THE ABUNDANCE AND DISTRIBUTION PATTERNS OF

GREAT ARGUS PHEASANT (*Argusianus argus*) IN

BUKIT BARISAN SELATAN NATIONAL PARK, SUMATRA, INDONESIA

by

NURUL LAKSMI WINARNI

(Under the direction of Dr. John P. Carroll)

ABSTRACT

I studied the abundance, habitat, and movements of Great Argus pheasants (*Argusianus argus*) in Bukit Barisan Selatan National Park, Sumatra, Indonesia. Distance methods using line transect conducted on monthly basis during 1998-2000 suggested that Great Argus pheasant density was about 2-3 individuals/km^2. However, there is a need for more technique refinement. I found that camera trapping offers an alternative method to study secretive and elusive pheasant such as Great Argus. My studies suggest that males of Great Argus pheasant selected forest with more open understory for their dancing grounds. I also found that undisturbed forest with large trees was used more than other forest types. Great Argus pheasant also has larger home ranges than previous studies and these were not correlated with food abundance.

INDEX WORDS: Great Argus pheasant, Sumatra, Indonesia, Abundance, Distribution pattern, Distance sampling, Line transect, Density, Camera trapping, Dancing ground, Lek habitat characteristics, Habitat use, Home range

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NURUL LAKSMI WINARNI

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NURUL LAKSMI WINARNI

Approved:

Major Professor: John P. Carroll

Committee: Robert J. Cooper
Daniel Markewitz

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
The University of Georgia
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TABLE OF CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

INTRODUCTION

The Great Argus pheasant (*Argusianus argus*) is one of the world's largest pheasants. It inhabits evergreen rainforest dominated by trees of the Dipterocarpaceae family in the lowlands and hills of the Malay Peninsula, Sumatra, and Borneo. It is considered a lowland forest specialist. In Borneo and Sumatra, the Great Argus pheasant is most commonly found in tall, dry, lowland primary and logged forest, at elevations up to 1200 m (MacKinnon and Phillipps 1993).

Great Argus pheasant has been protected by the Indonesian Government since 1970 (Noerdjito 2001). According to IUCN, it was considered Vulnerable, because of threats created by habitat loss, hunting, and trade (McGowan and Garson 1995), although the status has recently been changed into Near Threatened (Fuller and Garson 2000). There is actually little information on the species, however, other than occurrence records for Borneo and Sumatra (Holmes 1989 and 1996; van Balen and Holmes 1993), available by making these management classifications. The only research on the biology of Great Argus pheasant was on behavior and was conducted in Malaysia by Davison (1981a; 1981b; 1982). In Sumatra, information on all Galliformes species is insufficient for management and conservation of these species. In addition, as an understory bird sensitive to disturbances in forest structure, Great Argus pheasant may be potential as a reliable indicator of forest change (Wong 1985).

The Great Argus pheasant is well known for the extravagance of its plumage and behavior. The male has an elongated central pair of tail feathers, and large eyespot markings on the wings known as ocelli. The wings are uniquely shaped with secondaries longer than primaries (Johnsgard 1999). The female has a dull brown color and a shorter tail. Both sexes have bare blue skin on the head and neck, and a short dark crest (Delacour 1951; MacKinnon and Phillipps 1993). Males can weigh >2,500 grams and females can weigh >1,700 grams (Johnsgard 1999).

In spite of its conspicuous body size and plumage, Great Argus pheasant is difficult to observe because it is very secretive and sensitive to disturbance (MacKinnon & Phillipps 1993).   Its loud calls, however, are audible up to 1 km (Davison 1981a). It feeds on fallen fruits and seeds, ants, grubs, and slugs (Delacour 1951). Based on Davison's (1981a) observations in Malaysia, its food items are composed of a combination of insects and fruits dominated by the Palmae, Annonaceae, and Leguminosae families.

Individuals of both sexes are solitary, except during the brief mating period or when a female has chicks. An adult male clears a display area or "dancing ground" for mating purposes (Davison 1981b). The Great Argus pheasant mating system is considered as an exploded lek, where each male has their own display sites to attract females, invisible to one another but still in auditory range (Johnsgard 1994, Ligon 1999). Each morning, a male calls loudly from dancing ground for several hours and when a female approaches in response, he begins his elaborate display (Davison 1981b). The males use the same dancing ground from year to year (Davison 1983). The largest dancing ground was reported to extend to 72 m^2 (Davison 1981b). Larger numbers of dancing grounds have been associated with particularly heavy tree fruiting, palms, and water sources (Davison 1981b).   Recent surveys by Nijman (1998) in Kalimantan indicated that primary forest contains the highest Great Argus pheasant density. He concluded that the density was positively correlated with tree diameter, tree height, height of the first bough, and canopy cover.

A study on the conversion of primary forest to agroforest in Sumatra showed that changes in the landscape negatively affected interior forest species, such as the Great Argus pheasant (Thiollay 1995). The rapid rate of forest clearance, leading to loss and fragmentation of lowland forest in Sumatra, is steadily decreasing in the amount of lowland forests (McGowan and Garson 1995). In Sumatra, more than 60% of the habitat available to pheasants appears to have been lost (McGowan and Gillman 1997). McGowan and Gillman (1997) pointed out that not only is the lowland forest habitat being reduced in size, but the resultant fragmentation may result in blocks of habitat that are too small to support viable populations of lowland forest specialists. Presently, lowland dipterocarp forests survive only in nature reserves that cover about 10% of the island (McKinnon and Phillipps 1993). From an overall total of 168,200 km^2 of forested area in Sumatra, only 13% lowland forest remain (Holmes and Rombang 2001); however, the expansion of agricultural lands across park boundaries continues to occur in most nature reserves (O'Brien and Kinnaird 1996; MacKinnon and Phillipps 1993), and fire, as a result of illegal logging, is becoming a major threat to the reserves (Holmes and Rombang 2001).

Pheasants have always been of cultural and economic interest to humans (McGowan et al. 1998). Because of the large body size and poor flight ability, the Great Argus pheasant is easily trapped near its dancing ground (Johnsgard 1999), which makes it prone to losses from hunting and trading. This bird has been exploited for consumption in most parts of Southeast Asia (McGowan and Garson 1995), and its feathers are used for ornamentation (Johnsgard 1999). Although there are no official reports in Sumatra, hunting and trade of Great Argus pheasant is known to occur in Borneo (N. Winarni, *personal observation*).

By mapping positions of calling birds, Davison (1981a, 1981b) reported that male density is <3 birds per km^2, with no information on female density and nests. Davison (1981b) found that dancing grounds are located on top of hills or ridges, and are associated with palms. However, he did not present information on dancing ground density. These findings suggest some basic habitat differences between Malaysia and Sumatra. The most current research was conducted during a short survey in Kalimantan by counting the number of vocalizing males with the objective of evaluating the habitat preference of Great Argus pheasant (Nijman 1998). Still, little information is known on the abundance and density of Great Argus pheasant. While, habitat loss is worsening in Indonesia, there is still lack of information on habitat preference and availability for Great Argus pheasant. The major objectives of this research have been designed to gather basic information on the ecology of Great Argus pheasant. It is hoped, the information from this and previous studies can be added and applied to conservation management of this species in Indonesia, as well as other lowland forest specialists.

OBJECTIVES

This research project is a descriptive one because there is little information on the ecology of Great Argus pheasant other than occurrence records.

