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ESTIMATING POPULATION SIZE AND DISTRIBUTION OF HUME'S PHEASANT IN NORTHERN THAILAND

Apirat Iamsiri
Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, 91 Pracha Uthit Road, Tungkru, Bangkok, 10140, Thailand.
Email: apirat_i@yahoo.com (Corresponding author)

George A. Gale
Conservation Ecology Program, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, 83 Moo. 8 Thakham, Bangkhuntien, Bangkok, 10150, Thailand.
Email: george.and@kmutt.ac.th

ABSTRACT. – Hume's Pheasant, *Syrmaticus humiae*, is a poorly known species, currently classified as globally near-threatened. Population estimates are particularly difficult to obtain due to a low rate of detection in the field. In order to overcome these problems, we used a relatively simple quantitative habitat model to obtain an estimate of the Hume's Pheasant population in Thailand. Potential habitat of Hume's Pheasant was predicted based on a model derived from LANDSAT satellite images and field surveys. The predictive performance of the model was tested using historical records and field data collected from surveys and from local people. The models correctly identified all test areas where the pheasant was known to be present. In summary, total available habitat was estimated to be 2,667 km^2, of which only 23% fell inside either national parks or wildlife sanctuaries. The total population was estimated at 1,245 individuals, assuming national parks and sanctuaries offer at least moderate protection and are more likely to harbour populations compared to other sites. While larger than previous estimates, it suggests that there is an urgent need to conduct additional surveys outside the protected area system to assess the species status and perhaps develop additional conservation actions for these populations.

KEYWORDS. – Hume's Pheasant, *Syrmaticus humiae*, habitat suitability model, LANDSAT, Thailand.

INTRODUCTION

Defining the area of available habitat within a landscape can greatly assist in the designation of meaningful conservation strategies for species of interest (Nagendra, 2001), particularly for those species that are difficult to assess directly in the field (Boyce & McDonald, 1999). One way to do this is to determine the relationship between various features of the environment and the distribution of a species (Peterson et al., 2002). The relationship could be used to generate models to predict a species population size and distribution by assessing the availability of suitable habitat. These processes are available through remote sensing technologies (Austin et al., 1996; Osborne et al., 2001), which are widely and increasingly used to supplement field studies. In addition, once spatial habitat models have been developed, the possible effects of different types of habitat management can be identified (Austin et al., 1996).

Hume's Pheasant is considered a Near-Threatened species found in forested habitat in limited parts of India, Myanmar, China, and Thailand (BirdLife International, 2007). In Thailand its distribution is restricted to the northern region where initial rough estimates suggested that 200 to 500 individuals occur. This population is also likely threatened by hunting and habitat degradation (BirdLife International, 2001). Furthermore, despite the species having been recorded within several protected areas of northern Thailand (BirdLife International, 2001; Iamsiri et al., 2005; Iamsiri, 2006) a broader picture of available habitat within the country is largely unknown, particularly outside the protected area system. Field surveys for this species are particularly problematic because it occurs at low density and is very shy. For example, the pheasant was detected only 35 times during two years of study in evergreen forests where it was known to occur (Iamsiri et al., 2005). Better quantitative assessments of the total population size within the country may be more practically achieved by linking estimates to quantitative assessments of available habitat. With these techniques, we extend the work of Iamsiri et al. (2005) by quantifying the availability of suitable habitat in Thailand and by estimating the population size. Here we develop a simple habitat suitability model, map potential habitat for Hume's Pheasant in northern Thailand and predict the population size based on available habitat.

MATERIALS AND METHODS

Study area. **–** The study area focused on northern Thailand between approximately 17°51'–20°20'N 97°35'– 99°57'E. It is covered by two LANDSAT 7/ETM+ images, path 131/row 46 and path 131/row 47, which were acquired on Feb.2002. This period corresponded to the breeding season of Hume's Pheasant (Feb.–Jul.; BirdLife International, 2001) and also to when habitat use data were collected in the field (see Iamsiri et al., 2005 for details). The total area is approximately 39,607 km^2 and is a mainly mountainous region consisting of a mix of forest and agriculture covering the west and central portions of northern Thailand (Fig. 1). The west side is drained via the Salween River while parts of the central portion drain into the Ping River. The entire area lies above 200 m elevation and there are large forested areas of uplands above 1,000 m including three mountains over 2,000 m: Doi Inthanon, Thailand's highest mountain (2,565 m), Doi Pha Hom Pok (2,285 m) and Doi Chiang Dao (2,175 m). There are three distinct seasons: rainy (May.–Oct.), cool-dry (Nov.–Feb.), and hot-dry (Mar.–Apr.) (Maxwell, 2004). Average annual rainfall varies from 800–1,800 mm (OEPP, 2001).

