelanos*) (1.29 ± 0.66). The mammal groups present were herbivores (68.26%), carnivores (23.11% of which 97.70% were

small-medium carnivores and 2.30% large carnivores), omnivores (7.57%) and insectivores (1.06%).

The animal assemblage recorded at random camera trap locations was 61.13% mammals and 38.87% birds. The mammal groups present were herbivores (60.98%), carnivores (29%, including small-medium carnivore 95.95% and large carnivore 4.05%), and omnivores (10%). Galliformes were again the bird group represented in most photographs (66.39%): Grey Peacock-pheasant (5.24 ± 1.09), Bar-backed partridge (2.57 ± 0.61), Scaly-breasted Partridge (0.44 ± 0.15), Red Junglefowl (0.24 ± 0.10), and Kalij Pheasant (0.34 ± 0.12) (Additional file 1: Table S1).

The animal composition (species and abundance) at display scrapes was significantly different from the random camera trap locations (ANOSIM $p < 0.01$ and $R = 0.90$) (Fig. 3). There was less variation in the composition of the animal assemblage at display scrapes than at random camera trap locations (Fig. 3): Bray–Curtis dissimilarity between display scrape and random camera trap community was 23%, indicating a high number of shared species between the areas.

Grey Peacock-pheasant and potential predators

We detected 16 species of predators (carnivores) at both display scrapes and random camera trap locations, of which 14 species were found at display scrapes and 14 species were found at random camera trap locations (Additional file 1: Table S1). We excluded six species of

carnivores as potential predators based on our knowledge of predation of Galliformes in SE Asia, including Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Hog Badger (*Arctonyx collaris*), Crab-eating Mongoose (*Herpestes urva*), Large-toothed Ferret Badger (*Melogale personata*), and Asiatic Black Bear (*Ursus thibetanus*), and then identified ten species that were likely to have an impact on Grey Peacock-pheasant occurrence at display scrapes (Table 4). Because some species were rarely detected we only used the four species that had a mean camera trapping rate (number of photographs/100 day \pm SE) greater than 0.50 for analysis of their co-occurrence with Grey Peacock-pheasant (display scrape; random camera trap locations): Masked Palm Civet (*Paguma larvata*) (5.96 ± 1.45 ; 2.64 ± 0.61), Large Indian Civet (*Viverra zibetha*) (2.43 ± 1.13 ; 0.85 ± 0.22), Common Palm Civet (*Paradoxurus hermaphroditus*) (1.88 ± 1.12 ; 0.73 ± 0.19), and Yellow Throated Marten (*Martes flavigula*) (0.87 ± 0.34 ; 0.61 ± 0.16) (Table 4).

Both Masked Palm Civet and Large Indian Civet occurred significantly more at display scrapes than at random camera trap locations (Wilcox–Mann U test, $p < 0.001$, $p < 0.01$ respectively), whereas Common Palm Civet and Yellow Throated Marten did not (Wilcox–Mann U test, $p = 0.414$, $p = 0.130$, respectively) (Table 4). When the 10 potential predators were pooled, the mean camera trapping rate was significantly higher at display scrapes than random camera trap locations (Wilcox Mann U test, $p = 9.27E - 04$) (Table 4).

