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Effect of landscape variables on the long-term decline of Great Argus in the rainforest of Southern Thailand

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Summary

In Thailand, as for most of South-East Asia, large vertebrates are declining rapidly due to habitat degradation and increasing hunting pressure. Once relatively common in the evergreen forest of Southern Thailand, the Great Argus *Argusianus argus* is currently limited to a few populations, whose status is currently unknown. In this study we investigated changes in Great Argus abundance over the past 13 years in Hala-Bala Wildlife Sanctuary. Our aim was to estimate and compare the abundance and density of this species from an earlier two-year survey in 2001–2002 and ours in 2014, and to assess the effect of landscape change on its status of the species. We conducted surveys from March to August 2014 during the breeding season. We placed point counts that overlapped the line transects from the 2001–2002 survey. The results indicated a decline of > 35% in mean abundance from 2001 to 2014. In addition, male abundance has shifted and is now positively related to distance from the forest edge. High levels of human disturbance close to the forest edge may have resulted in the birds moving to the core of the forest, suggesting a need to increase protection and management of forest edge areas. In common with other studies of large vertebrates, our results confirm the importance of long-term studies to highlight the negative effects of human disturbance.

Introduction

Although South-East Asia represents one of the world's most important biodiversity regions, with four biodiversity Hotspots (Indo-Burma, Sundaland, Philippines, and Wallacea) (Myers *et al.* 2000, Brooks *et al.* 2002), it has also had the highest vertebrate extinction rate over the past 40 years (e.g. forest birds in Singapore, and generally endemic forest species in peninsular South-East Asia) (Sodhi *et al.* 2004, 2010b), with more than 2,000 vertebrate species being highly threatened with extinction in the region (Kummer and Turner 1994, Hoffmann *et al.* 2010, Myers *et al.* 2000, Sodhi *et al.* 2010b). Major threats to large vertebrates include hunting for food, illegal trade and deforestation, the latter higher than in other tropical regions (Sodhi *et al.* 2010a), which converts natural habitat to agricultural land and leads to increased forest fragmentation and edge effects (Lynam and Billick 1999, Kitamura *et al.* 2010, Sodhi *et al.* 2010b, Miettinen *et al.* 2011). More than 95% of forests in southern Thailand have been lost (Round 1988) due to human activities over the past several decades, and such transformations have most likely contributed to the increase in threatened status of vertebrate species found on the northern edge of the Sundaland hotspot, such as the Siamang *Symphalangus syndactylus* (Endangered; EN), Agile gibbon *Hylobates agilis* (EN), Rhinoceros hornbill *Buceros rhinoceros* (Near Threatened; NT) and Great Argus *Argusianus argus* (NT) (IUCN 2015).

Galliformes are particularly affected by human disturbance (Fuller 2000, McGowan *et al.* 2012), with the current conservation status of 70 species in this order highly threatened with extinction worldwide (McGowan *et al.* 2012). The Great Argus is among the largest of the pheasants, an elusive ground-dwelling bird restricted to lowland tropical rainforests of the Sundaland hotspot, including peninsular Malaysia, Sumatra, and Borneo (BirdLife International 2015). Its density in previous studies was described as highest in primary forest (Nijman 1998) and undisturbed forest (Winarni *et al.* 2009). Two subspecies are reported: Bornean Great Argus (*A. a. grayi*) and Malay-Sumatra Great Argus (*A. a. argus*), which inhabits the evergreen lowland forest of peninsular Malaysia and southern Thailand (Madge *et al.* 2002). Although defined as 'Near Threatened' (IUCN 2015), a large proportion of the population in southern Thailand occurs in the Bala section of Hala-Bala Wildlife Sanctuary (Kemp *et al.* 2011) suggesting that its national conservation status should be uplisted. Moreover, this population might also represent a large proportion of the northern extension of the whole range of the species.