LANDSAT images. **–** Following Iamsiri et al. (2005) there are three primary variables relating to Hume's Pheasant microhabitat selection in northern Thailand: grass species richness, average tree height and shrub cover over 100 cm. Grass species richness and average tree height are positively associated with the presence of the pheasant, while shrub cover over 100 cm is negatively associated. These variables were used to create a habitat suitability index (HSI) and produce a map of potential habitat of Hume's Pheasant based on LANDSAT 7/ETM+ images. However, due to logistical constraints, the evaluation of habitat was limited to these two image scenes, which covered all sites studied by Iamsiri et al. (2005) but did not cover the entire northern region of Thailand (Fig. 1). The two images were merged and geometrically corrected to the Thai/Vietnam datum with 13 ground control points using ENVI Version 3.4. Most of the ground control points were bridges across rivers and intersections of minor roads. The resulting root mean square error, $R^2 = 0.43$, was considered acceptable compared to the size of habitat patches collected as training data, approximately 100 × 100 m (Jensen, 1986).

The LANDSAT spectral bands used in this study were the three visible bands (TM1, TM2 and TM3), one near infrared band (TM4) and two middle infrared bands (TM5 and TM7). The resolution of TM band 6 was 60 × 60 m and deemed too low for the analysis relative to the field habitat sampling units (30 × 30 m, see Iamsiri et al., 2005) and therefore excluded from the analyses. Normalized difference vegetation index (NDVI) based on the ratio of (TM4 − TM3) ÷ (TM4 + TM3) and normalized burn ratio (NBR) based on (TM4 − TM7) ÷ (TM4 + TM7) were produced following Key & Benson (2003).

Collection of training data/assignment of habitat suitability index. **–** We developed an index based on the significant habitat variables tested by Iamsiri et al. (2005), focusing on the three habitat variables noted above. To select training samples for the habitat suitability classification, 283 ground truth data points were distributed throughout the study area where there was relatively easy access, such as along trails in protected areas (for example Mae Fang, Ob Luang, Doi Inthanon, and Doi Suthep-Pui National Parks) or along roads. Homogeneous areas of habitat approximately 100 × 100 m or larger were considered as adequate training samples.

For forest habitat, each sample was initially coded as evergreen (EG = 1) or non-evergreen (EG = 0). This simple classification eliminated large parts of non-suitable habitat since all of the species' records are in the evergreen forest (Iamsiri et al., 2005).

Although there was no significant difference in the percentage of crown closure between use and non-use points found by Iamsiri et al. (2005), no Hume's Pheasant was observed at locations with less than 35% crown closure. For purposes of field/remote sensing assessments, a cutoff of 25% evergreen forest canopy cover was used to further separate suitable from unsuitable habitat.

The average tree height (H) was classified by eye into four categories indicating degree of suitability as tall (> 15 m, coded as 3, most suitable), medium (5–15 m, coded as 2), short (< 5 m, coded as 1) and few trees (coded as 0, unsuitable). Ground vegetation above 100 cm (GV) was simply classified as open (score = 1), which could be occupied by Hume's Pheasant, or dense (score = 0), which was considered less suitable habitat. Whereas mapping of understorey vegetation is possible with LANDSAT (Linderman et al., 2004), influence of the diversity of understorey vegetation on remote sensing data is scant. Therefore, grass species richness was not included in the study.