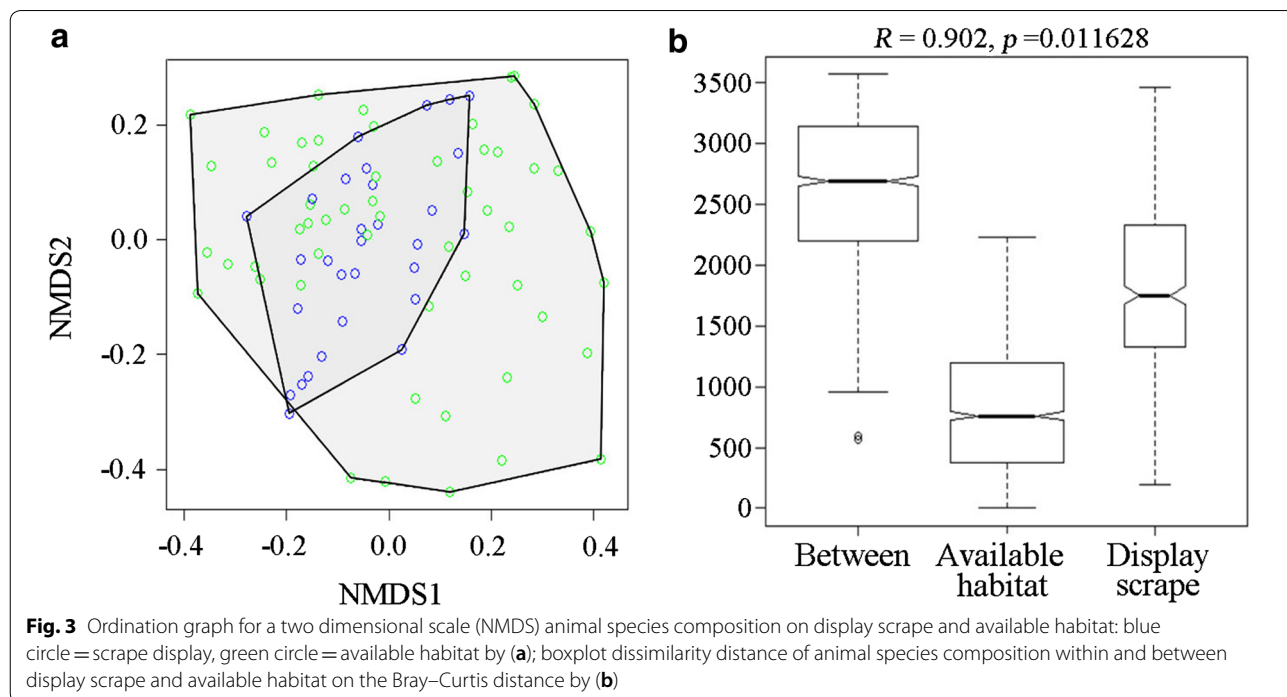


Table 4 Mean and median camera trapping rate (no. of photographs/100 day) of potential predators at display scrapes and available habitat

No.	Species (common name)	Display scrape		Available habitat		Mann U test
		Mean	Median	Mean	Median	
1	Masked Palm Civet	5.96	3.70	2.64	0.00	0.0007
2	Large Indian Civet	2.43	0.00	0.85	0.00	0.046
3	Common Palm Civet	1.88	0.00	0.73	0.00	0.409
4	Yellow-throated Marten	0.87	0.00	0.61	0.00	0.130
5	Marbled Cat	0.32	0.00	0.07	0.00	0.213
6	Leopard Cat	0.02	0.00	0.20	0.00	0.527
7	Asiatic Golden Cat	0.20	0.00	0.07	0.00	0.213
8	Small Indian Civet	0.06	0.00	0.00	0.00	0.075
9	Dhole	0.03	0.00	0.29	0.00	0.825
10	Clouded Leopard	0.00	0.00	0.08	0.00	0.436
	Pool predators	11.98 ± 2.12	7.41	5.81 ± 0.90	3.33	0.0004

Table 5 Top model of 4 highest ranking potential predators and prey co-occurrence (main prey Masked Palm Civet, Large Indian Civet, Common Palm Civet, and Yellow-throated Marten and Grey Peacock-pheasant) at display scrape

Predicting	Top model	Variable	Estimate	SE
Psi(occupancy)	PsiA, PsiBA = PsiBa	PsiA	0.7613	0.31
		PsiBA = PsiBa	-0.1461	0.10
P(detection)	pA! = rA, pB! = rBA = rBa	pA	-1.0514	0.24
		rA	-0.3822	0.17
		pB	-4.2371	1.05
		rBA = rBa	2.2203	0.28

PsiA probability of occupancy of predators, PsiBA probability of occupancy of Grey Peacock-pheasant when predators are present, PsiBa probability of occupancy of Grey Peacock-pheasant when predators are absent, Pa probability of detection for predators if there are no Grey Peacock-pheasant, pB probability of detection for Grey Peacock-pheasant if there are no predators, rA probability of detection for predators if Grey Peacock-pheasant are present, rBA probability of detection for Grey Peacock-pheasant if predators are present and detected, rBa probability of detection for Grey Peacock-pheasant if predators are present and not detected

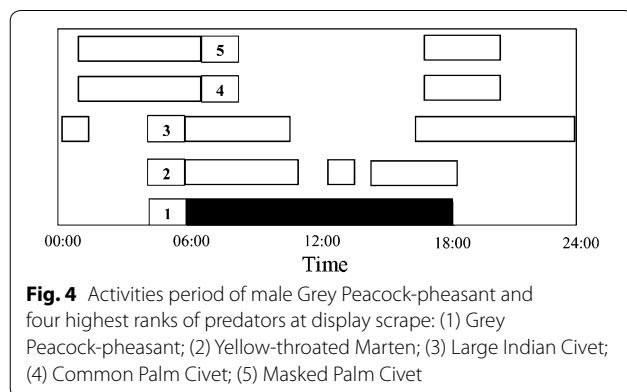


Fig. 4 Activities period of male Grey Peacock-pheasant and four highest ranks of predators at display scrape: (1) Grey Peacock-pheasant; (2) Yellow-throated Marten; (3) Large Indian Civet; (4) Common Palm Civet; (5) Masked Palm Civet

We evaluated the co-occurrence of the four most commonly photographed potential predators and Grey Peacock-pheasant at 31 display scrapes in terms of both occupancy and detection. The occurrence of Grey Peacock-pheasant at display scrapes did not depend on the occurrence of predators ($\Psi_{iBA} = \Psi_{iBa}$). However, the detection of Grey Peacock-pheasant did depend on the presence of the potential predators, but not on their detection ($p_B = r_{BA} = r_{Ba}$), and the detection of predators did depend on the presence of Grey Peacock-pheasant ($p_A = r_A$) (Table 5). Three of the main predator species were nocturnal mammals (Fig. 4).