Overall, studies demonstrating long-term declines of large vertebrates are limited and the causes of such declines are rarely reported in detail (Cardinale *et al.* 2012), and this is also true for the South-East Asian region (Sukumal *et al.* 2015). Furthermore, such studies are much needed to provide information to assist long-term management of threatened species (Hoffmann *et al.* 2010). Although conservation action to prevent extinction and reverse declines in South-East Asia has been formally undertaken (CBD 2010), detailed population information on the intensity and causes of such declines in the region are still very scarce (Sodhi *et al.* 2004).

We take advantage of a detailed survey on Great Argus conducted in 2001–2002 to estimate long-term (2001 to 2014) changes in the density of this species in an important area of its northern range. We attempt to explain possible variations in abundance by looking at topographical and landscape variables (distance to road, distance to forest edge, slope, and elevation). We used these variables to compare possible influences on the abundance and density of Great Argus in two periods (Gale and Thong-aree, unpubl. data in 2001–2002, and our study in 2014).

Methods

Study site

The Bala forest (5°44′N 101°46′E–5°57′N 101°51′E; Figure 1) of the Hala-Bala Wildlife Sanctuary (HBWS) covers 112 km² at elevations ranging between 50 m and 960 m above sea level in the extreme south of Thailand. This area consists of isolated tropical lowland evergreen forest patches within the watershed of the Sugai Kolok River. Commonly, the dry season lasts from February to May and rainy season from June to January. Annual rainfall averages around 4,400 mm. Temperatures fluctuate yearly between 23°C and 35°C. In the 1970s, Bala forest was selectively logged. In 1997 it was declared a Wildlife Sanctuary and logging was officially stopped. However, there is potential disturbance from various anthropogenic factors because it is bordered by villages, agricultural land and plantations (Kemp *et al.* 2009). Moreover, as observed in other protected areas in southern Thailand (Lynam and Billick 1999) Hala-Bala suffers from illegal logging, hunting and conversion to agriculture leading to fragmentation. For this study, we compared the abundance and density of the species using data collected in 2001 and 2014.

2001 survey

The survey was conducted between January 2001 and April 2002, using distance sampling as part of a project investigating density of hornbills (Gale and Thongaree 2006) and other threatened birds, including the Great Argus. The survey was conducted using 11 transects. We only used data from the period March to August, which corresponds to the breeding season in peninsular Malaysia (Davison 1981b, 1982) and in Sumatra (Winarni *et al.* 2009). For the analysis, we selected only calling Great Argus males, the loud resonant *kwow wow* call given exclusively by males (Lekagul *et al.* 1991),

