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Population density and habitat loss of chestnut-headed partridge in southwest Cambodia

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Abstract

In Southeast Asia, wildlife extinction risk has increased in recent decades, primarily due to habitat loss and over-exploitation. Consequently, it is predicted that 32% of bird species in the region will be extinct by the end of this century. However, this estimate could be even higher, as a result of other poorly understood threats, such as the impact of climate change and invasive species. One at risk species is the chestnut-headed partridge *Arborophila cambodiana,* which is near-endemic to southwest Cambodia's Cardamom Mountain range. We estimate the population densities of *A. cambodiana* in their remaining habitats, their current distribution range and broad-scale habitat changes from 1996 to 2016. We used line transects and camera traps to survey *A. cambodiana* in four protected areas in the Cardamom Mountains. *A. cambodiana* was mostly detected in evergreen forest at altitudes above 400 m and less in semi-evergreen forest. The presence of *A. cambodiana* was positively associated with elevation and slope. Over the past 20 years (1996-2016) the potential habitat of *A. cambodiana* was degraded by approximately 12% and the total evergreen forest cover in the Cardamom Mountain range has decreased by 20%. *A. cambodiana* has a very restricted range within which the habitat has been fragmented. Compounded by human disturbance and development activities that negatively affect the species, we suggest a revision of its status to 'Vulnerable' under IUCN Red List criteria A2abc; B1b (*iii*) c (*i*); C1 criteria.

Keywords:

Cardamom Mountain, Arborophila cambodiana, population density, habitat loss, distribution range.

Introduction

Recent global human population growth has resulted in the largest impacts on biodiversity ever recorded, mostly as a result of conversion of natural forest to agricultural land (Corlett, 2014). Over the past four decades, global biodiversity has decreased at an alarming rate, with the main declines occurring primarily in tropical areas, where most threatened vertebrates are found (Butchart *et al.*, 2010; Hoffmann *et al.*, 2010). In Southeast Asia, extinction risk has increased markedly due to anthropogenic activities (Hoffmann *et al.*, 2010; Duckworth *et al.*, 2012), such as overexploitation and deforestation, the rate of which are among the highest in the tropics (Heino *et al.*, 2015) and are still increasing (Miettinen *et al.*, 2011). A recent prediction estimated that nearly 50% of the region's mammal populations and 32% of bird populations will be extinct by the end of this century. At least half of these could represent global extinctions, and the number could be even higher due to other threats such as climate change and invasive species (Brook *et al.*, 2003). Within the region, Cambodia had the highest deforestation rate for 2013 (Hansen *et al.*, 2013; Corlett, 2014) as a result of its Economic Land Concession (ELCs) development and road system expansion with consequent increases in hunting and logging (Clements *et al.*, 2014).

Mainland Southeast Asia mostly lies within the Indo-Burma Biodiversity Hotspot (Myers *et al.*, 2000) and supports 72 galliform species (World Pheasant Association, 2017) mostly comprising three genera: *Lophura*, *Arborophila* and *Polyplectron*.

Galliformes show a globally high extinction risk with 25% of the 308 species in the IUCN Red List, compared to 13% for all bird species (BirdLife International, 2016), while for Southeast Asia this rises to 27% of galliform species threatened with extinction. As for most biodiversity in the region, the major threats are habitat loss and fragmentation and hunting. Unfortunately, the ecology and conservation status of most galliform species within the region is poorly known (Grainger *et al.*, 2018) and for some genera, such as *Arborophila*, almost no quantitative data are available, with the exclusion of few case studies (Vy *et al.*, 2017).

The chestnut-headed partridge, *Arborophila cambodiana*, is restricted to the Cardamom Mountains in southwest Cambodia with a small population also found in southeast Thailand (Eames *et al.*, 2002). Initially described from what is now Bokor National Park in 1928 (Delacour, 1929) and thought to be a common resident of the mid elevation (400-1400m) semi-evergreen and evergreen hill forests (Goes & Furey, 2013), the species is little known and limited information has been collected and reported over the last 60 years, in part due to civil war in the area from 1967 to 1998 (Poole, 1999). This paucity of information prompted *A. cambodiana* to be defined as Endangered in 2002 (BirdLife International, 2016). However as more information slowly trickled in, primarily consisting of anecdotal observations by bird watchers, the species was downgraded to Vulnerable in 2004 and to Least Concern in 2009, mainly based on the estimated available habitat (BirdLife International, 2016) and survey reports (Samnang *et al*., 2009). However, these assessments may not now reflect the true situation. Large areas of the Cardamom Mountains have been zoned as economic land concessions, which either have or are likely to be cleared for agro-industrial plantations. Areas of both Bokor National Park and Kirirom National Park are threatened with poorly controlled tourism development, whilst agricultural development (pepper farming) is increasing in Phnom Samkos Wildlife Sanctuary and Botum Sakor National Park. This resulted in 2146 km^2 (10% of the total area) of the Cardamom Mountain range being converted to agriculture through ELCs (Open Development Cambodia, 2014). In addition, in 2007 hunting was believed to be the major threat, followed by land conversion (Samnang *et al*., 2009).