The first objective of this study was to determine the abundance and density of Great Argus pheasant in Bukit Barisan Selatan National Park. This involved the development of line transect techniques, then using those techniques and estimates to calibrate camera trap data.

Second, I evaluated habitat associations of Great Argus pheasant. In this part, habitat use of Great Argus pheasant and habitat characteristics of dancing grounds were assessed.

Third, I determined home range and movement patterns of male Great Argus pheasant. This included comparisons of home range size among males, and utilization distribution within the home range. These were correlated to fallen fruit abundance.

STUDY SITE OVERVIEW

This research was conducted in Bukit Barisan Selatan National Park (BBSNP), Sumatra, Indonesia (Figure 1.1). This park is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien and Kinnaird 1996, Sunarto 2000). BBSNP contains some of the largest tracts of lowland rain forest remaining in Sumatra and functions as the primary watershed for southwest Sumatra (O'Brien and Kinnaird 1996). Bukit Barisan Selatan established as a national park in 1982, encompasses areas with elevation from 0–2000 m above sea level (Anon 1998, Holmes and Rombang 2001).

Research was carried out in the Wildlife Conservation Society (WCS)/*Perlindungan Hutan dan Konservasi Alam* (PHKA) Conservation and Training Research Center in Way Canguk area (5^o 39' S; 104^o 24' E), which is located in the southwestern part of the park (Figure 1.2). Mean annual rainfall is approximately 3000-4000 mm with the highest rainfall during October-February (WCS-IP *unpublished report*). The station is located in lowland forest and has high diversity of wildlife

(Sunarto 2000) including a number of high profile endangered mammals, such as Sumatran Tiger (*Panthera tigris*), Sumatran rhino (*Dicerorhinus sumatrensis*) and 187 species of birds including 3 species of Phasianidae (Winarni 1999). The study area contains a mosaic of lowland habitat types, including primary forest (50%), lightly disturbed forest (27%), and previously burned forest (23%). The latter category resulted from fires during 1992/1993 and during a 1997 drought (O'Brien et al. 1998). Tall canopy trees of the Dipterocarpaceae family dominate the primary forest (WCS-IP 2001), which is common in most lowland forest in Sumatra (Whitmore 1975). Other tall canopy trees are from families of Fabaceae and Moraceae, which are known to be important sources of food for birds and primates in BBSNP (WCS-IP 2001).

The study area encompasses an 800 ha forest with a grid of trails at 200 m intervals (Figure 1.2). The study area is bisected by the Canguk River and the two sections are referred to as North and South sides. All transects are permanently marked at 50-m intervals.