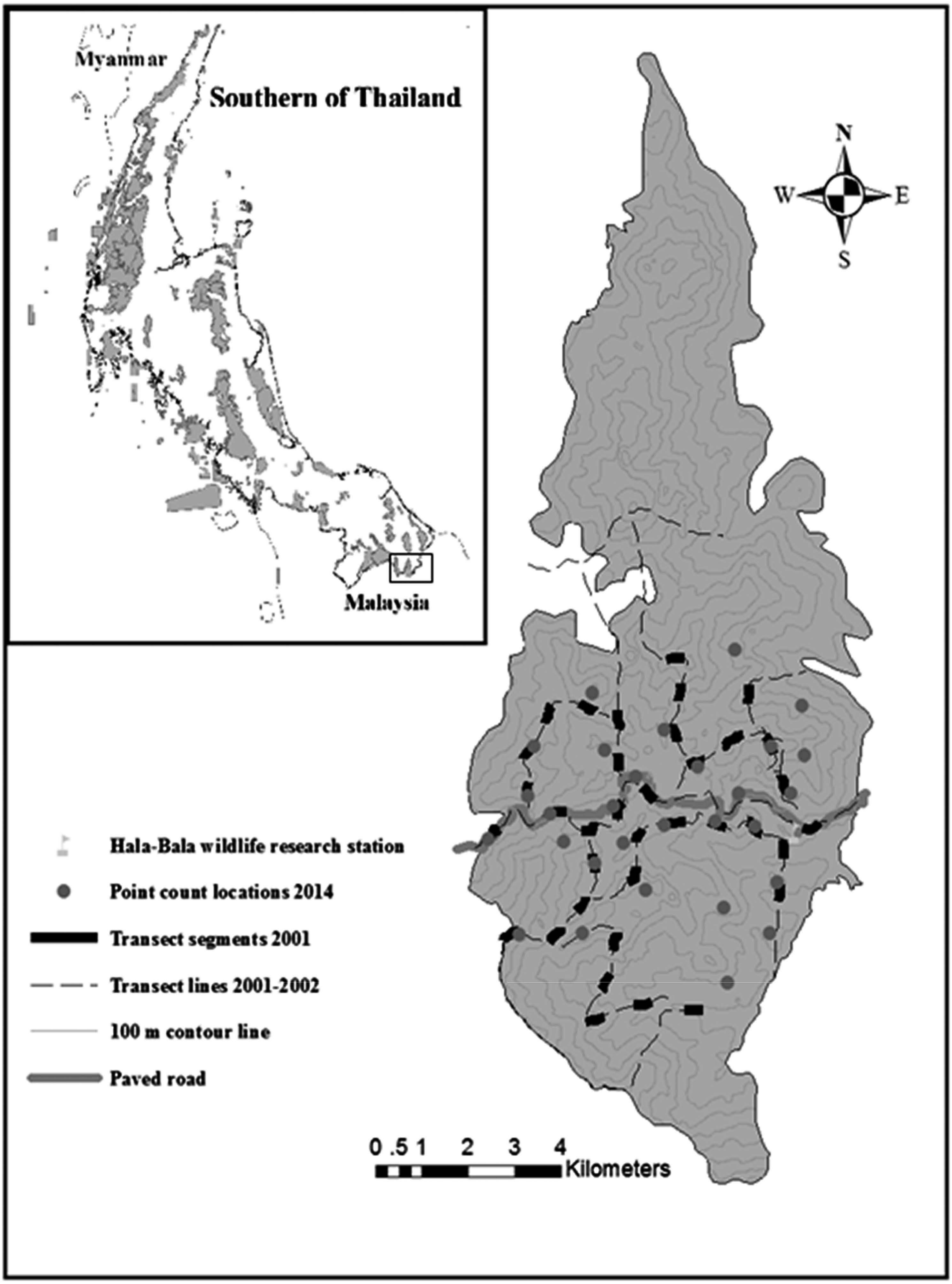

Figure 1. Map of the Bala portion of the Hala-Bala Wildlife Sanctuary showing the locations of the segment lines and point counts surveyed in 2001 and 2014, respectively.

detected from March to August 2001 (the same period as the 2014 survey; Figure 1). In 2001, surveys were repeated monthly from March to August (six times in total). Even though the male's loud calls can be heard up to 1 km away (Davison 1982, Nijman 2007), we restricted our data collection to calling males estimated to occur no further than 400 m away from an observer (in both study

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periods the observers were trained to estimate calling distance before running the surveys) to avoid double-counting birds heard on adjacent transects. In order to compare the results from this survey with the one carried out in 2014 (see below), we selected 400 m segments, from the whole transects, which overlapped as much as possible the point count locations used in 2014.

2014 survey

The survey was conducted between March and August 2014. Due to the rough and steep terrain in Bala, which proved to be difficult when using line transects in the 2001 survey, we used point-counts in 2014. We established 29 points within the Bala forest (Figure 1), covering the same area that was surveyed in 2001–2002. Five points were located on the paved road and 24 points were distributed within the forest. We established the point-count locations on ridges or hilltops, away from noisy streams and rivers (Nijman 2007, Kemp *et al.* 2011). The distance between each independent point-count location was 800 m to 1,200 m, to avoid double-counting the same individuals. The locations of point-counts were determined by a global positioning system (GPS) and topographic maps. In 2014 data were collected by one observer (TD) who listened at each of the 29 locations for three consecutive days. We recorded time of day when males started calling, and number of male birds calling within a 400 m radius. We did not collect data during high winds and heavy rain.