In order to assess the conservation status of *A. cambodiana* within its restricted and diminishing range, and to address the lack of detailed information on the species, We aim to: 1) estimate the current distribution and population density of *A. cambodiana* in the Cardamom Mountain range; 2) assess habitat change over the past 20 years; and 3) provide an updated recommendation for the specie's conservation status based on revised habitat availability and density information.

Methods

Study sites

We surveyed *A. cambodiana* at four sites in Cambodia’s Cardamom Mountains range: Bokor National Park, Central Cardamom National Park, Phnom Samkos Wildlife Sanctuary and Southern Cardamom National Park (Figure.1). The Cardamom Mountains cover approximately 23,000 km^2 and range in elevation from 0 to 1,800 m (Stuart & Emmett, 2006). The Cardamom are covered with tropical evergreen and semi-evergreen forests (Eames *et al*., 2002) and are subject to a tropical monsoonal climate with a wet season from May to October (2000 to 5000 mm total rainfall) and a dry season from November to March (2,000 to 3,000 mm). Average temperatures range from 25-30^o C, but can drop below 15^o C at higher elevations (Daltry & Momberg, 2000).

Bokor National Park (BKNP 10^{0}47’ N 104^{0}01’ E) is situated in the Elephant Mountains, a southern offshoot of the Cardamom Mountains, covering an area of 1,418 km^2 with an elevation range from 30 - 1,079 m. The park is dominated by a large massif with an extensive plateau at around 1,000 m. It mostly supports large and intact areas of evergreen forest, with wet evergreen forests found mostly in the south, and deciduous and semi-evergreen forests in the north.

The *Central Cardamom National Park* (CCNP, 11^{o}59’ N 103^{o}29’ E) covers an area of 4,015 km^2 and is characterized by large rivers and expanses of lowland evergreen forests on the rolling foothills with an elevation ranging from 300 to 1,300m. Unlike the other sites in the Cardamom Mountains range, this area is derived from Mesozoic sandstones.

Phnom Samkos Wildlife Sanctuary (PSWS, 10°29’ N 102°57’ E) covers 3,302 km^2 and is named after Samkos Mountain, which is Cambodia’s second highest peak (1,717 m). The vegetation consists of lowland evergreen forest, medium altitude evergreen forest, semi-deciduous forest, dry deciduous forest, lowland and medium altitude forests on limestone, pine forests and montane grasslands. PKWS ranges in elevation from 300 – 1,700 m.

Southern Cardamom National Park (SCNP, 11°48’ N 103°06’ E) covers 4,114 km^2 with an elevation range from 10 – 980 m. The vegetation is similar to the CCNP and constitutes one of the region’s largest continuous areas of rainforest. It is ecologically important as it provides the main corridor for Cambodia’s largest remaining population of Asian elephant (*Elephas maximus*), allowing them to move through the landscape, including into Thailand.

Density estimates

Bird densities were estimated using line transects in three different protected areas (BKNP, CCNP and PKWS). A total of 30 transects were established, 10 in each protected area, along existing human and animal trails when those were approximately straight. If trails were unsuitable, not straight, or not available, straight lines were cut through the forest, avoiding areas with land mines. In each protected area we established five study locations, each comprising two line transects spaced 300 m apart (Figure 1). Transect length varied from <1 km, where they were cut through the forest, to >4 km when existing human and animal trails were found. Line transects were surveyed from 28 January 2015 to 25 December 2015 and 09 January 2016 to 28 March 2016 which corresponded with the *A. cambodiana* breeding season (both nesting and mating) last three months (April-June) when detections are higher (Goes & Furey, 2013).

Each transect was walked by two different observers simultaneously four times a day (morning: 0600-0900 and 0900-1130 and afternoon 1400-1630 and 1630-1800) for three consecutive days, except during periods of heavy rain. The point at which a calling *A. cambodiana* was heard along a transect was recorded by GPS (Garmin 62SC), as well as time, the estimated distance from observers and direction from observer, using a compass bearing. These data were used to define the perpendicular distance of birds to the transect line using ArcGIS. To avoid double counting we assumed that if multiple birds were heard calling within three minutes of one another, within a bearing range of 10 degrees and within a radial distance of <100 m they were a single calling group. We excluded eight line transects that had no detection from analysis, where six were at an elevation of below 400 m (four located in BKNP and two at CCNP) and two line transects in high elevation pine forests at CCNP.

