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Original research article

Change in status of green peafowl *Pavo muticus* (Family Phasianidae) in Southcentral Vietnam: A comparison over 15 years

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ABSTRACT

Biodiversity declines in Southeast Asia have led to predictions that many vertebrate species will become extinct within 50 years. Examples of quantified deterioration in species status remain scarce, however. The Southeast Asian geographical range of the Endangered Green peafowl is still contracting due to hunting pressure and habitat disturbance. In Vietnam, the main population lies in the southcentral region with a relatively high density reported in 1998. The aim of this study was to assess the species' current status in Yok Don and Cat Tien National Parks, which are thought to contain the most important Vietnamese populations. We used line and point transects to investigate the density and analyze habitat selection and effects of human activity. The Yok Don population has decreased sharply during the past 15 years, while in Cat Tien, the estimated density was higher. Animals were most numerous close to water sources and lowest where cattle numbers were highest and ground vegetation cover absent. Here we document a significant negative population change in a previously widespread vertebrate species. Although comparisons of population data over long periods are rare, we demonstrate that taking advantage of opportunities to resurvey species can quantify population declines.

1. Introduction

Global biodiversity has declined markedly over the past 40 years (Butchart et al., 2010; Cardinale et al., 2012; Hoffmann et al., 2010). Declines in species status have been especially marked in tropical regions where the status of vertebrates is considered to have deteriorated most (Hoffmann et al., 2010) and the probability of vertebrate extinctions is highest in Southeast Asia (Sodhi et al., 2004). The decline is at such a rate that a high proportion of vertebrate species face extinction within the next 50 years (Bennett et al., 2002; Laurance, 2006; Sodhi et al., 2004). In Southeast Asia, there are two main anthropogenic drivers of these rapid biodiversity declines. First is a reduction in the extent of natural habitat as a consequence of both legal and illegal logging and conversion to large scale agricultural production (Ziegler et al., 2009): Southeast Asia has higher annual rates of deforestation, particularly in the lowlands, than other parts of the tropics (Sodhi et al., 2010).

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Secondly, declines have been driven by direct over-exploitation of individual species to meet various demands, including food, tonics, medicines, and trade in live animals and body parts (Corlett, 2007; Duckworth, 2012).

Although the overall status of vertebrate species is known, the causes of decline are still known only in general terms rather than in detail (Cardinale et al., 2012) and case studies that quantify declines over meaningful time periods are limited. Where such information is available (for example California condor *Gymnogyps californianus* see Walters et al., 2010, and crested ibis *Nipponia nippon* see Xinhai Li and Dianmo Li, 1998), it has been shown that concerted action can improve the overall global conservation status of threatened species (Hoffmann et al., 2010). There is a need, therefore, to harness all opportunities to provide quantitative information on both status changes and their causes to allow informed decision-making in order to reverse species declines. This is all the more pressing given the commitment of most of the world's governments to prevent the extinction of threatened species by 2020 and to improve and sustain the conservation status of those most in decline (CBD, 2010). Given the plight of Southeast Asia's vertebrates and the political commitment to stop extinctions and reverse declines of the species most at risk, new practical and scientific approaches must be found to provide detailed information on change in status of such threatened species, such that they are both cost effective and of greater applicability and relevance than a single survey event. We took advantage of a short-term small-scale funding opportunity provided by the Critical Ecosystem Partnership Fund (www.cepf.net) to provide quantitative information on change in population size of a threatened bird species over a 15 year period in two protected areas in southern Vietnam.

Green peafowl (*Pavo muticus*) is one of the most threatened species in Southeast Asia due to hunting pressure throughout its now highly fragmented geographic range (BirdLife International, 2001; McGowan et al., 1999). It was formerly distributed from northeast India and Yunnan in southwest China through Myanmar, Thailand, Laos, Vietnam, northern Cambodia and Peninsular Malaysia to Java in Indonesia (Delacour, 1977) but has been considered a high priority for conservation attention for 15 years (e.g. Brickle et al., 1998; McGowan et al., 1999). It was uplisted from Vulnerable to Endangered on the IUCN Red List in 2009 (BirdLife International, 2014).