We employed *N*-mixture models for estimating the abundance of Great Argus. These techniques model a relationship between count data and environmental variables to obtain abundances at point locations and a total abundance (Royle 2004, Joseph *et al.* 2009, Hunt *et al.* 2012, Fiske and Chandler 2014). Data analysis was conducted using PRESENCE 8.3 (MacKenzie *et al.* 2002, Hines 2006) and the repeated count model (Royle 2004). These models estimate two parameters, detectability (r), and mean abundance (λ), i.e. the numbers of individuals using each point location, and these models also estimate patch occupancy (ψ). In the two datasets, the models were fitted for each of the survey periods and then the mean abundance used to compare the two surveys.

The total abundance (N) in each survey period was converted to density by dividing by the effective survey area (Chandler *et al.* 2011, Amundson *et al.* 2014, Suwanrat *et al.* 2015), calculated based on the fixed radius of 400 m from each survey location, multiplied by the total number of survey locations, having a total area of 11.24 km^2 in 2001 and 14.27 km^2 in 2014 (Table 2). In order to be sure that parameters such as distance to forest edge were not having large effects on abundance estimates, we compared the density in the two survey years by using both the results from the constant models and the top models.

Effect of landscape variables

Variations in long-term abundance are often correlated with changes in landscape variables (see Brodie *et al.* 2015, Brickle 2002, O'Brien and Kinnaird 2008, Sukumal *et al.* 2015, Nijman 1998, Winarni *et al.*2009). The variables used were: slope, elevation, distance to roads and distance to forest edge. These variables were assumed to be related to Great Argus abundance as reported by previous studies (Nijman 1998, O'Brien and Kinnaird 2008, Winarni *et al.* 2009). Landscape variables were obtained from the Land Development Department and the Department of National Parks, Wildlife and Plant Conservation. Variables were extracted using the ArcGIS 9.3 "buffer" function to buffer the areas around each line segment at 400 m for the 2001 survey, and 400 m radius around each point location for the 2014 survey. We also calculated the standard deviation (SD) values for elevation (SD 17.63–80.24 in 2001 and 18.67–76.94 in 2014) and slope (SD 5.28–9.78 in 2001 and 4.71–13.01 in 2014) within the buffered polygons, high SD values indicating steep terrain and low values indicating flatter areas. We also measured variables associated with human disturbance, using the ArcGIS "near" function to calculate the distance to the nearest forest edge and distance to the nearest road (the paved road across the Bala forest).

These four landscape variables in our study were then used to assess the effects on bird abundance in the past 13 years. Variables, including distance to forest edge, distance to the road, slope, and elevation, were standardised by dividing values by twice their standard deviation (Gelman 2008), in order to transform data into the same scale. We tested whether the variables were highly correlated (r > 0.5) before being fitted in the model. The four landscape variables were not correlated and the model was able to fit all the variables together. We fitted 10 models in each survey year in 2001 and 2014, including abundance and probability of detection constants [λ (.), r (.)]. The best model was selected based on the lowest Akaike's Information Criterion (Akaike 1973, Burnham and Anderson 1998).

Results

Comparison of long-term abundance

The model of best fit for the 2001 survey was the model with slope λ (slope), r (.). During the 2014 survey, the abundance was affected by distance to the forest edge λ (edge), r (.) (Table 1). The abundance comparison between the two survey periods, based on constant models, demonstrated that mean abundance (λ) and patch occupancy (ψ) during the 2001 survey were higher than during the 2014 survey. The estimated probability of detection (r) in 2001 was much lower than in 2014 (Table 2). Mean abundance of males was estimated to have declined > 35% between 2001 and 2014, although this was not statistically significant (Table 2). However, the abundance from the best models between the two years surveyed was significantly different (Mann-Whitney U-test, w = 158, $P < 0.01$), with abundance in the best models in 2001 higher than in 2014 (2.69 and 1.46 respectively).