We used distance sampling protocols to estimate *A. cambodiana* density (Buckland *et al.*, 2001; Buckland *et al.*, 2008). Only calling male birds recorded from line transects were used to calculate density. Sighting-only detections were excluded from the analysis because only two groups of *A. cambodiana* were sighted during the survey period. Distance 7.1 (Thomas *et al.*, 2010) was used to estimate *A. cambodiana* detection probability and density. Key functions uniform, half-normal, and hazard with cosine adjustments were used to run the analysis. The model fitness was selected using a combination of visual assessment of the distribution curve, goodness-of fit test, and the lowest Akaike's Information Criterion (AIC) (Akaike 1973). As the number of detections of *A. cambodiana* from each study site was small, we tested the difference among detection functions of each study site by comparing the value of AIC between global and stratified models. For the global model, we estimated density by pooling all detections from each study site and with the stratified model, we estimated density by stratifying detection function with different study site and derived density at each site using the same half-normal key function. Finally, the best model selection were based on the AIC value and coefficient of variance (CV) from each model (Buckland *et al.*, 2001).

Camera trap survey and Habitat association

To increase the number of *A. cambodiana* detections that could be used in the habitat selection analysis, data from two camera trap surveys were included (Figure 1). The first data set consisted of a pair of cameras that were installed at 74 locations (total 15,080 trap-nights) from December 2013 to March 2014 by the Wildlife Conservation Research Unit of Oxford University to target the common leopard (*Panthera pardus*) at CCNP between elevations of 565 and 1,169m. The second survey consisted of a single camera at 66 locations (total 8,236 trap-nights) set from December 2015 to January 2016 by Wildlife Alliance - Cambodia to target Indochinese tiger (*Panthera tigris*) prey at SCNP between elevations of 105 to 620m. In both cases camera traps were set in a systematic 2 km grid placed 20 to 50 cm above the ground. Elevation, slope and distance to the nearest water source were considered as the main environmental variables likely to influence *A. cambodiana*. Elevation and slope were extracted from the ASTER GDEM at a scale of 30 x 30 m (Global Digital Elevation Model) downloaded from the Earth Remote Sensing Data Analysis Center (http://www.jspacesystems.or.jp/ersdac/GDEM/E/4 -.html). Distance to the nearest water source (DS) was derived from the map that was made by the Ministry of Environment Cambodia. All data was re-projected to the WGS1984 datum before analysis.

Habitat use of *A. cambodiana* was investigated using a combination of data from camera traps and line transects. Generalized linear mixed models with binomial distribution including the null model were developed to determine the association between the selected ecological variables and the presence of *A. cambodiana*. The glmmTMB (Template Model Builder) package (Bolker, 2016) was used with R version 3.4 (R Development Core Team, 2017) for fitting generalized linear mixed models and extensions when sampling methods (camera trap and line transect) were treated as random effects. Explanatory variables were elevation, slope, and distance to water sources. Habitat selection models were developed using 619 km surveys from 22 transects and 23,296 trap-nights of 140 camera trap locations. The detection of calling (from line transect) and captures (from camera trap) of birds from each survey were treated as the response variable (detection or non-detection). Forest type was excluded from the analysis because birds were detected by calling from the line transects in the evergreen forest within only two call from semi-evergreen forest and no detection from line transect located in pine forest. A set of five binomial regression models including the null model were developed to determine the association between the selected ecological variables and the presence of *A. cambodiana*.

Prior to running the models, the continuous variables including elevation, slope, and distance to water sources were checked and outliers were removed; these variables were then standardised by subtracting from the mean and dividing by its standard deviation (x variable – mean of x/sd of x) (Gelman, 2008). We did not include highly correlated variables ($r > 0.5$) in the same model. The survey effort (number of visits multiplied by transect length and number of camera trap-nights) was treated as a fixed coefficient and set to 1 by using an "offset" (Gelman & Hill, 2006). Model selection was based on comparing Akaike information criterion (AICc) values adjusted for small samples. Akaike model weights (AIC-*w*) were calculated as the weight of evidence in favour of a model among the models being compared. We assessed model accuracy using the area under the receiver operating characteristic curve (Hosmer & Lemeshow, 2000; Franklin, 2010) by using the "Presence/Absence" package (Freeman & Moisen, 2008). We chose an optimal threshold cut-off value for classification using the minimised difference between the proportion of presences correctly predicted (sensitivity) and the proportion of absences correctly predicted (specificity) (Franklin, 2010).