Two populations in Vietnam were known to offer long-term survival prospects: Dak Lak Province and Cat Tien National Park. Fifteen years ago Dak Lak was thought to hold the country's largest population of the species, centered on Yok Don National Park and enhanced protection was seen as important for ensuring that the population remained (BirdLife International, 2001; Brickle, 2002). Cat Tien in Dong Nai Province held an estimated density of 17 calling males in approximately 13 km^2 in the center, southeast and northeast part of the protected area (Robson et al., 1991; see also McGowan et al., 1999).

The aims of this study were (1) to determine population densities of green peafowl at its two strongholds in Vietnam; (2) to compare these density estimates with estimates made 15 years ago; and (3) investigate the habitat use of green peafowl in these two national parks.

2. Study area

Cat Tien National Park (11°20′N, 107°09′E), has a total area of 720 km^2 in three provinces (Dog Nai, Lam Dong and Binh Phuoc). It lies at an elevation of 119–200 m but isolated hills up to 300 m can be found within the park. It is dominated by evergreen forests, which covers 63% of the park, and wetland (comprising a marsh and wet grassland) and dry grassland where green peafowl is found, occupies 8% in the southeast, center and northeast of the national park (Fig. 1a). Cat Tien National Park was well known for a small populations of lesser one-horned rhinoceros (*Rhinoceros sondaicus annamiticus*) in Cat Loc. However, this species was confirmed as extinct in the area in 2011 (Brook et al., 2011).

Yok Don National Park (12°47′–13°00′N, 107°29′–107°50′E) is the largest national park in southcentral Vietnam and is located in Dak Lak Province, where it borders Cambodia. The total area of Yok Don National Park is 1155 km^2 mainly dominated by dry deciduous forest (75% of total area) (Fig. 1b) which is thought to comprise the majority of suitable habitat for Vietnam's remaining green peafowl population (BirdLife International, 2001; Brickle, 2002; Brickle et al., 1998). The area is relatively flat at an elevation of about 200 m, but with high spots up to 474 m (Sterling et al., 2006). Evergreen forest is found on Yok Don Mountain in the south and Chu Minh Mountain in the north. Prescribed burning is conducted commonly during the dry season (November–April). The green peafowl survey throughout Dak Lak Province in 1998 reported that the largest number of green peafowl was in northwest part of the park.

3. Methods

3.1. Density estimation

Surveys were conducted during two breeding seasons (January 2012 and 2013) when the birds frequently call (Brickle et al., 1998; Johnsgard, 1999; Ponsena, 1988). Density was defined using line transects. In both protected areas line transects were located on existing non-asphalt roads inside the park where traffic was very limited. Each transect was 2 km long and was marked every 20 m before the survey was conducted. Each transect was walked 10 and 14 times, by different observers, during daily peak calling periods. These times were 06.30–08.30 (at Cat Tien in 2012) and 06:00–08:00 (at Yok Don in 2013) in the morning (time adjusted to reflect difference in the start of calling at each site) and 16.15–18.15 in the evening. The distance to each calling bird was assigned within 50 m distance categories and the farthest detection distance was set at 1 km for both auditory and visual detection from the observer (Brickle et al., 1998; Indrawan, 1995). Before data collection