The density of Great Argus males appeared to have decreased between the two surveys, looking at the 95% CI reported (see Cumming and Finch 2005). Density estimated using the constant model for the 2001 survey was 7.37 (95% CI 3.16–17.17) calling males/km^2 and for the 2014 survey was 3.02 (2.18–4.19) calling males/km^2. Density estimated for the best fitted models was of 8.08 (3.05–25.43) calling males/km^2 for 2001 and 3.05 (1.97–4.80) calling males/km^2 in 2014. For both the constant and the best models, the density was significantly different between 2001 and 2014 (Figure 2).

Effect of landscape variables on abundance

For the 2001 survey, slope was negatively associated with male Great Argus abundance β = -0.42 (± SE 0.19) (Table 1 and Figure 3a) (AIC $_{weight}$ 66%). During the 2014 survey, the model indicated

Table 1. Model selection for the 2001 and 2014 Great Argus surveys in Bala forest. "λ" indicates the abundance affected by the parameter in parenthesis, "r" indicates the detection probability affected by the parameter in parenthesis and "(.)" indicates the null model.

Survey	*No. Par*	*AIC*	*ΔAIC*	*wgt*	*-2*LogLike*
2001					
λ (slope), r (.)	3	261.81	0.00	0.66	255.81
λ (.), r (.)	2	265.14	3.33	0.13	261.14
λ (elevation), r (.)	3	265.36	3.55	0.11	259.36
λ (edge), r (.)	3	266.87	5.06	0.05	260.87
λ (road), r (.)	3	266.92	5.11	0.05	260.92
2014					
λ (edge), r (.)	3	188.81	0.00	0.51	182.81
λ (slope), r (.)	3	190.90	2.09	0.18	184.90
λ (.), r (.)	2	191.34	2.53	0.14	187.34
λ (road), r (.)	3	191.96	3.15	0.11	185.96
λ (elevation), r (.)	3	192.96	4.15	0.06	186.96

Note: *No. Par* is the number of parameters, and *wgt* refers to the *AIC* weight.

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Table 2. The abundance (λ, mean abundance with standard errors and 95% confidence intervals) and patch occupancy (ψ, site occupancy estimation with standard errors and 95% confidence intervals) estimations, including the probability of detection (r, and 95% confidence intervals) of Great Argus males in Bala forest, based on constant models in the 2001 and 2014 surveys.

Year	Number of survey locations	Survey area (km²)	λ (±*SE*)	95%CI	Ψ (±*SE*)	95%CI	r (±*SE*)	95%CI
2001	36	11.24	2.30±0.99	0.99 – 5.36	0.90±0.10	0.63 – 0.99	0.11±0.05	0.04 – 0.23
2014	29	14.27	1.48±0.25	1.07 – 2.06	0.77±0.06	0.66 – 0.87	0.67±0.06	0.54 – 0.78

that proximity to forest edge had a significant negative effect (β = 0.35 ± SE 0.17) on abundance (Figure 3b). In the 2014 survey the abundance appeared to increase relative to the edge of the sanctuary (> 1,000 m from forest edge), with mean abundance of more than 1.5 individuals at distances greater than 2,263 m from the forest edge (Figure 3b). Overall, abundances appeared to be lower in 2014, but in the interior of sanctuary > 3,000 m from the edge, abundances were relatively similar between the 2001 and 2014 surveys, 2.30 individuals/location and 1.85 individuals/location respectively (Figure 3a, b).

Discussion

We estimated the abundance and density of Great Argus in two surveys conducted 13 years apart in the Bala forest. The overall abundance of males decreased from 2001 to 2014. In addition, probability of detection was much lower in 2001 than 2014. We also monitored landscape variables affecting the abundance of male birds. Results indicated that only slope affected Great Argus site-to-site differences in abundance in the 2001 survey. The birds were negatively associated with slope, suggesting that the birds preferred the flatter areas within the sanctuary when calling and displaying on their