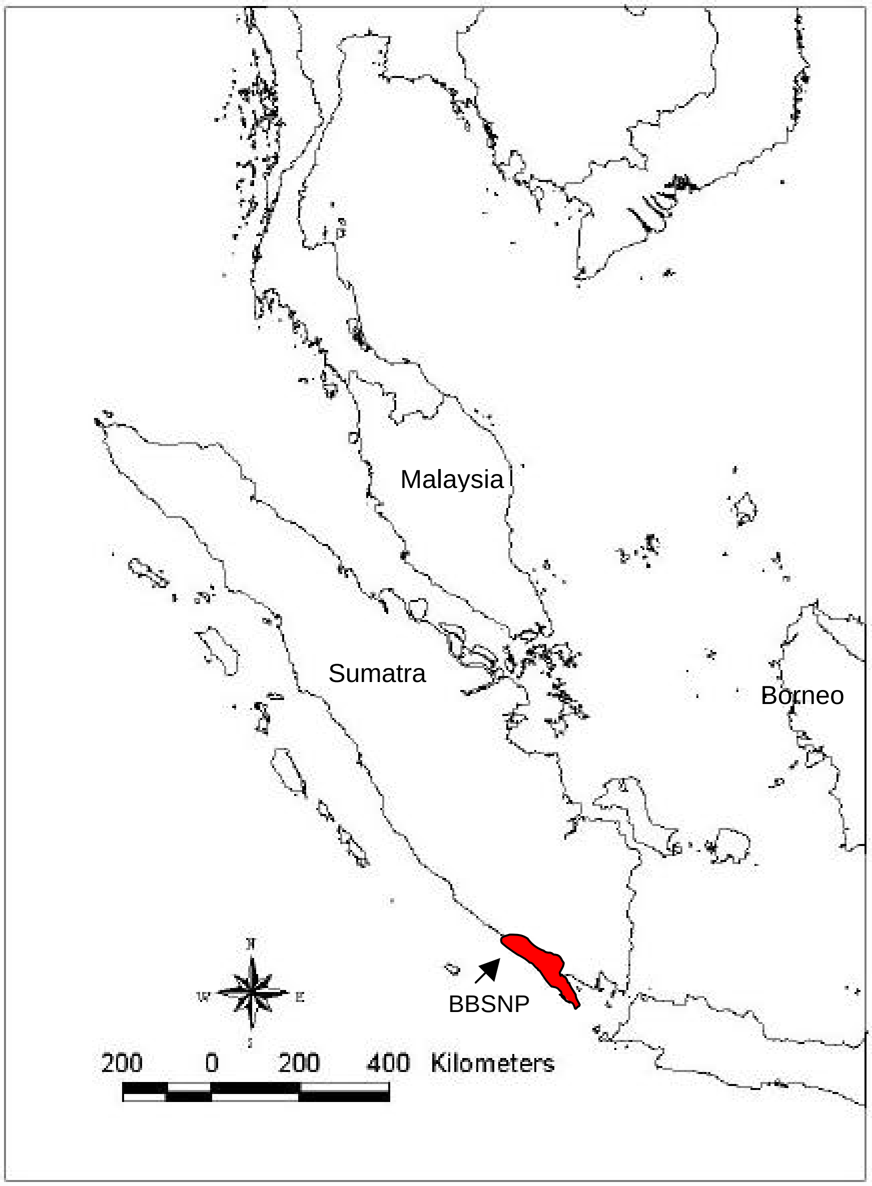

Figure 1.1. Location of Bukit Barisan Selatan National Park, Sumatra, Indonesia

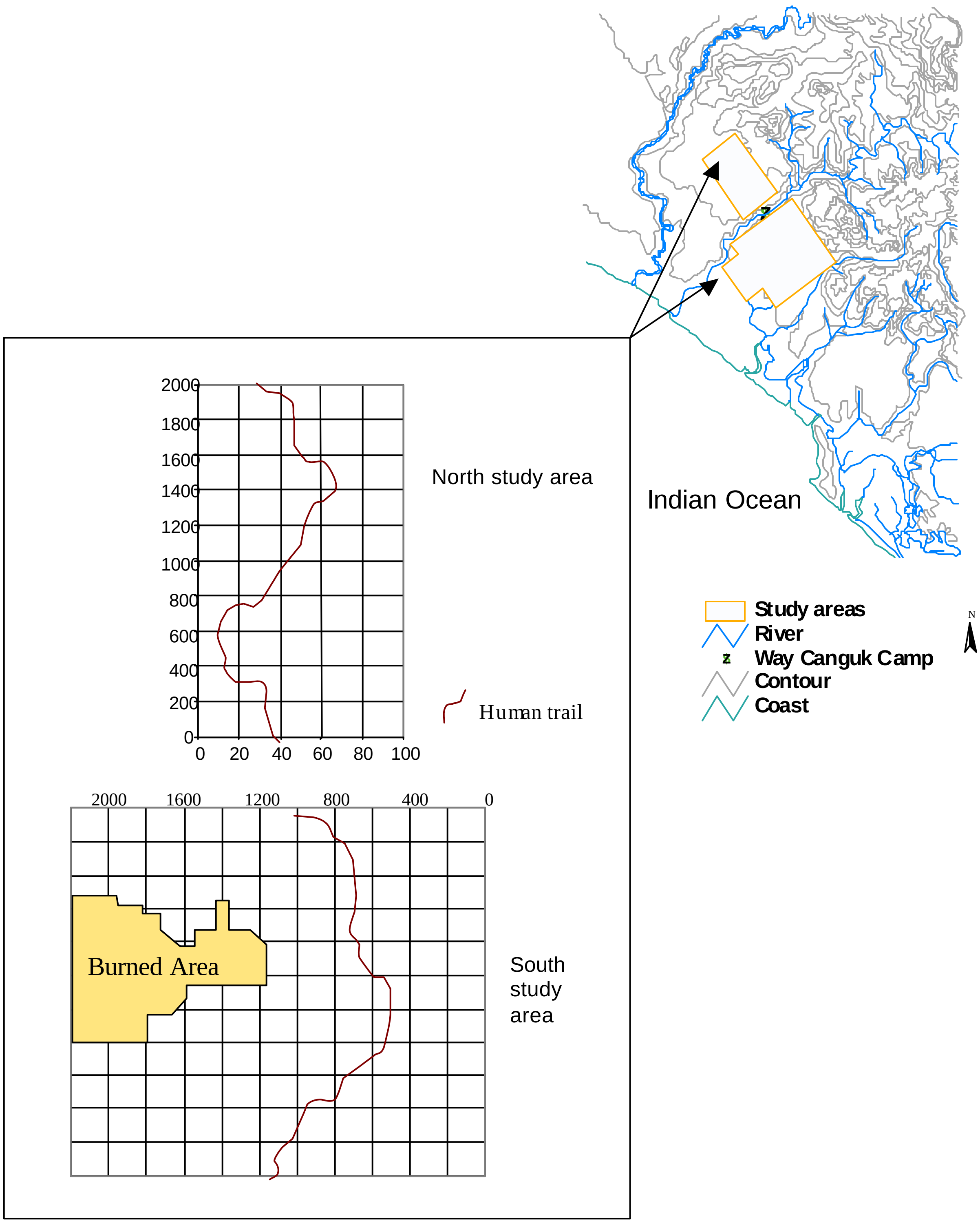

Figure 1.2. Wildlife Conservation Society (WCS)/*Perlindungan Hutan dan Konservasi Alam* (PHKA) Conservation and Training Research Center - Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing North and South study areas.

CHAPTER 2

ASSESSMENT OF LINE TRANSECT AND CAMERA TRAPPING TECHNIQUES IN ESTIMATING THE ABUNDANCE OF GREAT ARGUS PHEASANT (*Argusianus argus*) IN SOUTHERN SUMATRA, INDONESIA

INTRODUCTION

Estimation of abundance is a cornerstone of conservation efforts for most species and a large number of techniques for quantifying abundance have been developed to contend with a large diversity of habitats and species behaviors. Among available techniques, distance sampling through point transect or Variable Circular Plot (VCP) and line transect methods have been used widely to estimate bird population densities. Although VCP has been used for songbirds, it is unlikely that this method could be used in estimating Galliformes species because assumptions of the method can be violated due to low detection probability and inaccurate distance estimation (Bibby et al. 2000). Thus, many species of Galliformes are still relatively unstudied due to their secretive behavior (Conroy and Carroll 2001). The abundance of Great Argus pheasant has not been quantitatively assessed.

The alternative method of distance sampling is the line transect method. In this method, researchers traverse a line and detect animals as the target objects (Burnham et al. 1980). However, estimating absolute densities from this method requires meeting four assumptions: (a) animals on transect line are always detected, (b) animals are detected at their initial location, (c) distances are measured correctly, and (d) sightings are independent (Burnham et al. 1980, Buckland et al. 1993). Meeting the assumptions can be very critical in the survey situations especially when it comes to detectability. Ideally, distance should be measured correctly to reduce bias of estimating the population (Buckland et al. 1993). Species behavior and habitat type have a strong influence on detection (Bibby et al. 2000). In addition, data often exhibit heaping and outliers that affect robustness of the estimation (Burnham et al. 1980). During surveys, observers tend to heap or round the distance into a more convenience value. Heaping of data during observations in the field may result in serious bias in estimating the density, although this can be avoided by using appropriate tools for estimating the distance, such as laser range finders. In the case of Great Argus pheasant, estimating the distance can be critical since the bird is secretive, but the call can be heard up to 1 km away. These factors contribute to difficulty in estimating the distance. Therefore, data heaping should be undertaken during the analytical step, which can be done by grouping the data into appropriate intervals (Burnham et al. 1980). In addition, robust density estimation often requires truncation of the farthest data due to the outlying observations beyond the normal range of data to produce better estimation of density (Buckland et al. 1993, Bibby et al. 2000).

The use of distance sampling has been applied to many studies on animal such as birds, which are detectable by coloration or calls during survey (Buckland et al. 1993). As a method to measure the absolute density of a species, line transect is known to have a high cost and representative samples are hard to obtain, especially in remote lowland tropical forests (Bull 1981).

Recently, biologists have made some modification by using camera traps to estimate tiger (*Panthera tigris*) densities in a framework of capture-recapture methodology (Karanth 1995, Karanth and Nichols 1998, Wildlife Conservation Society 2000). During 1999, the Wildlife Conservation Society-Indonesia Program began a program of assessing the abundance of Sumatran tiger (*Panthera tigris sumatranus*) in Bukit Barisan National Park. Their results shown that camera trap may be a useful tool to obtain images on tigers prey, e.g. mousedeer (*Tragulus* spp.), wild pigs (*Sus* spp.), macaques (*Macaca* spp.), and Great Argus pheasant (Wildlife Conservation Society

2000). Although it is difficult to distinguish individual Great Argus pheasant without marking birds, it might be possible to use double sampling techniques to estimate populations of Great Argus pheasant in areas where camera trapping is used.

In this paper, I assessed the utilization of line transect techniques in estimating the density of Great Argus pheasant in the park. To assess possible data biases, different heaping and truncation models were applied to the data. In addition, we also assessed the use of camera trapping techniques for detecting Great Argus pheasant.

STUDY AREA

We studied Great Argus pheasant in Bukit Barisan Selatan National Park (BBSNP), Sumatra. BBSNP is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien and Kinnaird 1996, Sunarto 2000). The park contains some of the largest tracts of lowland rain forest remaining in Sumatra and functions as the primary watershed for Southwest Sumatra (O'Brien and Kinnaird 1996).