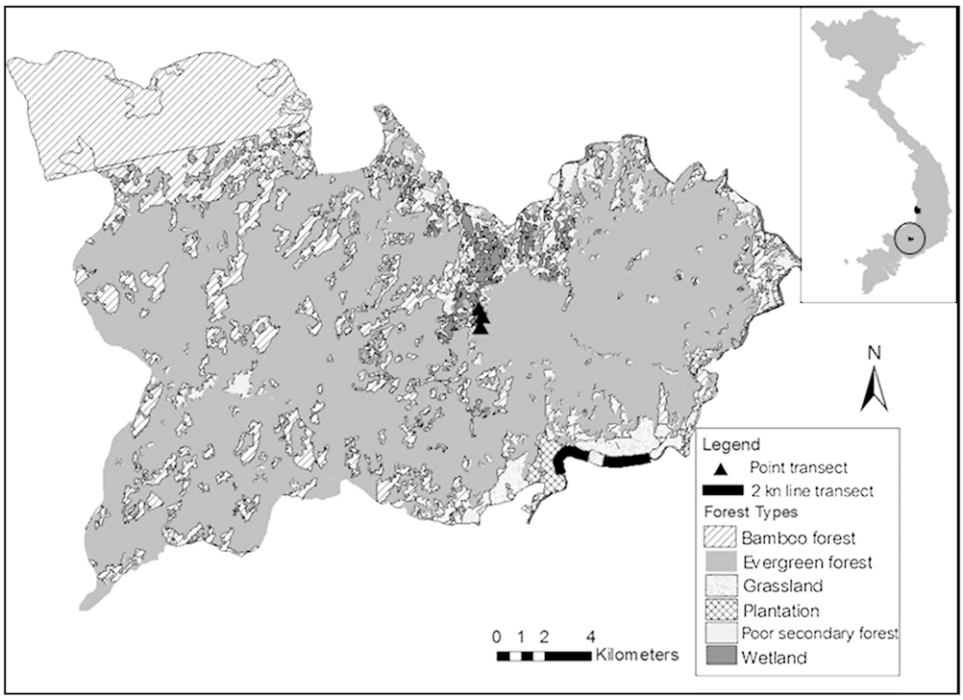

Fig. 1a. The map of Cat Tien National Park with two lines transects conducted on the grassland in southeast part and three points transects conducted on Crocodile Lake in center part.

started, all observers conducted preliminary surveys together to standardize estimates of distance to calling birds in order to minimize errors between observers (Buckland et al., 2001).

In Cat Tien National Park, we surveyed only the southern portion of the protected area where we focused on the southeast and central part areas from where the species has been reported (McGowan et al., 1999; Robson et al., 1991). In the southeast part, two 2 km line transects, that were 540 m apart, were set along the road that runs parallel to Dong Nai River, demarcating the park boundary, through the grassland (Fig. 1a). Two observers walked each transect at the same time for seven consecutive days so that each transect was walked twice a day and 14 times in total. The survey in the central part was focused around Crocodile Lake where point transects were used instead of line transects as it was not possible to conduct line transect surveys because the topography made the area inaccessible. Around the lake three accessible point locations were established 400 m apart (Fig. 1a). Point counts were conducted twice a day by three observers for seven consecutive days giving 14 repeat surveys per point.

Yok Don National Park was divided into three sectors (south, center and north) separated by Yok Don Mountain in the south and Chu Minh Mountain in the north. In each sector we located 2 km line transects (15 in total) along the accessible road system that runs within the park (Fig. 1b). One observer walked each transect twice a day for five consecutive days (five observers in total), giving 10 repeat survey per transect.

The number of detected calling males at each survey was treated as a response variable. The location of each calling bird was defined, after collecting bearing and distance estimated from each surveys, using ArcGIS 9.3. Double count of a single calling bird within the same location was corrected for each survey to estimate a number of bird occurrence at each survey.

3.2. Long term density comparison

The number of calling birds observed in 2013 at Yok Don National Park was compared with the observations made by Brickle et al. (1998). The areas surveyed in the two years did not overlap entirely with the area surveyed by Brickle et al. (1998) because of changes to the forest as a result of human settlement. In 2013, therefore, we sought to cover as much of Yok Don National Park as possible. For practical purposes, we divided the green peafowl population into three sectors separated by Yok Don and Chu Minh Mountains (Fig. 1b). In 1998 there were 13 point count observations and in 2013 there were 15 line transects. All transects in 1998 and 2013 covered the south, center and north of Yok Don National Park. For further detailed comparison, we sought to compare the mean number of calling birds in 2013 with the data provided by Brickle et al. (1998) for each of these three sectors.