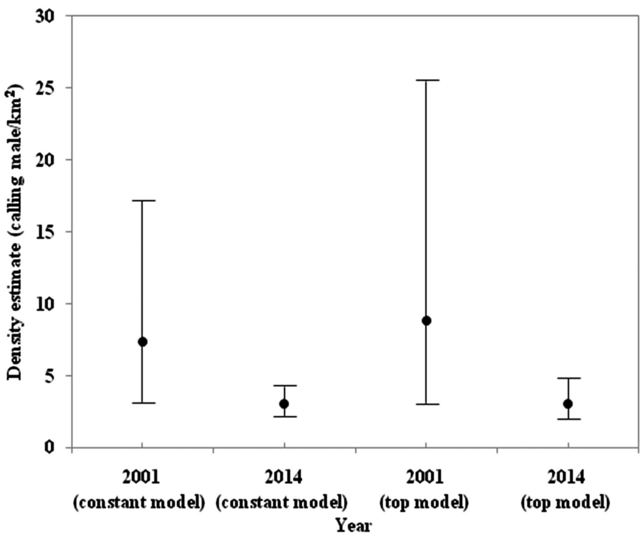

Figure 2. Comparison of the density (per km²) of male Great Argus in two survey years. The black dot represents the mean densities in 2001, 7.37 ± 3.18 and in 2014 was 3.02 ± 0.51 for the constant models, and 8.80 ± 4.76 in 2001 and 3.05 ± 0.69 in 2014 for the top models, respectively. The whiskers represent the 95% CI (the constant models in 2001 was 3.16–17.17 and in 2014 2.18–4.19, and the top models was 3.05–25.43 in 2001 and 1.97–4.80 in 2014, respectively).

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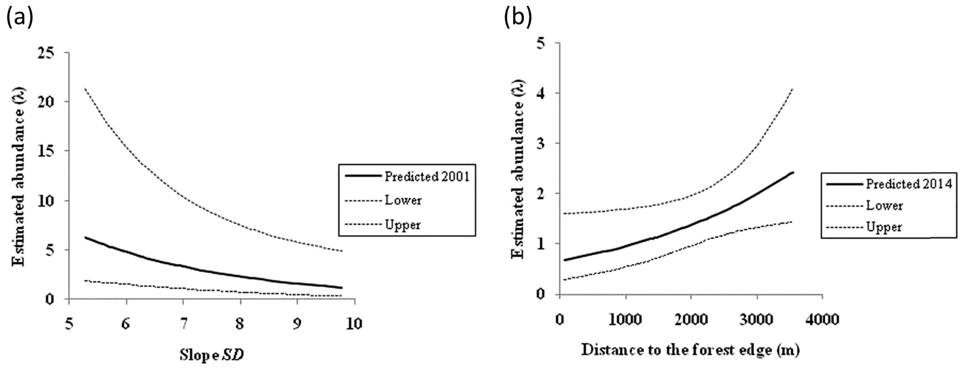

Figure 3. The effect of landscape variables on the abundance of male Great Argus, (a) the relationship to slope in 2001 and (b) the distance to the forest edge in 2014. Flat lines indicate the absence of a relationship. The dotted lines represent the 95% CI for the slope and edge effects.

dancing ground. In the 2014 survey, the primary significant variable was distance to forest edge, with abundance increasing away from the edge. Bala forest is surrounded by secondary forest, agricultural land and villages (Kemp *et al.* 2011). It is relatively easy for poachers to penetrate the forest from the forest edge. Therefore, distance to the forest edge in 2014 might imply greater disturbance from anthropogenic activities, which may have led to fewer detections near the edge (Figure 4).