This research was carried out in the Wildlife Conservation Society (WCS) Conservation and Training Research Center in Way Canguk area (5^o 39' S; 104^o 24' E), which is located in the southwestern part of the park. The station is located in lowland forest and has a high diversity of wildlife (Sunarto 2000) counting some endangered mammals, such as Sumatran Tiger (*Panthera tigris*), Sumatran rhino (*Dicerorhinus sumatrensis*), and 187 species of birds including 3 species of Phasianidae (Winarni 1999). The study area encompasses an 800 ha forest with a grid of trails at 200 m intervals. The study area is bisected by the Canguk River and the two sections are referred to as North and South sides. All transects are permanently marked at 50-m intervals. The study area contains a mosaic of lowland habitat types, including primary forest (50%), lightly disturbed forest (27%), which cover other non-primary forest, and previously burned forest (23%), the latter category resulting from fires during 1992/1993, and during a 1997 drought (O'Brien et al. 1998).

METHODS

Line transect

Line transect methods were used to obtain the density estimates of Great Argus pheasant. Because Great Argus pheasant is very sensitive and secretive, the counts included calling birds and those actually seen. All trails were walked once a month during 1998-2001. A team of two people conducted the population estimates at each 2.2 km on the South side (12 trails, Figure 2.1) and 2 km trails on the North side (6 trails, Figure 2.2). Usually, three teams walked on transects next to the each other at the same time with a pace of 7-9 minutes/200 m. Angle and sighting distance from the observer to the bird were recorded. Angles were measured using a digital compass and distances from sighting were measured using a laser range finder. However, distances from aural cues were measured by estimation. Then, perpendicular distances were calculated using the equation:

$$x = r \sin \alpha$$

In addition, since transects were laid every 200 m, double counting birds was avoided by crosschecking the data among teams after each survey.

Estimation of line transect data is based on the idea that the probability of detecting an animal decreases as it gets farther from the transect (x). The detection function can be written as the conditional probability of observing an animal given at a perpendicular distance x: $g(x)$ = Pr (animal observed | x). Since the probability of detecting an animal decreases as the distance increased, then the probability of detection on the line should be 1, or $g(0) = 1$ and $g(x)$ is monotonically decreasing as x is getting farther from the line (Burnham et al. 1980, Buckland et al. 1993).

Line transect data were analyzed using DISTANCE (Buckland et al. 1993). Several levels of heaping were used during analysis. Four different grouping models: default (intervals automatically set by the program), 5, 8, and 10 intervals were applied to the Great Argus pheasant data. I made comparisons between North side and South side. Then for each side, 1998, 1999 and 2000 data were compared. Cut points with equal intervals were defined automatically by the DISTANCE program. Results are presented through histograms of detection probability over perpendicular distance.

Estimation of Great Argus pheasant distance from the center line can be a problem especially as distance from the transect line increases. Although in data collection I tried to use the fixed width of 100 m, observations near 100 m can act as outliers because of the difficulty in estimating this distance. Therefore, a model without truncation and three different models with truncation of 5%, 10%, and 15% were applied in the analysis. Results are also presented through histograms of detection probability over perpendicular distance.

Modeling processes for the detection function $f(0)$ were conducted in two steps by selecting key function based on histogram of distances and by series expansion (Buckland et al. 1983). Models chosen were based on the lowest coefficient of variance in estimating the density and the detection function curve on histograms. There are four key functions commonly used: uniform, half-normal, hazard-rate, and negative exponential. Uniform and half-normal are recommended for initial consideration. Models were considered reliable when fit with three properties: model robustness, shape criterion, and estimator efficiency. Then, model fitting was determined using Akaike's Information Criteria (AIC) value (Buckland et al. 1993). AIC values of different models can only be compared using the same data (Rosenstock et al. 2002). Because of different use of data with heaping and truncation, direct AIC comparison was not possible, therefore comparison of heaping and truncation models was done using coefficient of variance (CV).

Camera Trapping

Camera trapping data were provided by the Large Mammal Survey Project of the Wildlife Conservation Society-Indonesia Program. We used CAM-TRACKER camera traps that were set to record 24 hours per day and were deployed for approximately 30 days. Cameras were assigned at a density of 1 camera/16 ha throughout the South study area resulting in each transect being assigned 3 cameras (Figure 2.1). Cameras were placed on locations assumed to be animal trails and were mounted on a tree at approximately 0.5 m above the ground. Three different periods of sampling were conducted during 1999–2000, with approximately 6 months intervals between each sample. In addition to this survey, 10 other locations throughout the Bukit Barisan Selatan National Park were also surveyed with camera traps at a density of 1 camera/1 km^2 (The Wildlife Conservation Society 2000). Motion sensors triggered the cameras and photos were imprinted with date and time of exposure.

Camera trap data from Way Canguk were separated from the other 10 locations. Each-16 ha area deployed with camera traps from Way Canguk data were overlaid onto line transect encounter data from the South study area. Then, further analyses were conducted using data pooled at each transect. I used program CAPTURE to estimate camera trap capture probability among 3 sample occasions. Capture history computed in program CAPTURE (Otis et al 1978, White et al. 1982) was based on whether the camera trap detected any Great Argus pheasant. Program CAPTURE (Otis et al 1978, White et al. 1982) offers several estimators to model the capture probability: Model M_0 for constant capture probability, Model M_b that allows variation in behavioral response of the animal captured, and M_t that permit time heterogeneity. In addition, program CAPTURE (Otis et al 1978, White et al. 1982) also offers estimator that include two sources of variation in capture probability, M_{bh}, M_{th}, and M_{tb}.

Then, to test the relationship between line-transect detection rate and camera trap detection rate, linear regression was performed. All statistical analyses were executed using SPSS version 10 (SPSS Inc. 1999).

RESULTS

Density of Great Argus Pheasants

My line transect surveys resulted in most sighting encounters being recorded at a distance between 0-40 m whereas most calling encounter were recorded at a distance >60 m. Only one calling encounter was recorded at <20 m (Table 2.1).

Results for fitting the detection function with several different keys showed that for both North and South side data, the half-normal distribution produced the best model fit for most heaping models (Tables 2.2 and 2.3). Selection of best detection function model based on AIC values for best heaping levels is presented in Tables 2.4 and 2.5. However, there were some variations of the best model fitted with 1999 and 2000 data for

South side (Table 2.2) and based on the lowest AIC value, the uniform function was selected. Both models, the half-normal and uniform are considered robust (Buckland et al. 1993). Best heaping models are depicted in histograms of detection probability (Figures 2.3 and 2.4).

When fitting the detection function with different levels of truncation, I found that for both North and South side data, uniform and half-normal keys fitted the best model for most truncation models based on the lowest AIC value (Tables 2.6 and 2.7). Selection of best detection function model based on AIC values for best heaping levels was presented in Tables 2.8 and 2.9. Similar to the results of heaping models, different truncation models did not seem to influence the density estimation, although a 10% truncation produced better estimation in the South side 1998 data (Table 2.6). However, truncation was not needed for the South side 1999 and 2000 data (Table 2.6). Moreover, for North side, 5% truncation produced the smallest variance in the estimation (Table 2.7). Best truncation models are depicted in histograms of detection probability (Figures 2.5 and 2.6).

Overall results suggest that densities of Great Argus pheasant from North and South sides may have increased during 1998 to 2000 (Figures 2.7-2.10). Densities of Great Argus pheasant in the South side increased from about 0.5 individuals/km^2 during 1998 to 1.4 individuals/km^2 during 1999, and 1.9 individuals/km^2 during 2000. Densities of Great Argus pheasant in the North side were about 1.8 individuals/km^2 during 1998, increasing to 3.2 individuals/km^2 during 1999, and 3.1 individuals/km^2 during 2000 (Tables 2.2 and 2.3).