The only previous quantitative assessment of green peafowl numbers in Cat Tien National Park was provided by Robson et al. (1991: see also Robson et al., 1993), who reported 17 calling birds in 13 km^2. They gave no details of survey method or

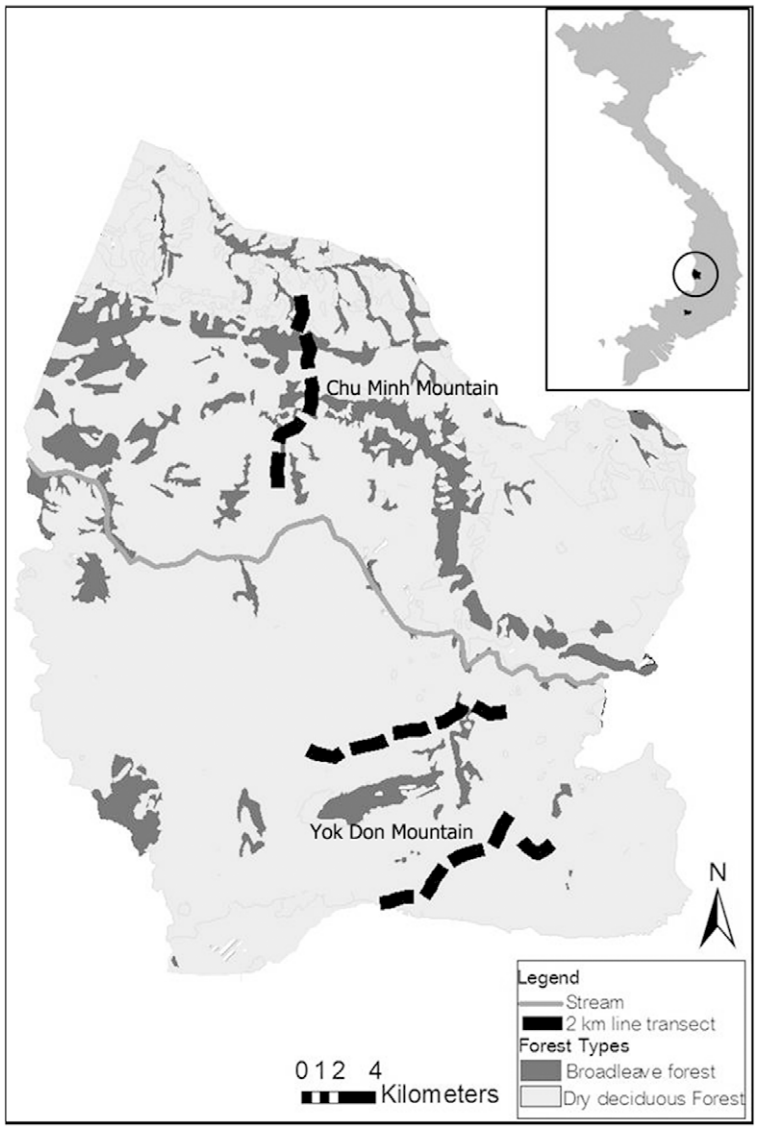

Fig. 1b. The map of Yok Don National Park with 15 lines transects in the south, center and north parts.

effort: the density from this study was compared, therefore, with the number of birds per square kilometer given by Robson et al. (1991).

3.3. Investigating habitat use and effect of human activity

We measured habitat variables both at a small scale, directly along each transect, as well as at large scale, using Google Earth 7.1.2. The small scale variables recorded were: (1) ground vegetation coverage (absent, low and high) every 100 m along each transect; and (2) presence of domesticated cattle (present or absent) at every 100 m on transect. Large scale variables recorded were: (3) distance to permanent running or standing water, determined using Google Earth direct observation, discussion with rangers and consulting maps; and (4) distance to permanent human settlement, which was determined by observation, discussion with rangers and map consultation. All habitat variables and presence of human activities were treated as predictor variables.