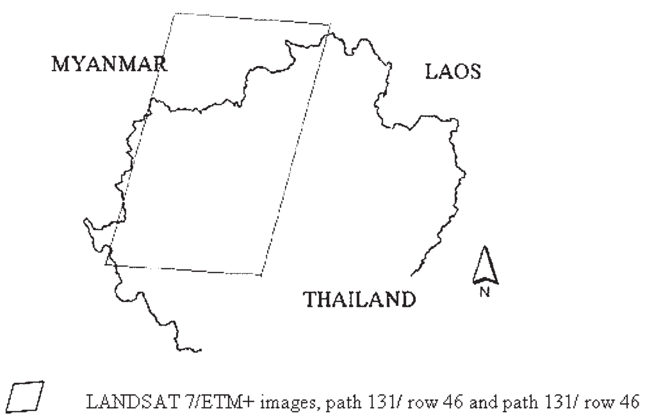

Fig. 1. Study area is covered by two LANDSAT 7/ETM+ images, path 131/row 46 and path 131/row 47, which were acquired in Feb.2002.

Table 1. Potential habitat of Hume's Pheasant in northern Thailand and type of protection assigned to the habitat. "Other forest" includes national forest reserves, forest parks, and non-hunting areas. Although hunting and degradation of habitat in these forests are technically prohibited, law enforcement is typically lacking.

Land use / land cover designation	Area of predicted habitat, km^2	Proportion of the total predicted habitat, %
Non-forest	132.3	4.9
Wildlife Sanctuary	32.3	1.2
National Park	590.4	22.2
Other forest	1912.0	71.7
Total	2667.0	100

Categories used to weight the probability of habitat suitability, the habitat suitability index (HSI), were calculated:

$$\text{Habitat suitability index (HSI)} = EG \times H \times GV \quad (1)$$

Descriptions of each category are shown in Table 1. There were four categories of the composite HSI, 0–3. The categories "0" and "1" were classified as unsuitable habitat because they represented land cover that was not evergreen forest, or was evergreen forest but with few trees, or was evergreen with dense ground vegetation. The categories "2" and "3" were assessed as possible Hume's Pheasant habitat; these were evergreen forest with medium or large trees and less dense ground vegetation.

One hundred and twenty-six pixels with a HSI of "0" or "1" were grouped as unsuitable habitat and used to model the habitat suitability, and 157 pixels that had HSI scores greater than "1" were assigned as possible habitat. The unsuitable habitat derived from the 126 pixels included areas without trees, forest that was other than evergreen, agricultural areas including paddy fields, grasslands and evergreen forest with dense ground vegetation which generally occurred in valleys.

***Modeling habitat suitability*. –** All training samples were then mapped onto the LANDSAT images by developing regions of interest (ROI). An ROI is a selected image subset of samples within a dataset identified for a particular purpose (ENVI Version 3.4). There were two groups of ROI developed from training samples, unsuitable habitat (0) and suitable habitat (1). The unsuitable habitat ROI was derived from training points containing HSI scores of "0" or "1". The ROI representing possible habitat was developed from the 35 use points resulting from field observations of Hume's Pheasant (Iamsiri et al., 2005). Both ROIs ("0" for unsuitable habitat and "1" for suitable habitat) were used to develop a model to predict suitable habitat.

Reflectance data of the ROI pixels were modeled and entered into a logistic regression analysis as independent variables. The ROI was the dependent variable, "0" for unsuitable habitat and "1" for suitable habitat following Austin et al. (1996).

$$ROI = Constant + aTM1 + bTM2 + cTM3 + dTM4 + eTM5 + fTM7 + gNDVI + hNBR \quad (2)$$

Backward stepwise functions with a significance level of 0.05 were applied to eliminate non-significant variables from the model following Manel et al. (2001).

***Producing a map of potential habitat.* –** The model resulting from the logistic regression analysis was then applied to predict whether or not a particular pixel contained suitable habitat. It was applied to every pixel to predict the probability of being habitat as;

$$\text{Probability score} = 1 \div [1 + e^{(-y)}] \quad (3)$$

where y equals the logistic regression model (Hosmer & Lemeshow, 2000). Pixels with less than 0.5 probability of being habitat were defined as unsuitable habitat and pixels containing the probability equal to or greater than 0.5 were assigned as possible habitat. In addition, pixels identified as possible habitat were then overlaid with an elevation map. Areas above 1,000 m were considered likely to be the most suitable habitat, since the forest occupied by Hume's Pheasant has been found to be evergreen hardwood forest with or without pine above 1,000 m (Iamsiri et al., 2005). These two classes, unsuitable habitat and suitable habitat above 1,000 m, were combined into a single map layer. Once the classification was complete, there were many isolated, small patches of potential habitat. A low-pass, 3 × 3 filter was used to eliminate these small (≤ 90 × 90 m) areas throughout the classified image following Campbell (1996).