Assessment of Camera Trap Techniques

My camera trapping results from Way Canguk revealed that percentage of cameras detecting Great Argus pheasant ranged from 23-34% (Table 2.6). Great Argus pheasant were never detected on the day the camera was set up, but first detection was most often <10 days after set up (Table 2.10).

Analyses of capture histories based on detectability of camera traps using program CAPTURE, identified M_h (heterogeneity) as the most robust model (Model value = 0.62). Although program CAPTURE identified M_0 (constant capture probability), M_{th} (time-heterogeneity), and M_{tbh} (time-behavior-heterogeneity) as appropriate model, M_0 was not considered robust to violation of the assumption that there is no variation in capture probability. The other models, M_{th} and M_{tbh} are rarely used since there are no estimators associated with these models (Otis et al. 1978), although non-parametric estimator may be used (Chao et al. 1992). Thus, I decided to use M_h due to its robustness. Under the M_h model, which allows heterogeneity of individuals, capture probability was quite high (average $\hat{p} = 0.7037$). In this case, heterogeneity of individuals should be considered as variations of each detection, since capture histories were based on detection of Great Argus pheasant, not on the individual itself.

Comparison of detectability between camera traps and line transect surveys showed that when Great Argus pheasant were detected in transects, the bird also was likely to be detected in camera traps (Table 2.11). Numbers of Argus detected by camera traps showed a positive relationship with detection rate from line transect surveys ($F = 3.24$, 1, 34 df, $P = 0.08$, Figure 2.11).

My camera trap results revealed that camera trap photos were taken at a peak about one hour after sunrise and declined gradually during the day. However, there was a slight increase in activity at approximately 2 hours before sunset (Figure 2.12). The camera data suggest that Great Argus pheasant are almost strictly diurnal (Figure 2.12).

DISCUSSION

Assessment of line transect techniques

Problems of estimating distance commonly occur in the line transect methodology. There is often a tendency to round perpendicular distance to convenient values such as 5, 10, 50, or 100 m (Buckland et al. 1993), which becomes a problem when studying secretive birds that can be recorded mainly by singing/calling where distance measurement relies only on estimation. Utilization of a fixed width of 100 m brought a tendency to use the exact *w* as the distance for encounters near *w* (Burnham et al. 1980, Buckland et al. 2001). To overcome this problem, however; grouping data into appropriate intervals during analysis will allow a better density estimation (Buckland et al. 1993). However, it is recommended to group the data into no more than 10 intervals (Burnham et al. 1980). Four different heaping models applied to North and South side revealed that various heaping models did not seriously affect the density estimation. Different grouping intervals were selected for each data. Most histograms of the detection function showed that heaping into 50-60 is still occurred during data collection. However, the shape criterion should be taken into consideration. If the histogram appears to be spiked, then a robust model must be chosen (Buckland et al. 2001). A histogram considered to be spiked if the first interval is considerably higher than the rest (Buckland et al. 2001). Most of my resulting histograms showed a “shoulder” near 0 that correspond to the g(x) = 1 or the assumption " all individuals on the line are detected (Burnham et al. 1980). Only North side 1998 and 2000 data lack the "shoulder."

Although Great Argus pheasants are distinctive by their calls, the bird is secretive and sensitive. In this research, data from sighting and calling are pooled. My sighting data showed that encounters dropped off >40 m from the line. At some closer distances the bird seemed able to detect the observers and, thus, tried to be less conspicuous. Calling data, however, increased as object moved farther from the line and tended to get higher >60 m from the line. If sighting and calling encounters were combined, detections were not synchronized and voiceless individuals that might be found >40 m were not detected, which would lead to biases in the density estimation. In addition, distance estimation based on calling can be quite a problem, especially when we do not have much information on the species such as territory and behavior. Although calling of Great Argus pheasant is distinct, their long and short calls can be heard up to 1 km (Davison 1981a). The occurrence of heaping also indicated that development of standard survey protocols critically needs to be improved. Bibby et al. (2000) recommended using exact distances even though data collection is more time consuming. Distance estimation from sighting encounters is more likely to be improved since exact measurement is possible. Exact measurement of distance from calling encounter, however, would be hard to achieve, especially when the bird is farther than 50 m from the line. Anderson et al. (1979) suggested that line transect sampling is well suited to Ring-necked pheasant (*Phasianus colchicus*) and Sage Grouse (*Centrocercus urophasianus*) because these species inhabit open areas where flushing is feasible. This situation cannot be applied to Great Argus pheasant. My data suggests that application of line transect sampling on

Great Argus pheasant should be modified. Due to restricted visibility in the tropical rainforest and the bird's behavior, I suggest that fixed width transects should be no more than 50 m.

Outliers can produce bias in density estimation. The existence of outliers provides little information for estimating the density function $f(0)$. Therefore, it is generally suggested to eliminate 5-10 percent of the farthest observations (Buckland et al. 1993). Even though I used a fixed width of 100 m, due to the difficulty of distance estimation observers tend to ignore encounters near w. Thus, observations near w could act as outliers.

My results suggest that truncation was needed to achieve better density estimation for North side and for South side 1998 data. Truncation for 1998 South side data was probably linked to heaping 100 m during surveys. Thus, eliminating data >70 m away probablywould give a better density estimation. Nevertheless, during 2000, we could see that truncation is no longer needed to improve our density estimation

It should be noted that heaping during analysis sometimes is sufficient to produce better density estimation without truncating the data. Deletion of furthest data may decrease precision (Buckland et al. 2001). As a measure of precision to true population value (Thompson 2002), coefficient of variance should be checked when one has to decide on using of heaping or truncation. In this study, I use a fixed-width transect of 100 m so that outliers were avoided earlier during observations. Thus, in my case truncation should be considered a second step.

By using a fixed-width transect of 100 m and conducting crosschecking data between each team, it appears that detection probability can be improved. However, observers still need to improve distance estimation. Estimating distance will likely improve as knowledge is gained on the bird's behavior and ecology. Observer's variability also might influence the probability of detection. When several different observers walk on the same transect, each observer may have different perception on detecting objects (Ringvall et al. 2000). In this study, I generally used the same observers over time. Therefore observers had gained knowledge on the species as well as experience in estimating the distance since line transect survey were conducted once every month since 1998. However, day-to-day walking in the same study area can bring fatigue to observers (Buckland et al. 1993). Furthermore, seasonal changes may also affect the probability of detection (Best 1981), since the males tend to perform their calls during breeding season. Nevertheless, this factor should have already been avoided, since data were organized to cover non-breeding and breeding seasons.

Although the study area may have recovered from the 1997 drought and may affect the population of Great Argus, the increase density of Great Argus pheasant in the area, however, do not necessarily suggested that population is actually increased. This study suggests that improvement of detection probability over time affected the density estimation.

Assessment of camera trapping in detecting Great Argus pheasant

My results showed that during camera trapping surveys, Great Argus pheasant was never detected on the same day the camera was set. Cameras started detecting Great Argus pheasant on the next day, although the first day detections were varied among cameras. Setting up a camera usually involved 2-3 people. As a disturbance-sensitive bird, Great Argus pheasant would avoid the area of human visitation. During the trapping period of radio telemetry study of Great Argus pheasant, the bird was never captured at the same day the snares were set up (N. Winarni *personal observation*). However, detection of Great Argus pheasant can be considered random. Great Argus pheasant movement was shown not to be related to food and did not show any particular foraging patterns (see Chapter 4).