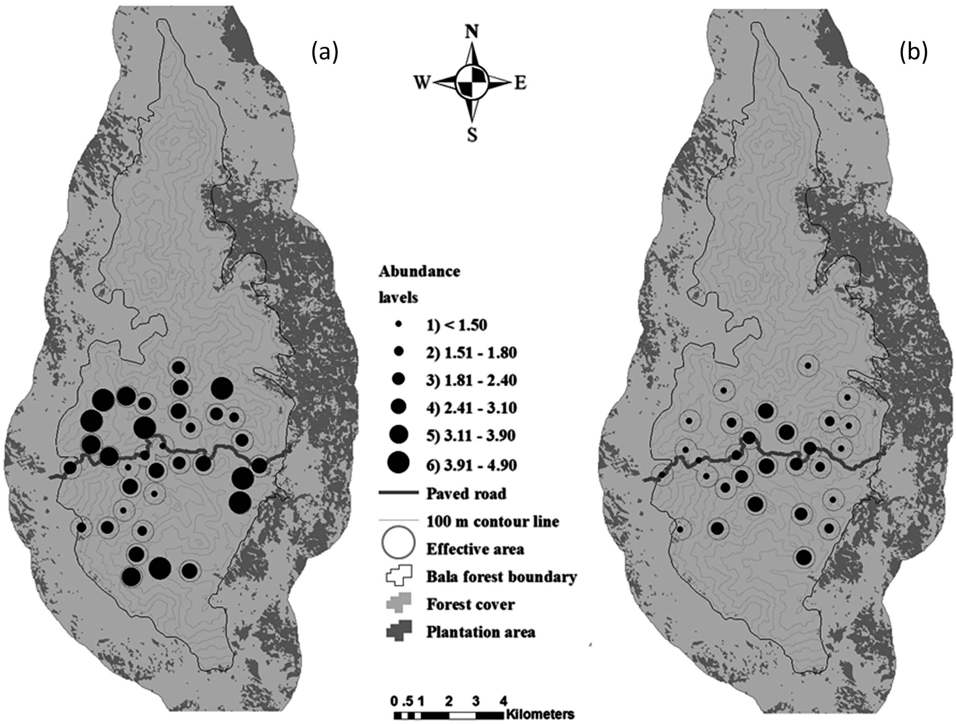

Figure 4. Map of Great Argus abundance levels for each location as affected by the distance to the edge of the forest in (a) the 2001 and (b) the 2014 surveys.

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Great Argus abundance and differences between the two surveys

All of our observations were performed during the peak of calling during the breeding season. The recorded difference in detection probability between the two survey periods could be related to inter-annual variation in food availability in the area, which affect the number of breeding males (Davison 1981b), or perhaps weather conditions. However, our abundance estimates were lower in 2014 when detection probability was higher. Our estimated decline by nearly one half of calling male Great Argus in Bala forest may be explained by anthropogenic activities around the sanctuary boundaries. In addition, in 2004 a roadside spot map sample in the core area of Bala estimated the density at 95% CI 7.38–9.36 males/km^{-2} (Kemp *et al.* 2011). This estimate was very close to the density we estimated from the 2001 survey data, and supports the evidence of the 2014 survey that the population has undergone a severe decline during the past 10 years. Nevertheless, as verbally reported by the park staff and the head of Papru-Pa Hala-Bala Wildlife Research Station, the level of human disturbance appeared to be high during the 2014 survey (frequent observations of wildlife traps, snares, and poaching).

Although we were unable to quantify the hunting of animals directly in this area, observations of hunting activity included snares, cartridges and bird cages, as well as the hunters themselves. Human density in other areas has led to anthropogenic activities and to declining wildlife populations (Parks and Harcourt 2002, Sodhi *et al.* 2010a, Woodroffe and Ginsberg 1998, Woodroffe 2000), and we suggest that this has also been the case for the Great Argus population in the Bala forest.