3.4. Statistical analysis

The possibility of double counting the same bird was first considered by observers during the survey based on direction and distance from transects of each call. Subsequently, we also used ArcGIS 9.3 program to place each calling bird along each transect to define possible overlaps. All double counts were eliminated before conducting density analysis.

Table 1
Density estimates for green peafowl in Yok Don and Cat Tien National Parks.

Sites	Survey method	Survey area (km^2)	Density estimates (calling birds/km^2)	95% confidence intervals	Number detected
Yok Don National Park	Lines	40	0.253	0.116–0.553	54
Cat Tien National Park South (grassland)	Lines	8	3.025	1.443–6.342	203
Center (crocodile lake)	Points	4.74	4.694	2.148–10.261	156

First, we combined all line transects for each national park and stratified the analysis between the two national parks to estimate a density. Second, we analyzed line and point transects from Cat Tien National Park and Yok Don National Park separately. The density at Crocodile Lake in Cat Tien National Park was determined by combining all three point transects and stratifying the analysis for each point transect, and reporting the pooled estimates for a density at Crocodile Lake.

Density was estimated using DISTANCE version 6.0 (Thomas et al., 2010) as we considered a detection probability to provide the best approximation of actual densities for green peafowl in each area. Detections were entered as single objects and only aural detections were analyzed. We excluded visual detection as there were too few and they included both males and females, in contrast to the calls, which were only from males. All key functions of uniform, half-normal, hazard, and negative exponential with all series adjustment of cosine, simple polynomial, and hermite polynomial were examined to select the best model with lowest Akaike's Information Criterion (AIC), following Buckland et al. (2001).

The statistical analysis was conducted using program R (Crawley, 2007) to compare the number of green peafowl observed in 1998 and 2013, and to investigate habitat selection. We used non-parametric Mann–Whitney *U*-tests to compare between the number of calling birds observed along each transect in 2013 and each survey point observed by Brickle et al. (1998). A habitat selection model was developed using a total of 178 surveys from 17 line transects comprising 150 surveys from 15 line transects in Yok Don National Park and 28 surveys from 2 line transects in Cat Tien National Park. The response variable (number of calling birds) was over-dispersed (ratio of variance to mean = 5.535) and contained more zeros than expected indicating that a zero-inflated negative binomial model was most appropriate for these data. We ran the model using mixed effects, treating day as a random component of our repeated surveys on each transect (Zuur et al., 2009). Each continuous predictor variable (i.e. distance to permanent human settlement or to water) was standardized by dividing the values by twice the standard deviation (Gelman, 2008) in order to transform the data to the same scale. The best model was selected based on the lowest AIC value (Burnham and Anderson, 1998).

4. Results

4.1. Density estimation

In Cat Tien National Park birds were detected both in the grassland and around Crocodile Lake. In Yok Don birds were detected in two of the three sections (north and south) and were absent from the central section.

Density estimates from distance sampling were obtained for 12 line transects, 10 from Yok Don National Park and two from Cat Tien National Park, and for three point transects around Crocodile Lake in Cat Tien National Park. We excluded five line transects from the center of Yok Don National Park from the analysis because there were no green peafowl detections there. The minimum number of detections for distance sampling analysis followed the recommended minimum number of 60–80 detections (Buckland et al., 2001). As the number of detection for Yok Don National Park was 54, after eliminating double counted records of same calling bird, we combined the detections from both Yok Don and Cat Tien National Parks into one data set and stratified the analysis by site.

The density of green peafowl was 0.25 calling males/km^2 for Yok Don National Park, while in the southeast of Cat Tien National Park the density was 3.03 calling males/km^2 and in the center, around Crocodile Lake, it was 4.69 calling males/km^2 (Table 1).