***Estimating accuracy of the predicted habitat map*. –** To test the accuracy of the predicted map, we compared our predicted habitat with historical records cited in Birdlife International (2001) and records derived by interviewing local people such as forestry officers and villagers. Based on the interviews, areas of 1 km^2 centered on locations where the pheasant had been reported were roughly drawn on the predicted habitat map.

RESULTS

***Modeling habitat suitability*. –** The final model included TM band 5 and NDVI, but in the opposite direction indicated by different signs, -0.058 and 6.208 respectively. NDVI exhibited the greatest reflectance in response to Hume's habitat with small but negative association with TM5. This was not surprising as NDVI is negatively correlated with TM5 (Spearman's r = -0.643, $P < 0.001$).

Map of potential habitat. – In total, 2,667 km^2 (6.73 % of the study area) was classified as suitable habitat for Hume’s Pheasant (Fig. 2). Based on digital maps produced by the Royal Forest Department (November, 2003), Thailand, 622.7 km^2 of the suitable habitat was forested, located inside the boundaries of national parks and wildlife sanctuaries, whereas 1912.0 km^2 was located in other forested areas, and 132.3 km^2 was in non-forest (Table 1). There are several types of government classified forested lands that are outside national parks or wildlife sanctuaries, including national forest reserves, forest parks, and non-hunting areas. Although hunting and degradation of habitat in these forests are technically prohibited, law enforcement is typically lacking (Arbhabhirama et al., 1988; Panusittikorn & Prato, 2001). The only land categories that are reasonably protected by law from encroachment, logging, and hunting are national parks and wildlife sanctuaries (Arbhabhirama et al., 1988).

Accuracy of the predicted habitat map. – The only historical record from BirdLife International (2001) that was not used for model development was from Doi Lang-ga (within Khun Jae National Park). It fell within areas of the predicted habitat map. There were four other separate sites not used for model development and predicted as suitable habitat, which were independently assessed during this project to have Hume’s Pheasant.

1. Doi Khun Mae Surin in Nam Tok Mae Surin National Park, a male Hume’s Pheasant was observed by forestry officers in November, 2005 at 18°55'59"N 98°07'17"E. Approximately 59.9% of the area in and around Doi Khun Mae Surin was predicted as suitable habitat for the pheasant.

2. Doi Khun Puai, Bann Phamon village, two sets of pheasant remains were collected by local hunters inside Doi Inthanon National Park (18°35'12"N 98°32'22"E). The area included 85.1% suitable habitat. The forest here is in a very good condition with large pines and other evergreen hardwoods.

3. Doi Pui-Luang, a forest belonging to the Ban Huai Hee village, we observed what were likely feeding tracks of Hume’s Pheasant at approximately 19°12'15"N 98°04'34'E, in Feb.2006. Villagers also confirmed the presence of the pheasant in this area and described closely the plumage and calls suggesting that at least a few individual birds were still present. The suitable habitat here was small, only 7.1%, and isolated. The forest was dominated by medium to small oaks (shorter than 10 m) with few and small pines along the ridges.

4. Doi Dam, Bann Namon village, there were remains collected in 2003 by a local hunter. The area is situated one km from the Myanmar border, at 19°40'01"N 98°34'32"E, and is under military control. Approximately 32.4% of the area was classified as suitable habitat for the pheasant.