Effect of landscape variables on abundance

Slope in 2001 and distance to the forest edge in 2014 were the best models for the respective surveys. The predictors revealed that the abundance of the Great Argus increased with decreasing slope and increasing distance away from forest edge (for the 2001 and 2014 surveys respectively), the latter, perhaps as suggested, caused by increased anthropogenic activities at the edges of the sanctuary (poaching and selective logging). Selective logging and its edge effects is associated in terrestrial mammal species with avoidance of disturbed areas (e.g. sambar *Rusa unicolar*, muntjac *Muntiacus* spp., and small carnivore species; Brodie *et al.* 2015). Similarly, Brickle (2002) and Sukumal *et al.* (2015) in studies of Green Peafowl *Pavo muticus* (Phasianidae), found that human disturbance (the distance to human settlements) also negatively affected the number of Green Peafowl. Winarni *et al.* (2009) reported that the Great Argus in Bukit Barisan Selatan National Park (BBSNP), Sumatra, avoid inhabited and disturbed forest, preferring primary forest away from edges. Undisturbed primary forest probably offers a greater food supply for the bird than other forest types and also different vegetation structure, along with reduced hunting pressure (and the consequent need for vigilance), and increased plant species richness, presumably resulting in greater carrying capacity and hence higher densities (Davison 1981a, Nijman 1998). In addition, and contrary to our results, the study in BBSNP reported that Great Argus occupancy was not significantly affected in forests adjacent to the park boundary with villages and agricultural areas, but habitat occupancy did decrease with rising elevation, showing a strong association with forest structure and elevation (Nijman 1998, O'Brien and Kinnaird 2008). Our results in 2014 indicated that abundance of males was unrelated to elevation but they were more frequent in the core area than in areas close to the edge of the forest. This was also recorded in BBSNP by Winarni *et al.* (2009) who reported that the species shows an overwhelming use of undisturbed forest with birds avoiding disturbed areas (traditional rubber, resin and durian agroforests adjacent to primary forest). O'Brien *et al.* (2003) showed that Great Argus abundance was not affected by human density, forest edges and proximity to villages. The reason for this could be that the overall area surveyed by O'Brien *et al.* (2003) was little disturbed by human activities (poaching and hunting) and was adjacent to another park with fewer people.

Our interpretation that Great Argus prefers gentle slopes is related to the dancing behaviour of male. Previous studies did not investigate the effect of slope on relative abundance, but only of elevation (see O'Brien and Kinnaird 2008). The species apparently prefers lowland and hill forest below 1,200 m, with a low density of undergrowth and the presence of climber vines (Davison 1981b, Nijman 1998). In the breeding season, males seek areas with low ground cover to establish their dancing and calling areas (dancing grounds) (Madge *et al.* 2002). In the hilly areas in Ampang, Malaysia, dancing ground size ranged from 12 to 18 m^2 (Davison, 1981b), while in our hilly study site dancing grounds ranged from 8 to 50 m^2 ($n = 32$) and were mainly located on flatter patches. This differs from what was observed in the flat areas of Pasoh where the largest display site, 72 m^2, was recorded (Davison 1981a). Moreover, at the two sites in Malaysia (Ampang and Pasoh) no dancing grounds were found far from water, most likely because no ground suitable for dancing displays was found elsewhere (Davison 1981b).

Conclusion

Our results show a declining population trend of the Great Argus over the last 13 years at Bala forest. In addition, the 2014 data suggested that the birds avoided the forest edge. This might be explained by human disturbance (aquilaria tree *Aquilaria baillonil* poaching, hunting or bird catching for the wildlife trade), as confirmed by evidence found during a different camera trap survey (T. Dawrueng unpubl. data). The Bala forest is now a relatively small (~100 km^2), isolated forest area surrounded by agricultural land and villages, and so poachers can probably easily access the area. Our results were based on abundances from the best model, where forest habitat that contained the most calling males was > 2,000 m from the edge of the forest.

Our results suggest that the sanctuary authorities need to concentrate patrolling efforts in the border areas as the first step toward reducing disturbance from poachers, and to apply this in conjunction with outreach to local communities regarding the consequences of unsustainable forest use (Steinmetz *et al.* 2014). Over the past decade, patrolling effort in this area has been difficult due to the dangerous situation linked with political instability in the surrounding area. In our context, establishing an outreach program with the surrounding local communities to build motivation and promote the importance of direct and indirect benefits of conservation to villagers, and illustrating the importance of wildlife and forest resources would be most relevant (see Steinmetz *et al.* 2014). Finally, we strongly suggest the national status of the species be uplisted from its current status of 'Near Threatened'.

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