Current suitable habitat

A. cambodiana habitat loss was defined as the reduction of evergreen forest above 400 m from 1996 to 2016. Loss was calculated using LANDSAT 5 (1996), LANDSAT 7 (2006) and LANDSAT 8 images from http://glovis.usgs.gov/ using supervised classification (ESRI, 2011) in ArcGIS 10.1 (ESRI, Redlands, USA). The images were downloaded for the Cardamom Mountain range for February 1996, 2006 and 2016 when there was likely to be the lowest level of cloud scatter (<10%).

The images were defined into different colour bands (different vegetation types) based on the Cambodian forest cover layer (Open Development Cambodia, 2016), then the total area of evergreen forest above 400 m each year was calculated using summary statistics in ArcGIS 10.1. The evergreen forest above 400 m was calculated for two ten year periods (1996 to 2006 and 2006 to 2016) and compared to the whole area of evergreen forest. Separate loss statistics were generated for the Cardamom Mountains as a whole, as well as BKNP, CCNP and PSWS.

Results

Density estimation

A total of 148 calling males were recorded along the 619 km of surveyed line transects across the three study areas. The half-normal key function was the most supported model with detection probability p=0.48 and calling birds were effectively detected up to 97 m from the transect line (Figure 2) and the overall density estimate was 1.23 calling males/km^2. Study area stratification was the most supported model with AIC=189 compared to the global one (AIC=1491). Estimated density was high in BKNP (2.65 calling males/km^2), but lower in PSWS (~60% less) and in CCNP (~90% less). As there was minimal overlap between 95% confidence intervals between estimates for CCNP and BKNP it would appear that the density of the latter was higher. There was likely little difference between PSWS and either of the other two sites (Table 1).

Habitat association

Model selections were based on ΔAIC and AIC weights. Results suggested that the presence of *A. cambodiana* was positively associated with elevation and slope, whereas distance to water had no effect (Table 2). This best fitted model provided reasonable discrimination between A. cambodiana presence and absence (AUC = 0.79).

The AUC threshold suggested the cut-off value was 0.4 based on the minimized difference between sensitivity and specificity with the highest correct classification at 78%.

Based on our regression model (Generalized linear mixed models), the suitable habitat for *A. cambodiana* is currently estimated to be 2,308 km^2, about 45% of the estimated total area of evergreen forest above 400 m within the Cardamom Mountain range in Cambodia where 96% (2,221 km^2) of this area is located inside of the protected area (Figure 3).

Habitat loss

Based on LANDSAT 8 from 2016, evergreen forest from the lowlands to the highest mountain peak in Cambodia covered 15,007 km^2 (65%) of the Cardamom Mountain area with 2,308 km^2 (15%) located above 400 m at sea level, with the slope range from 11° to 43° (predicted suitable habitat). This range was reduced by 173km^2 (7%) between 1996 and 2006 with a further reduction of 118 km^2 (5%) between 2006 and 2016. Comparing the three study areas, in 20 years, the rate of habitat loss was to be the highest in CCNP (80%), followed by PSWS (16%) with the lowest rate in BKNP (4%) (Figure 3 and Table 3).

Discussion

Bird density

Our overall density estimates of *A. cambodiana* were low compared to studies of similar partridge species. For example, density of *A. davidi* in southern Vietnam was estimated at 3.63/km^2 (Vy *et al*., 2017), *A. chloropus* (now *T. chloropus* (Chen *et al*., 2015) in Khao Yai National Park, north-eastern Thailand was estimated to occur at a density of ~18/km^2 (Ong-in, Unpublished data) and density of *A. arde* on Hainan Island, China was estimated at 6.54/km^2 (Gao, 1999). However, it was higher than the density of *A. rufipectus* estimated in Sichuan, China at 0.48/km^2 where the natural habitat was highly fragmented and replaced by non-native conifer plantations (Dai *et al*., 1998).