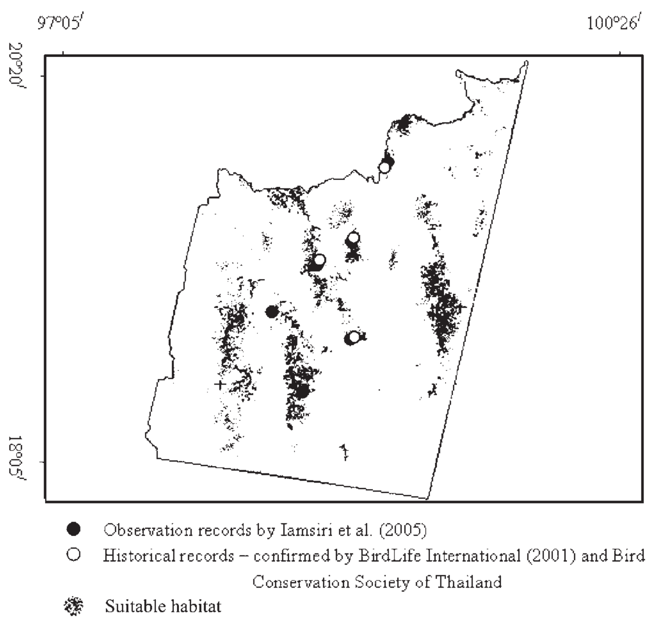

Fig. 2. Predicted habitat of Hume’s Pheasant in northern Thailand.

Estimating abundance of Hume’s Pheasant. – The estimated home range of Hume’s Pheasant is 1.47 km^2 in relatively disturbed habitat (Iamsiri, 2006). Given that no other density data was available for northern Thailand, we used 1.5 km^2 as the baseline area required by an average group consisting of one male and two females. Although the pheasant has been found outside the protected area system (Iamsiri, 2006), where law enforcement was lacking, such occurrences are probably rare. We therefore assumed that 622.7 km^2 or roughly 23.4 % of the suitable habitat, was most likely to be occupied, as these areas receive at least some protection within the national parks and sanctuaries. Based on these assumptions, abundance was then calculated by dividing the area of 622.7 km^2 by 1.5 km^2. Thus, perhaps 415 groups or 1,245 individuals could be supported by the predicted suitable habitat. This estimate is 2.4–6.2 times higher than the population estimated by P. D. Round (BirdLife International, 2001).

Total population estimates for the species are relatively crude throughout its range, particularly for southern China where no estimate is available as far as we are aware (BirdLife International, 2007). However, if we assume that China has at least the same amount of protected suitable habitat as Thailand, using the lowest published density estimates of 6 individuals per km^2 from Fan Xishun et al. (2004), would give China a population of 3,700 individuals. Following published BirdLife International (2007) estimates and this study, the combined population from India, Myanmar, China, and Thailand would be roughly 15,000 individuals. Even with the sizeable increase in Thailand’s estimated population derived from this study, using the above set of assumptions, Thailand is still likely to hold < 10% of the species’ total.

DISCUSSION

Applicability of LANDSAT data

The habitat suitability model was based primarily on the

NDVI which was negatively correlated with TM band 5. In this case the habitat probability score increased when the logistic model (y) had a larger value. Thus, increasing values of NDVI and decreasing values of TM band 5 increased the probability of the habitat being suitable. NDVI represents a "greenness index" and is commonly used for a variety of vegetation mapping (Campbell, 1996). For example, Kuhnell et al. (1998) indicated that there was a strong correlation between woody shrub cover and NDVI, specifically in the dry season imagery, as in this study. Huete (2004) also found that NDVI could be used to represent soil water content, for example poorly-drained organic soils had the lowest NDVI values while well-drained soil classes had the highest.

TM band 5 on the other hand is sensitive to the amount of water in plants (Lillesand & Kiefer, 1999). Decreasing values of TM band 5 partially indicate the greater amount of water in forests (Kuhnell et al., 1998). Because the images were acquired in the late dry season, higher moisture content in plants indicate evergreen rather than deciduous or dipterocarp forest. Thus, increasing values of NDVI and decreasing values of TM band 5 indicate the significance of woody shrub cover on well-drained soils within evergreen forest. In our study area, well-drained areas tended to be on the ridges, which is typical of evergreen/hardwood with pine forest categorized by Maxwell (1998). A combination of these two indices approximates moisture content of evergreen forest which may be applicable to other parts of its range. However, soil background reflectance, which particularly affects NDVI scores and TM band 5, is different for each LANDSAT image (Huete, 2004); thus a model generated from one image may not be applicable to other images.