4.2. Long term density comparison

There was a significant difference between the number of calling birds observed in 1998 and 2013 in Yok Don National Park (Mann–Whitney *U*-test, $w = 141.5$, $p < 0.05$). The number of calling birds observed in 2013 was lower than observed in 1998 (Fig. 2). Moreover, the mean numbers of calling birds in the southern and northern sectors (i.e. south of Yok Don Mountain and north of Chu Minh Mountain respectively) were also lower in 2013 than in 1998. In 2013 we observed 0.7, 0.26 and 0.03 in the south (from 5 line transects in the south of Yok Don Mountain), center (from 7 line transects between Yok Don and Chu Minh Mountain) and north part (from 3 line transects in the north of Chu Minh Mountain) respectively; while Brickle et al. (1998) reported 2, 1 and 3.86 respectively in those three parts (Fig. 3).

The only previous density estimate made in Cat Tien National Park was that by Robson et al. (1991), who recorded 17 calling birds in approximately 13 km^2 in the center, southeast and northeast part, giving a density estimate of about 1.31 calling birds/km^2. The density estimation from our survey in 2012 was 3.03 and 4.69 calling birds per square kilometer in

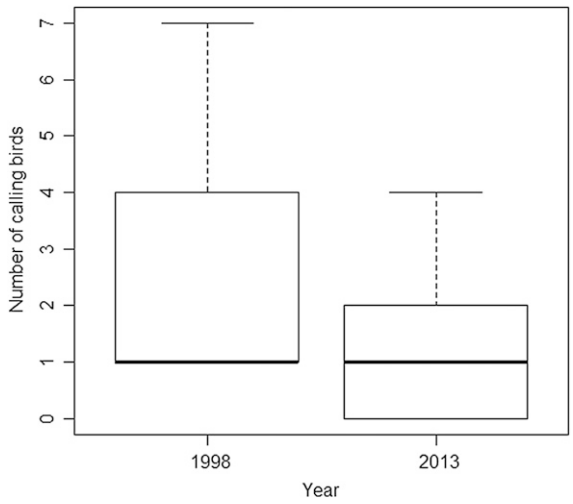

Fig. 2. The comparison between number of calling birds observed in 1998 by Brickle et al. (1998) and the observations in 2013 at Yok Don National Park. The darkest horizontal lines represent the medians and the whiskers represent 25% and 75% quartiles.

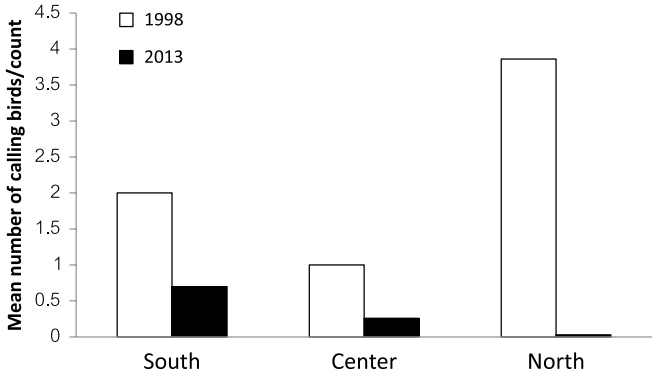

Fig. 3. The comparison between the mean numbers of calling birds observed in 1998 by Brickle et al. (1998) and the observation in 2013 on the south (south of Yok Don Mountain), center (between Yok Don and Chu Minh Mountain) and north parts (north of Chu Minh Mountain) of Yok Don National Park.

Table 2
Detail of parameters in final accepted model with lowest AIC = 395.714 show in the table.

Parameter	β	z-value	p-value
(Intercept)	1.913	15.97	<0.0001
Distance to water	−2.832	−7.12	<0.0001
Presence of cattle	−1.241	−5.5	<0.0001
Low ground vegetation coverage	−2.038	0.608	0.0008

the southeast and center part respectively. In contrast to Yok Don National Park, the density estimates in these two areas of Cat Tien National Park were higher in 2012 than in 1991.