The higher density at BKNP is likely to be due to relatively little habitat change at this site over the last 20 years as only 4% was lost, compared to 80% in CCNP and 16% in PSWS. In addition, the remaining suitable habitat (evergreen forest above 400 m) at BKNP is isolated and inaccessible to humans, as it occurs on a plateau in part, surrounded by high, steep cliffs and as a result has low inside-protected area fragmentation, which is known to be more favourable for many bird species (Ewers & Didham, 2006; Chan, 2010). This is unlike the other study areas which are much more accessible and as a result more fragmented. Moreover, from 2007, much of the southern part of BKNP has been granted to a private company to develop ecotourism (Open Development Cambodia, 2014) and as a result the area is much better protected, such that the collection of NTFPs has been banned. Some aspects of ecotourism are known to benefit galliformes conservation, for example bird watching in Cat Tien National Park, Vietnam (Sukumal *et al.*, 2015) ; bird watching; green peafowl, a species that 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. 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 communities to avoid disturbing the forest (i.e. hunting and grazing cattle in the park) as well as increased the park's management effectiveness. During the survey, calling males of *T. chloropus* were also recorded along line transects when surveying *A. cambodiana* showing an estimated density of approximately 15 calling males /km^2 in BKNP (Chhin unpublished data) which is close to what has been recorded for the same species in the well protected Khao Yai National Park, Thailand, with about 18 calling males/km^2 (Ong-in, Unpublished data). *T. chloropus* was also found at low density in of the two study areas (3 calling males /km^2 in CCNP and 6 calling males /km^2 in PSWS).

The lower density recorded in the CCNP is likely to be the result of fragmentation of the suitable habitat, with evergreen forest interspersed with grassland and more open canopy cover (Stuart & Emmitt, 2006) which has been shown to be unsuitable habitat for several *Arborophila* species (Dai et al., 1998; Gao, 1999; Ong-in *et al.*, 2016; Vy et al., 2017). For instance, two line transects located in the southwest part of CCNP, at an elevation above 900 m, had a patchy habitat of large pine trees with grass cover at ground level in which no detections were recorded. A study of Sichuan hill-partridge (*A. rufipect*) in China found that coniferous forest was also not selected (Dai et al., 1998).

Habitat use

For this study, *A. cambodiana* was mainly recorded in evergreen forest at elevations above 400 m and on steep slopes, which indicated that the terrain structure are important for this species. This micro-habitat preference pattern was also found within *Arborophila* studies such as: common hill-partridge *A. torqueola* (Liao *et al.*, 2007a) and Sichuan hill-partridge *A. rufipectus* (Dai et al., 1998; Liao *et al.*, 2007b) in China and orange-necked partridge *A. davidi* (Vy *et al*., 2017) in southern Vietnam. Moreover, based on the habitat use model we predicted that density of *A. cambodiana* should be highest in the CCNP, followed by PSWS and lowest in BKNP (Figure 2, D). However, our survey data showed the opposite (Table1). This contradictory finding is most likely the result of human disturbance (Hiller *et al.*, 2004; Rimbach *et al.*, 2013). Based on our observations, logging from small (targeted valuable timber) to large-scale (land clearance for agricultural purpose) was observed almost everywhere within CCNP, with extensive evidence of numerous paths criss-crossing the area to export timber from the CCNP through Phnom Aural Wildlife Sanctuary. In addition there were numerous ELCs and there was less government patrolling in the area. Logging is known to increase opportunistic hunting that targets small terrestrial animals including galliformes (Samnang *et al.*, 2009; Poulsen *et al.*, 2011; Rimbach *et al.*, 2013). *Arborophila* species avoiding human disturbance areas were also observed within several studies (Nijman, 2003; Liao *et al.*, 2007a; Liao *et al.*, 2007b; Vy *et al.*, 2017). In addition, the low density estimation of *A. cambodiana* may also result from the presence of other species such as *T. chloropus* which also occurs in area. The effect of potential competitor presence in the same area was also predicted for *A. davidi* in Vietnam (Vy *et al.*, 2017). *A. davidi* in South Vietnam was found in low densities in the presence of *T. chloropus*. *A. cambodiana* did not extend through much of the Southern Cardamom National Park south to the Gulf of Thailand, where the topography is mostly flat with the altitude below 1000 m, and thus less suitable for the species. Human disturbance such as logging, hunting and land clearance may also be the cause of low density estimation of both *A. cambodiana* and *T. chloropus* (Samnang *et al.*, 2009; Sodhi *et al.*, 2010).

Habitat Loss

Our results suggested that over the past 20 years (1996-2016) the evergreen forest of the Cardamom Mountains ranging from low levels to the highest peak have decreased by

20% (3,551 km^2) including a 12% reduction in suitable habitat for *A. cambodiana*. This is equal on average to a rate of about 100 km^2 in every 10 years. The biggest loss occurred between 1996 and 2006 when the Pol Pot-led military occupied the area. Most logging, hunting and wildlife trade found common in the country. The peak of commercial logging was between 1996 and 1999 and it continued at a lower rate until 2004 (Chut & Anthony, 2005). From 2006 to 2016 the remaining areas were impacted by selective logging, land encroachment and economic development (through ELCs), which started to extend from lowland areas into the highlands.