Analysis of my results using program CAPTURE results suggests that behavioral responses did not influenced the capture probability. The identification of M_h as the best model suggested that camera traps allow variations of each detection. Heterogeneity is influenced by sex and age and by accessibility to camera relative to individual home ranges (Otis et al. 1978, White et al. 1982). Since capture histories were not based on the individual itself, individuals detected by a camera might not be the same individual detected later. Although the chance of detecting the same individual is high, particularly on an area within adult male home ranges, there are always possibilities to detect females or sub-adult males.

My results using camera traps to estimate abundance is fraught with difficulty because I could not generate transect level population estimates. From 3 sampling periods, the percentage of cameras detecting Great Argus pheasant was low, <35%. My data suggest that when Great Argus pheasant is detected during surveys, it is likely to be detected in camera traps as well. When the surveys detected Great Argus pheasant, but the camera traps failed to detect them, placement of camera may be the possible cause. In the study of tiger population density using camera trapping, cameras were positioned on areas based on tiger cues such as scats, scrapes, and scent deposits (Karanth 1995, Karanth and Nichols 1998). Except droppings, cues of Great Argus pheasant are relatively difficult to distinguish. Furthermore, the period of sampling should be taking into consideration as well. From 3 sampling periods, camera traps were each deployed in a different month (Table 2.10). Although, there is no information on the difference of Great Argus pheasant movement among months, it is possible that seasonal behavior may affect the camera trap detectability.

The regression graph revealed that camera traps resulted in fewer detections than line transect surveys (Figure 2.11). However, this is not surprising. Line transect surveys involve observers, which make the detections higher since the searching method is active, and includes vocalization. Camera traps, on the other hand, are stationary. Detectability of camera trap depends on placement. Although, the relationship between detection rates of camera traps and line transect survey was not strong, the possibility of improving the use of camera traps still exist. Camera trap are beneficial in that they detect Great Argus pheasant beyond periods of peak activity (Figure 2.12), whereas line transect surveys only detect birds during the period of survey. Although Great Argus pheasant may call in the afternoon, the bird usually spends more time perching. A study on Great Argus pheasant in Malaysia suggested that during breeding season, an adult male spent most of his time perching close to the dancing ground (Davison 1981b).

Even though line transect is more reliable to estimate density of a population, density estimation depends on detection probability. Behavior of Great Argus pheasant, thus, affected the probability of detection. Camera trapping offers alternative methods of detecting Great Argus pheasant. Camera traps would be appropriate tool to acquire information of vigilant animals such as Great Argus pheasant. Recently, camera traps were used not only to indicate presence and absence of animals, but also to estimate the population size of rare and secretive animals such as tigers (Karanth 1995, Karanth and Nichols 1998). In a framework of capture-recapture, tiger densities in India were estimated based on stripe pattern to differentiate between individuals. Thus, stripe patterns were used as a marker (Karanth and Nichols 1998).

So far, there is no literature suggesting that camera traps have been utilized in any Galliformes studies. Galliformes species are distinctive for their secretive habit and some species are less conspicuous in calling (Bibby et al. 2000). Hence, camera traps showed potential use for the future of Galliformes studies. The use of camera traps in BBSNP has proved that this method can provide information on rare animals such as tigers and their prey (Wildlife Conservation Society 2000). Great Argus pheasant was found to prefer forest interior (Wildlife Conservation Society 2000). The camera trap data also showed occurrence of other Galliformes species such as Cested wood-partridge (*Rollulus rouloul*) and Bronze-Tailed peacock-pheasant (*Polyplectron chalcurum*). While providing information on presence and absence, relative abundances of rare and secretive species also were revealed as well as other baseline ecological information. Hence, application of camera traps to study Southeast Asian pheasants having similar habitat affinities is promising.

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Table 2.1. Great Argus pheasant encounter based on cues from line transect data 1998, 1999, 2000 of both South and North sides, Bukit Barisan Selatan National Park, Indonesia. Distances (in meters) of calling encounters were based on estimation, whilst sighting distances were measured using laser rangefinder.

Distance (meters)	**1998**		**1999**		**2000**	
	heard	seen	heard	seen	heard	seen
0-20	1	6	0	13	0	23
20-40	3	6	5	4	6	11
40-60	3	1	18	1	11	0
60-80	8	0	51	2	24	0
>80	10	0	50	0	23	0

Table 2.2. Summary outputs for different heaping applied to South study site line transect data 1998-2000 from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing density of Great Argus pheasant (numbers/km^2), low and upper confidence interval, coefficient of variance, and key function selected.

Heaping	*Density*	*Low CI*	*Upper CI*	*% CV*	*Key function*
South 1998					
0	0.626	0.296	1.327	0.386	Neg. exponential
5	0.696	0.318	1.522	0.402	Neg. exponential
8	0.637	0.289	1.404	0.406	Neg. exponential
10	0.549	0.289	1.011	**0.314**	Half normal
South 1999					
0	1.389	1.127	1.711	**0.106**	Uniform
5	1.389	1.127	1.711	0.106	Uniform
8	1.389	1.127	1.711	0.106	Uniform
10	1.647	1.222	2.221	0.153	Half normal
South 2000					
0	2.113	1.399	3.191	0.211	Half-normal
5	1.858	1.259	2.740	**0.199**	Uniform
8	2.042	1.342	3.107	0.215	Half-normal
10	2.086	1.379	3.155	0.212	Half-normal

.

Table 2.3. Summary outputs for different heaping applied to North study site line transect data 1998-2000 from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing density of Great Argus pheasant (numbers/km^2), low and upper confidence interval, coefficient of variance, and key function selected.

Heaping	***Density***	***Low CL***	***Upper CL***	***%CV***	***Key Function***
North 1998					
0	1.873	0.887	3.956	0.384	Half-normal
5	1.788	0.864	3.700	0.374	Half-normal
8	1.815	0.984	4.547	**0.366**	Half-normal
10	2.116	0.891	3.700	0.392	Half-normal
North 1999					
0	3.088	2.116	4.504	0.193	Half normal
5	3.319	1.908	5.774	0.285	Uniform
8	3.285	2.305	4.682	**0.181**	Half normal
10	3.289	1.939	5.579	0.271	Uniform
North 2000					
0	5.305	3.200	8.795	0.259	Half-normal
5	3.078	2.031	4.666	**0.212**	Half-normal
8	5.035	2.944	8.610	0.275	Half-normal
10	4.602	2.802	7.558	0.254	Half-normal

Table 2.4. Best heaping models of Great Argus pheasant data from South study area during 1998-2000, from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing defection function models and the AIC value. Best detection function model is based on the lowest AIC value.