4.3. Habitat use and effect of human activity

The habitat type was not included in the model as all the survey transects in Yok Don National Park were located in dry deciduous forest, while the survey transects in Cat Tien National Park were conducted mainly in grassland and on the edge of a lake.

Distance to human settlement was strongly correlated with distance to water ($r = 0.389, P < 0.0001$) and thus we selected only distance to water to run in the models. The best model (i.e. that with the lowest AIC) had distance to water ($\beta = -2.832, p < 0.0001$), presence of cattle ($\beta = -1.241, p < 0.0001$) and vegetation coverage ($\beta = -2.038, p = 0.0008$) all having a significant negative influence on the number of green peafowl detected (Table 2).

5. Discussion

We conducted surveys of the two most important green peafowl populations remaining in Vietnam, and which are found in two key protected areas. The density of green peafowl was lower in Yok Don National Park than in Cat Tien National Park. Moreover, the number of calling birds in Yok Don National Park recorded in 2013 was significantly lower than that observed in 1998. The higher density estimate from Cat Tien may be a result of the different distributions of habitat patches in the two parks, with birds aggregating in the open grassland and wetland in Cat Tien. The density recorded in Yok Don was much lower than expected for the whole of the national park, given large extent of dry deciduous forest (see BirdLife International, 2001; Brickle, 2002; Brickle et al., 1998) that was thought capable of sustaining a larger population. The habitat selection model suggested that the green peafowl mainly used areas close to water sources and that had a high coverage of undergrowth vegetation and few or no cattle. The lower density and drastic reduction of the green peafowl population in Yok Don might be a consequence of higher disturbance, through grazing, bushfires and poaching, than in Cat Tien. All of these were also observed during the survey.

Historical information on population status was limited and this makes it difficult to monitor change. In Vietnam, historical information is almost entirely species occurrence records (McGowan et al., 1999) and the Dak Lak province distribution survey in 1998 (Brickle, 2002) providing the only population estimate prior to our study. The different survey methods and effort may influence the resulting density estimates. Nonetheless we have provided the most reliable current estimates of green peafowl densities that allow the monitoring of change. This can provide a basis from which to identify appropriate conservation action, which is otherwise a considerable challenge for the most threatened species in Southeast Asia and requires the highest conservation action priorities.

5.1. Density change

The comparison of calling birds observed in 1998 and 2013 shows a decrease in Yok Don National Park. The survey in 2013 was conducted on January while the survey by Brickle and co-authors in 1998 was conducted between February and April, both of which are during the green peafowl's November–April breeding season (Johnsgard, 1999). Conducting the survey in different months within the breeding season should not give different detection probabilities as the green peafowl calls frequently during breeding season (Brickle et al., 1998; Johnsgard, 1999; Ponsena, 1988). All of our observations in Yok Don National Park were conducted in dry deciduous forest which is suitable habitat for green peafowl. The small and decreasing population of green peafowl in Yok Don may be explained by the high disturbance levels in the park, as evidenced during the survey (i.e. signs of grazing, bushfires and poaching).

5.2. Habitat use and effect of human activity

The habitat selection model revealed that the distance from peafowl to human settlement was significantly correlated with distance to water and villages were found mostly near the river where the green peafowl also occurred. Water sources have been reported as important for green peafowl (Brickle, 2002; Johnsgard, 1999; Madge and McGowan, 2002), although the open habitat surrounding water source might also be a factor for their habitat selection. The habitat model showed that presence of domestic cattle had a negative effect on the number of green peafowl, with large numbers of cattle resulting in few green peafowl. Overgrazing in the area causes habitat degradation, especially on ground vegetation and year round grazing may disturb ground nesting birds during breeding season (Ammon and Stacey, 1997). A study in China showed that grazing intensities had negative effects on grassland biomass especially above ground biomass and during drought periods, plants were more vulnerable to grazing (Liang Yan et al., 2013). Green peafowl were found mainly in areas with high coverage of ground vegetation, where seeds, leaves and insects provide food. We found feces along a track of green peafowl footprints on one transect in Yok Don National Park and it contained a grass seed.