Today the threat from this unregulated and unplanned development remains. For example, in BKNP there are five different ELCs including a large one located on the plateau, for developing a casino, hotel and encouraging ecotourism (Open Development Cambodia, 2014). Within PSWS there are two giant pepper farm ELCs being developed directly inside the Sanctuary, covering 10% of its total area. The concern is that as the revenue from the area increases, the ELCs will be enlarged (Sodhi et al., 2010), as evidenced by losing around 20% of evergreen forest in the Cardamom over the last 20 years. If it continues at this rate the negative impacts on *A. cambodiana* are likely to increase.

Our findings also indicated that approximately 40% of the total remaining suitable habitat for *A. cambodiana* is located in CCNP. However, we recorded very low densities of the species in CCNP compared to BKNP. As we have already discussed, this is likely to be due to higher fragmentation and human disturbance in the area. So a large area of the species remaining habitat is currently negatively affected. Long term conservation of the species in the CCNP is hampered by a lack of human capacity and protected area management planning (Conservation International, 2016).

Reassessment of Red List criteria and categories of *A. cambodiana*

A. cambodiana is especially vulnerable to habitat loss and disturbance, as it occurs mostly in well-developed forest with deep litter and complex ground structure (Nijman, 2003; BirdLife International, 2016). Logging and hunting are still a cause for concern, despite the protected status of the protected status of most of its remaining habitat (Samnang *et al*., 2009). Addressing these issues is mainly a legal matter, although research into ways in which forestry practices may be less harmful to this and other pheasant species may provide vital information. The information from this study can be used as the basis of an awareness programme on the plight of these galliformes and other wildlife in the Cardamom Mountains. With regard to IUCN Redlists status and criteria, we have shown that *A. cambodiana* is range and habitat restricted (Brickle *et al*., 2008), its habitat has been dramatically fragmented and that human disturbance and development activities negatively affect the species. We also believe that these threats and pressures will only increase across the species' range. Based on this study, the estimated density was small (0.63-2.39 calling males/km^2) compared to other range restricted *Arborophila* species such as the Vulnerable orange-necked partridge (0.89 -

4.32) (Vy *et al.*, 2017) and Hainan hill-partridge (6-8) (Gao, 1999). The remaining suitable habitat is estimated at 2,308 km^2 and extrapolating this density estimate to the extent of remaining forest gives a possible population of 1,400 – 5,500 pair respectively. There is limited biological and ecological information on aspects such as survival rate and micro-habitat use. We believe there is a strong case to revise the global status of *A. cambodiana* under the IUCN Red List from 'Least Concern' to 'Vulnerable' (A2abc; B1b (*iii*) c (*i*); C1) under the following criteria: **A.** Reduction in population size based on **2.** An observed (**a**) direct observation (20,000-50,000 individuals (BirdLife International, 2016)) compared to this study (1,400-5,500 pair); (**b**) an index of abundance appropriate to the taxon measured as density was small (0.63-2.39 calling males/km^2); (**c**) a decline in area of occupancy, over the past 20 years (1996-2016) the potential habitat of *A. cambodiana* was degraded by approximately 12% and the total evergreen forest in the Cardamom Mountain range has decreased by 20%). **B**. Geographic range **1**. Extent of occurrence estimated to be less than 20,000 km^2, and estimates indicating at **b.** continuing decline (***iii***) quality of habitat lost by 20% over 20 years; **c.** Extreme fluctuations in (***i***) extent of occurrence (18,200 km^2 within 'Least Concern' status then this study 2,308 km^2). **C**. Population size estimated to number fewer than 10,000 mature individuals (this study 1,400-5,500 pair) and **1.** an estimated continuing decline of at least 10% within 10 years or three generations.

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Figure 1: *A. cambodiana* study sites at Bokor National Park (BKNP), Central Cardamom National Park (CCNP), Phnom Samkos Wildlife Sanctuary (PSWS) and Southern Cardamom National Park (SCNP) with the location of camera traps and line transects.

Figure 2: The detection function curve of A) the global model (all sites); B) Bokor National Park, C) Central Cardamom National Park and D) Phnom Samkos Wildlife Sanctuary.

Figure 3: Change in suitable habitat for *A. cambodiana* in the Cardamom Mountains over 20 years (1996-2016).