Qualitative assessment of the accuracy of the predicted habitat map

Areas where the birds were reported did match in varying degrees to predicted habitat but in different proportions. Bann Phamon village where remains were found had a greater proportion of the predicted habitat than the other areas (85%), while the lowest proportion of predicted habitat was found at Bann Huai Hee village (7%). This may reflect the fact that suitable habitat actually chosen by the pheasant is wider than the model predicts and/or habitat factors not measured here (such as slope and aspect) are also influencing selection. This may also suggest that the pheasant is tolerant of habitat fragmentation and can survive at least temporarily in marginal habitat. For example, in Doi Suthep-Pui National Park the pheasant was thought to have been extirpated for over 60 years (Deignan, 1945; Round, 1984), as intermittent bird surveys failed to detect it (e.g. Round, 1984). However, the pheasant was rediscovered in November 1998 and has been frequently observed since (records submitted to and held on file by Bird Conservation Society of Thailand Record Committee). It is possible that a very small population remained throughout this period when the forest was heavily disturbed (Maxwell & Elliott, 2001), but went undetected.

In addition, it was possible that the 35 use-sites entered into the model as the habitat ROI was too small, compared to 100 sites recommended by Campbell (1996). The habitat category might not exist with respect to spectral properties; however a combination of diverse training sites representing obvious unsuitable habitat could make the habitat designation more reliable because the difference between suitable and unsuitable categories would be larger (Campbell, 1996).

There were areas predicted as suitable habitat, which fell within the protected area system, but where pheasants were never detected. We suggest in these cases the model maybe overestimating available habitat or there are still other variables in addition to those modeled that are limiting the birds' distribution, as it seems unlikely with moderate levels of law enforcement and large increases in bird watchers and researchers that the species is still being overlooked. More accurate results maybe obtained by using additional variables from this study. In addition, identifying suitable habitat at a broader spatial scale such as using data from the Advanced Very High Resolution Radiometer (AVHRR) would yield different results such as in the study by Osborne et al. (2001) where habitat of Great Bustards, *Otis tarda*, was assessed. This might generate additional ideas concerning distribution of Hume's Pheasant throughout its entire range.

Conservation implications. – Placing our population estimate for Thailand in the context of the species total population size is hampered by the absence of an estimate of China's population (BirdLife International, 2007). Although density estimates for particular sites are available from the country (Fan Xishun et al., 2004; Liew Xiahwang, 1991), there does not appear to be an estimate of available habitat, which renders our estimate for China as particularly problematic. We can only speculate as to why site density estimates from China are so much higher than ours (3–16.5 times greater). Such differences could have conservation implications and require further investigation. Furthermore, although our total estimate for the species lacks precision, the available data from elsewhere in combination with this study suggests that Thailand's population is relatively smaller than the other three range countries. Unless the data from India, Myanmar, and China have been greatly overestimated, Thailand probably constitutes less than 10% of the total population. As our data suggests, there is a clear need to refine population estimates for the species throughout its range.

Critically, this study suggested that only a small part of the potential habitat in Thailand was under at least some minimal level of protection within the protected area system. Furthermore, hunting was documented in at least one wildlife sanctuary and one national park (Iamsiri et al., 2005). This indicates that extirpation, particularly from areas with minimal protection, may occur more rapidly than previously thought. However, establishing additional protected areas requires significant amounts of money and does not guarantee a cessation of hunting and habitat degradation. We therefore suggest that establishment of more protected areas is not a long-term solution for Hume's Pheasant or other threatened species unless more emphasis is placed on improving capacity of protected area staff to enforce existing laws. This could be done in tandem with encouraging local participation in research and developing ecotourism activities that could generate income from conservation of Hume's Pheasant or other charismatic species inside as well as outside the protected area system. Additional target areas are located close to the international border. As there are both military stations and national park or wildlife sanctuary offices located in these areas, coordination of conservation/management activities including research and ecotourism may also be possible among these agencies.

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