5.3. Conclusion

This study provides much-needed quantification of population status over a time scale that is longer than many short-term studies and which can be used to assess management effectiveness. Our results suggest that Yok Don, once so important for this species, has not been effective at maintaining the population, whereas Cat Tien National Park, in contrast, has been. Within Cat Tien, however, there is variation and it appears that the part of the park that is most well known for tourism has not only the best current population but it has not declined either. Where there is little tourism, however, problems can be acute, as demonstrated by the extinction of the lesser one-horned rhinoceros in Cat Loc in 2010 (Brook et al., 2011). The status of the green peafowl population in northeast part which was recorded in 1991 (Robson et al., 1991) is still not clear and might also be subject to a decline from hunting pressure as it lies far from highly visited area. In Costa Rica the population of scarlet macaw (*Ara macao*) increased after by stakeholders stimulated economic activities focusing on the development of ecotourism (Vaughan et al., 2005).

We recorded 165 bird species in Yok Don, of which five were categorized as threatened or near-threatened (IUCN, 2012): great slaty woodpecker (*Mulleripicus pulverulentus*) (Vulnerable), great hornbill (*Buceros bicornis*) (Near Threatened),

red-headed vulture (*Sarcogyps calvus*) (Critically Endangered), white-rumped falcon (*Polihierax insignis*) (Near Threatened), lesser adjutant (*Leptoptilos javanicus*) (Vulnerable). We also encountered two Near Threatened (IUCN, 2012) species of mammals: silvered langur (*Trachypithecus cristatus*) and black giant squirrel (*Ratufa bicolor*). All of this information demonstrate the importance of these two sites, even if there is no planned quantitative tracking of the status of key species over time. We have quantified change in conservation status of a large-bodied terrestrial vertebrate and shown that in Yok Don National Park the species has declined substantially, whereas in Cat Tien National Park it has maintained its population in important tourist areas. The increase in tourist activity in Cat Tien National Park, with a consequent increase in financial revenue for the area, might have encouraged the adjacent rural communites to avoid disturbing the forest (i.e. hunting and grazing cattle in the park) as well as increased the park's management effectiveness. Outside such managed areas, however, there are serious problems, as evidenced by the loss of the last one-horned rhinoceros in the park and which marked its extinction in Vietnam and mainland Southeast Asia.

Limiting free-range grazing and the setting of bushfires inside Yok Don National Park might reduce the level of disturbance to green peafowl and other wildlife. An increase in protection around water sources is necessary because green peafowl and other wildlife seem likely to gather here, especially in the dry season if not all year round. The streams and rivers in Yok Don National Park, such as Dak Na, Dak Klau and Dak Ken streams in the south part, Sero Pok River in the center and Dak Rue stream in the north which would benefit from an increase in protection on both sides should be a first priority for conservation action in Yok Don. The grassland in the south-east of Cat Tien National Park is very close to a village and it seemed that green peafowl was less sensitive to human settlement as it had been reported flying across Dong Nai River and roosting near a village outside the park. Green peafowl in this area is well known to birdwatchers and as a result villagers have given importance to the species, which is now subject to low hunting pressure inside Cat Tien National Park. In contrast, Yok Don National Park is not easily accessible for general tourists and birdwatchers. Several bird species that we recorded during the survey were birds of dry deciduous habitat and are listed as threatened species. These species may be of interest to birdwatchers and the area could be promoted for this activity. This may, in turn, lead to the villagers inside and around the park increasing their awareness and giving importance to wildlife and the forest in Yok Don. Ideally, a wildlife monitoring program would be conducted at the same time to provide an assessment of trends in wildlife populations and identifying threats, if present in the area.

The results from this study have been presented and discussed with the chief and staff of both Cat Tien and Yok Don National Parks. In Yok Don National Park, we have discussed concentrating patrolling effort in the areas where there is important habitat as a way of addressing problems of disturbance and as a first step towards appropriate management. Park staff took part in the survey and so understand the field protocols used.

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