Figure 1

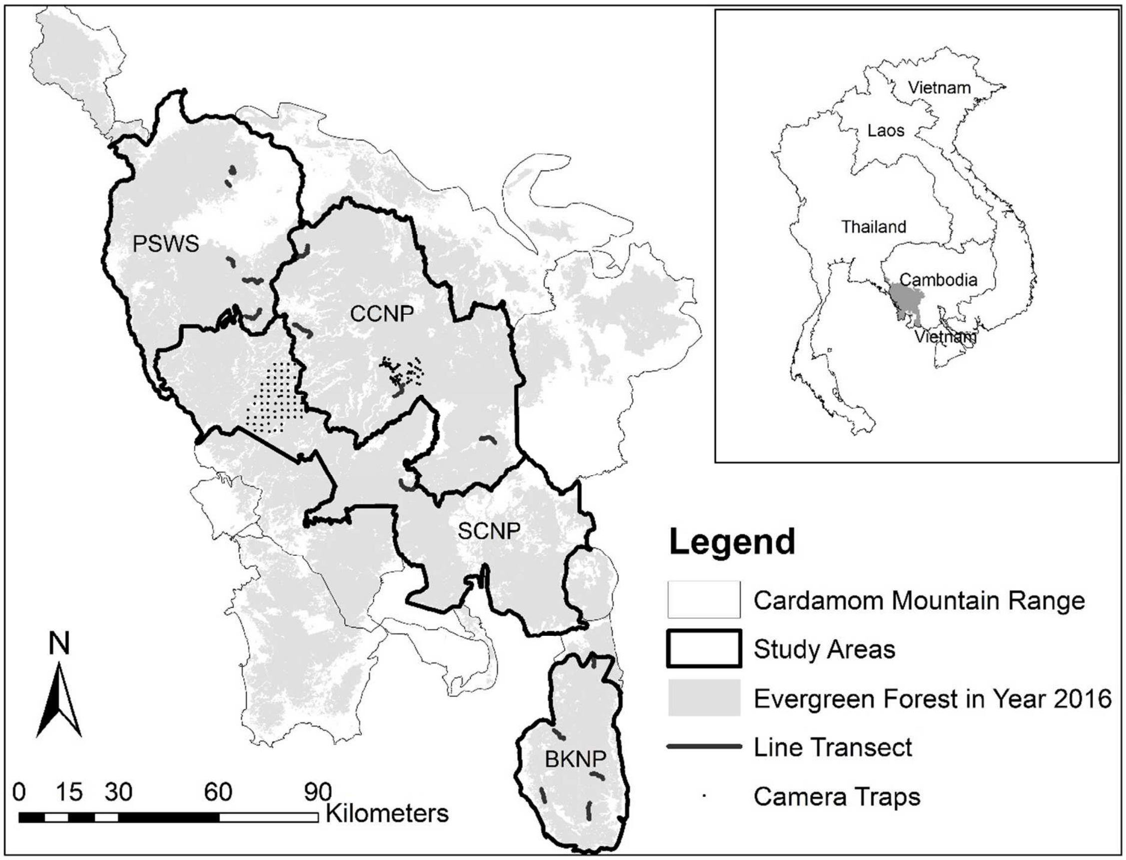
Vietnam
Laos
Thailand
Cambodia
Vietnam
PSWS
CCNP
SCNP
BKNP
N
0 15 30 60 90
Kilometers
Legend
Cardamom Mountain Range
Study Areas
Evergreen Forest in Year 2016
Line Transect
Camera Traps

Figure 2

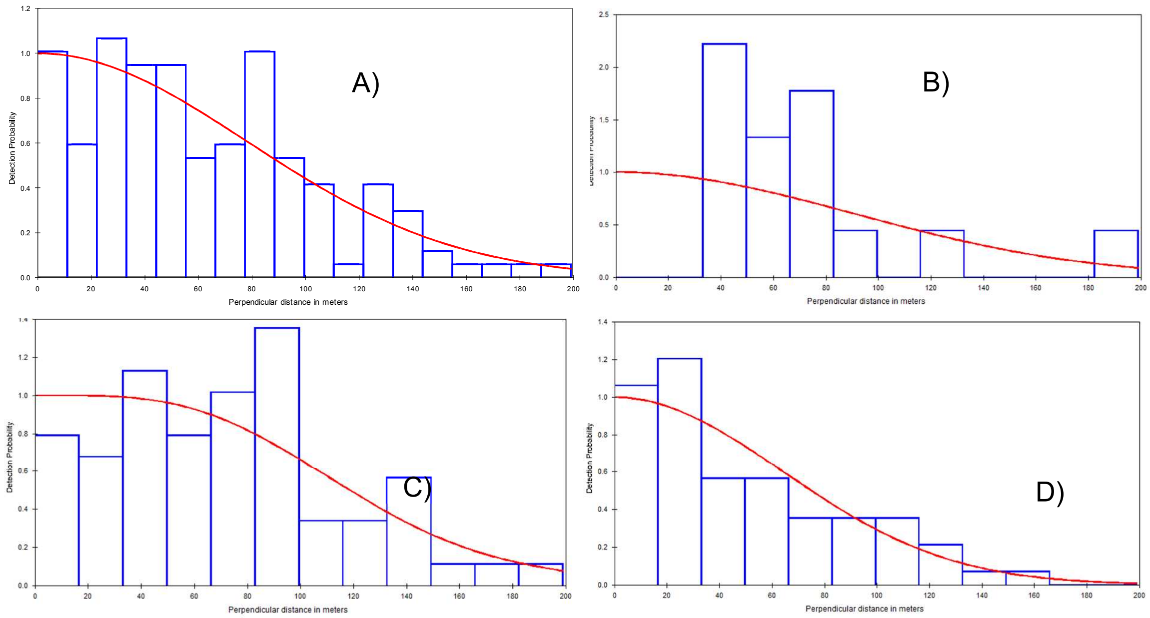
A)
B)
C)
D)
Detection Probability
Perpendicular distance in meters