Discussions

Our results show that whilst Grey Peacock-pheasant used most of the microhabitats that were available throughout the study area, they had quite specific requirements for constructing and maintaining display scrapes during the breeding season. These sites presumably provide benefits for males as they seek to attract females (Morris 2003; Kajin et al. 2012) and, for this species, seems likely to be associated with display of the males, as in the closely related Great Argus (Davison 1981) and suggested for the congeneric Malaysian Peacock-pheasant (McGowan 1994).

Display scrapes were located in flat open areas with a low density of insects. Other species of forest Galliformes species are thought to use open understorey where they can detect approaching ground predators, i.e. Sichuan Hill-partridge's (*Arborophila rufipectus*) (Bo et al. 2009), Siamese Fireback (*Lophura diardi*) (Sukumal et al. 2017) and Hume's Pheasant (*Syrnaticus humiae*) (Iamsiri and Gale 2008)). However, we assume that in this case this allows males to show off their eyespots to females during

courtship behaviour (Davison 1983b). Visibility during male display was also suggested as the main reason why Green Peafowl (*Pavo muticus*) also predominantly selected open areas during their mating season (Sukumal et al. 2017) as displaying eyespots on its train has an important sexual selection function (Petrie 1994). Moreover, in dense tropical Sundaic forest with relatively steep slopes, flat patches were also selected for the creation of ‘dancing grounds’ by Great Argus (Davison 1982; Dawrueng et al. 2017) and this species also exhibits eyespots on spread wings during courtship behaviour. Moreover, our model showed that the density of insects was negatively related to display scrape microhabitat selection. We assume that this was because the male in the scrape had already fed on the insects (this assumption was supported by evidence from the video camera traps).

We asked if Grey Peacock-pheasant display scrapes were sited in microhabitats with relatively few potential predators. We found, however, that there were significantly more potential predators at scrapes than random locations. The occurrence of the pheasant was not influenced by these predators, and, therefore, it suggests that they may use tactics other than spatial segregation to avoid these predators. Morris (2003), Ferrari et al. (2009) and Gorini et al. (2012) reported that prey can modify its behaviour in response to predators and shifts in spatial use may also be a response to temporal variation in predation risk. However, our detection of predators depended on the presence of Grey Peacock-pheasant, and it is well known that habitat selection of mammalian carnivores may be driven by prey availability (Flaxman and Lou 2009; Keim et al. 2011; Wolff et al. 2015). Diets of omnivorous predators can shift in response to food availability (e.g. Zhou et al. 2008, 2011; Jothish 2011). Therefore, male Grey Peacock-pheasant may be at greater risk of predation during the breeding season as this is in the dry season where there is least fruit available in the environment.

Conclusions

Grey Peacock-pheasant selects flat and open microhabitats for its display scrapes in dry and hill evergreen forest. There is a higher population of potential predators at these sites than elsewhere in its habitat, but the Grey Peacock-pheasant is able to carry out its courtship at these selected sites as it is diurnal, whereas most of its predators are nocturnal. In subsequent stages, the species may use different tactics to avoid predators, such as using vegetation cover during the nesting and brood rearing phase (Kirol et al. 2012; Latif et al. 2012; Suwanrat et al. 2014). When displaying at scrapes there might be a trade-off between

successful mating and predator risk similar to that in male Lesser Prairie-chicken (*Tympanuchus pallidicinctus*), which selects open areas for leks to display for females in spring, but also suffer from peak mortality at the same time (Hagen et al. 2005; Larsson et al. 2013).

Additional file

Additional file 1. Table S1. Number of camera trap photographs and mean camera trapping rate (photographs/100 days) \pm 95% confidence interval of animal community at display scrape ($n = 31$) and available habitat ($n = 100$) as 1200 m \times 1200 m in Huai Kha Khaeng Wildlife Sanctuary, Thai Thani, Thailand.

Authors' contributions

ST designed field study, collected data in field work and performed the analysis. MJG advised on data analysis. PJKM and TS, contributed to the design of the field study. All authors contributed to writing the manuscript. All authors read and approved the final manuscript.

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Competing interest

The authors declare that they have no competing interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Ethics approval and consent to participate

This study was permitted to do fieldwork in Huai Kha Khaeng Wildlife Sanctuary under the permission from National Parks Wildlife and Plant Conservation Department.

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