Model (key function + expansion)	AIC
South 1998, 10 intervals	
Half-normal	**86.36**
Half-normal+cosine adjustment order: 1	88.36
Half-normal+hermite polynomial adjustment oder: 4	88.30
Uniform	87.50
Uniform+cosine adjustment order: 1	86.50
Uniform+cosine adjustment order: 1, 2	88.23
Negative exponential	86.50
Negative exponential+cosine adjustment order: 1	88.19
South 1999, default heaping	
Half-normal	810.57
Half-normal+cosine adjustment order: 2	812.34
Half-normal+hermite polynomial adjustment oder: 4	811.81
Uniform	**810.51**
Uniform+cosine adjustment order: 1	811.48
Negative exponential	810.74
Negative exponential+simple polynomial adjustment order: 2	812.25
South 2000, 5 intervals	
Half-normal	167.09
Half-normal+cosine adjustment order: 2	167.50
Half-normal+hermite polynomial adjustment oder: 4	169.07
Uniform	183.48
Uniform+cosine adjustment order: 1	166.84
Uniform+cosine adjustment order: 1, 2	**166.78**
Uniform+cosine adjustment order: 1, 2, 3	168.77
Uniform+simple polynomial adjustment order: 2	170.80
Uniform+simple polynomial adjustment order: 2, 4	168.83
Uniform+simple polynomial adjustment order: 2, 4, 6	168.63
Uniform+simple polynomial adjustment order: 2, 4, 6, 8	170.63

Table 2.5. Best heaping models of Great Argus pheasant data from North study area during 1998-2000, from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing defection function models and the AIC value. Best detection function model is based on the lowest AIC value.

Model (key function + expansion)	AIC
North 1998, 8 intervals	
Half-normal	72.16
Half-normal+cosine adjustment order: 2	**71.08**
Half-normal+cosine adjustment order: 2, 3	71.57
Half-normal+hermite polynomial adjustment order: 4	74.16
Uniform	74.86
Uniform+cosine adjustment order: 1	72.46
Uniform+cosine adjustment order: 1, 2	73.74
Uniform+simple polynomial adjustment order: 2	71.98
Uniform+simple polynomial adjustment order: 2, 4	73.97
North 1999, 8 intervals	
Half-normal	254.46
Half-normal+cosine adjustment order: 2	255.68
Half-normal+hermite polynomial adjustment order: 4	255.11
Uniform	262.01
Uniform+cosine adjustment order: 1	255.60
Uniform+cosine adjustment order: 1, 2	255.18
Uniform+cosine adjustment order: 1, 2, 3	**254.68**
Uniform+cosine adjustment order: 1, 2, 3, 4	256.36
Negative exponential	255.88
Negative exponential+simple polynomial adjustment order: 2	254.88
Negative exponential+simple polynomial adjustment order: 2, 4	256.45
North 2000, 5 intervals	
Half-normal	**135.29**
Half-normal+cosine adjustment order: 2	135.50
Half-normal+hermite polynomial adjustment order: 4	137.27
Uniform	151.29
Uniform+cosine adjustment order: 1	135.51
Uniform+cosine adjustment order: 1, 2	136.30
Uniform+simple polynomial adjustment order: 2	138.42
Uniform+simple polynomial adjustment order: 2, 4	137.59
Uniform+simple polynomial adjustment order: 2, 4, 6	138.42

Table 2.6. Summary outputs for different truncation models applied to South study area line transect data 1998-2000 from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing density of Great Argus pheasant (numbers/km^2), low and upper confidence interval, coefficient of variance, and key function selected.

Truncation	***Density***	***Low CL***	***Upper CL***	***% CV***	***Key Function***
South 1998					
0%	0.626	0.296	1.327	0.386	Neg. exponential
5%	0.653	0.298	1.433	0.404	Neg. exponential
10%	0.487	0.302	0.786	**0.245**	Uniform
15%	0.474	0.289	0.779	0.255	Uniform
South 1999					
0%	1.389	1.127	1.711	**0.106**	Uniform
5%	1.501	1.208	1.864	0.110	Uniform
10%	1.529	1.226	1.906	0.112	Uniform
15%	1.504	1.199	1.886	0.115	Uniform
South 2000					
0%	2.113	1.399	3.191	**0.211**	Half-normal
5%	2.205	1.452	3.348	0.214	Half-normal
10%	2.354	1.547	3.581	0.215	Half-normal
15%	3.398	2.015	5.729	0.268	Uniform

Table 2.7. Summary outputs for different truncation models applied to North study site line transect data 1998-2000 from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing density of Great Argus pheasant (numbers/km^2), low and upper confidence interval, coefficient of variance, and key function selected.

Truncation	*Density*	*Low CL*	*Upper CL*	*% CV*	*Key Function*
North 1998					
0%	1.873	0.887	3.956	0.384	Half-normal
5%	1.967	0.937	4.130	**0.379**	Half-normal
10%	2.064	0.970	4.390	0.386	Half-normal
15%	2.200	1.035	4.676	0.386	Half-normal
North 1999					
0%	3.088	2.116	4.504	0.193	Half normal
5%	2.606	1.980	3.429	**0.138**	Uniform
10%	2.760	2.076	3.668	0.143	Uniform
15%	2.880	2.155	3.849	0.146	Uniform
North 2000					
0%	5.305	3.200	8.795	0.259	Half-normal
5%	4.984	3.070	8.093	**0.248**	Half-normal
10%	6.461	3.885	10.811	0.262	Half-normal
15%	7.268	4.139	12.762	0.289	Uniform

Table 2.8. Best truncation models of Great Argus pheasant data from South study area during 1998-2000, from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing defection function models and the AIC value. Best detection function model is based on the lowest AIC value.

Model (key function + expansion)	AIC
South 1998, 10% truncation	
Half-normal	154.95
Half-normal+cosine adjustment order: 1	156.95
Half-normal+hermite polynomial adjustment oder: 4	156.95
Uniform	**152.95**
Uniform+cosine adjustment order: 1	154.95
Negative exponential	154.95
Negative exponential+cosine adjustment order: 1	156.95
South 1999, no truncation	
Half-normal	810.57
Half-normal+cosine adjustment order: 2	812.34
Half-normal+hermite polynomial adjustment oder: 4	811.81
Uniform	**810.51**
Uniform+cosine adjustment order: 1	811.48
Negative exponential	810.74
Negative exponential+simple polynomial adjustment order: 2	812.25
South 2000, no truncation	
Half-normal	503.57
Half-normal+cosine adjustment order: 2	**499.66**
Half-normal+cosine adjustment order: 2, 3	501.03
Half-normal+hermite polynomial adjustment oder: 4	505.52
Uniform	511.23
Uniform+cosine adjustment order: 1	502.10
Uniform+cosine adjustment order: 1, 2	500.02
Uniform+cosine adjustment order: 1, 2, 3	500.93
Uniform+cosine adjustment order: 1, 2, 3, 4	501.19
Uniform+simple polynomial adjustment order: 2	506.04
Uniform+simple polynomial adjustment order: 2, 4	504.13
Uniform+simple polynomial adjustment order: 2, 4, 6	503.18
Uniform+simple polynomial adjustment order: 2, 4, 6, 8	503.98

Table 2.9. Best truncation models of Great Argus pheasant data from North study area during 1998-2000, from Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing defection function models and the AIC value. Best detection function model is based on the lowest AIC value.