Figure 3

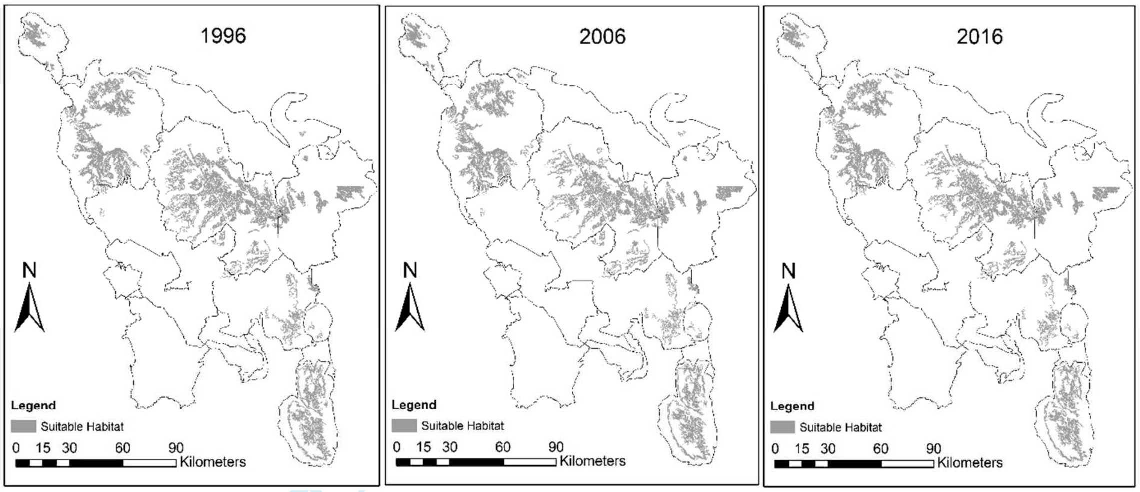
1996
2006
2016
N
Legend
Suitable Habitat
0 15 30 60 90
Kilometers

Table 1: Distance sampling (CDS) of detected calls using line transect from three study areas with estimated abundance from a single object to the remaining evergreen forest with elevation above 400 m.

Study area	Effort* (Km)	No detection	Encounter rate (n/L)	p detection	Density (Calling birds km^2)	Coefficient of variation (%)	95% Confidence interval
BKNP	100.55	65	0.64	0.61	2.65	47.75	0.92 – 7.62
CCNP	252.37	15	0.59	0.55	0.26	65.28	0.06 – 1.15
PSWS	265.76	68	0.25	0.40	1.60	44.67	0.61 – 4.16
GD**	618.69	148	0.23	0.48	1.23	32.21	0.63 –2.39

* Total length of line transect (line length in km multiplied by observation times)

** Global density estimation

Table 2: Detail of parameters in final accepted habitat use model with beta coefficient and 95% CI

Model	Variable	K	AIC	Δ AIC	AIC-w	Coefficient	95% CI	
							Lower	Upper
1	Elevation	4	872	0	0.7	4.17	2.69	5.64
	Slope					0.78	0.003	1.56
2	Elevation	3	874	1.69	0.3	4.23	2.73	5.74
3	Distance to Water	3	910	38.13	0	0.79	0.20	1.38
4	Slope	3	911	38.97	0	0.88	0.18	1.59
5	Null	2	915	42.84	0	-113.37	-241	14.98

Table 3: Predicted remaining suitable habitat for A. cambodiana in square kilometers (Evergreen forest at elevation above 400 m from sea level with steep slope) changed from 1996 to 2006 and 2006-2016

Study areas	1996	2006	2016
BKNP	379	378	370
CCNP	1079	940	903
PSWS	697	682	661
Cardamom*	2599	2426	2308

*Total predicted suitable habitat of *A. cambodina*