Model (key function + expansion)	AIC
North 1998, 5% truncation	
Half-normal	148.59
Half-normal+cosine adjustment order: 2	**145.73**
Half-normal+cosine adjustment order: 2, 3	147.13
Half-normal+hermite polynomial adjustment order: 4	150.56
Uniform	147.39
Uniform+cosine adjustment order: 1	147.54
Uniform+simple polynomial adjustment order: 2	148.90
North 1999, 5% truncation	
Half-normal	527.22
Half-normal+cosine adjustment order: 2	529.16
Half-normal+hermite polynomial adjustment order: 4	529.02
Uniform	**525.77**
Uniform+cosine adjustment order: 1	527.50
Negative exponential	526.93
Negative exponential+simple polynomial adjustment order: 2	526.98
North 2000, 5% truncation	
Half-normal	387.80
Half-normal+cosine adjustment order: 2	386.25
Half-normal+cosine adjustment order: 2, 3	**382.94**
Half-normal+cosine adjustment order: 2, 3, 4	383.50
Half-normal+hermite polynomial adjustment order: 4	389.78
Uniform	401.86
Uniform+cosine adjustment order: 1	387.79
Uniform+cosine adjustment order: 1, 2	388.80
Uniform+simple polynomial adjustment order: 2	391.71
Uniform+simple polynomial adjustment order: 2, 4	389.79
Uniform+simple polynomial adjustment order: 2, 4, 6	391.53

Table 2.10. Camera trapping data from 3 different sampling periods in Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia during 1999-2000, indicating percentage of camera detected Great Argus and first capture of Great Argus.

Sample	Date deployed	# camera	% camera detecting Great Argus	Time of first capture (days)			
				0	1-10	11-20	21-30
1	Apr-May 99	39	23.08%	0	5	1	2
2	Sep-Oct 99	35	28.57%	0	6	3	1
3	Jun-Jul 00	32	34.38%	0	7	0	3
Total				0	18	4	6

Table 2.11. Comparison of line-transect surveys and camera traps in detecting Great Argus in Bukit Barisan Selatan National Park, Sumatra, Indonesia, during 1999-2000: A) Detection based on transect detected, camera detected, B) transect detected, camera not detected, C) camera detected, transect not detected, D) camera not detected, transect not detected.

Sample	A	B	C	D
	transect y, camera y	transect y, camera n	transect n, camera y	transect n, camera n
1	4	4	1	4
2	8	4	0	0
3	4	4	2	2
Total	16	12	3	6

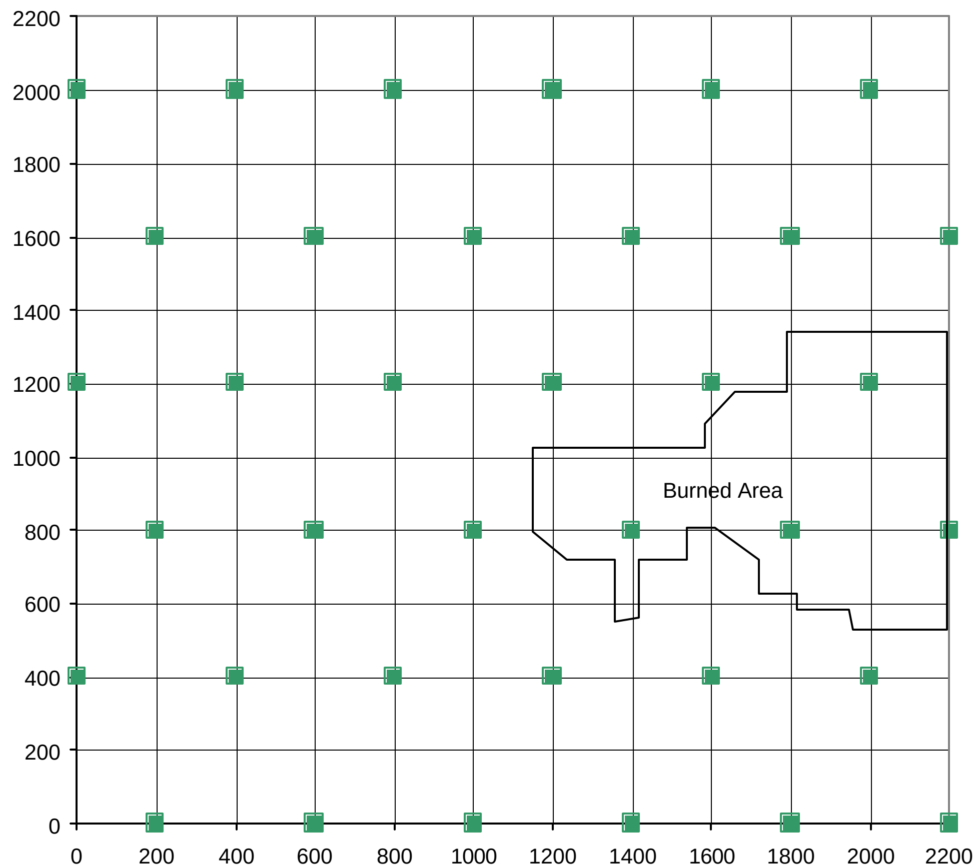


Figure 2.1. Distribution of camera traps (indicated by squares) throughout Way Canguk South study area, BBSNP, Sumatra, Indonesia. Cameras were assigned at a density of 1 camera/16 hectares. Line transect surveys were conducted on each of vertical lines on monthly basis.

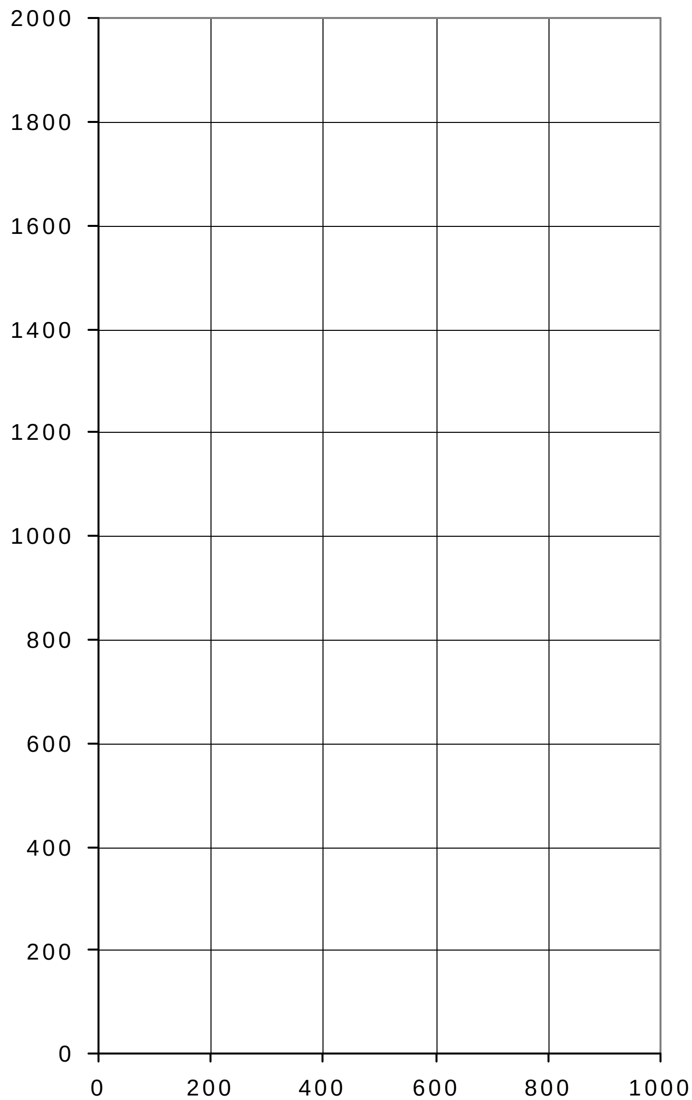
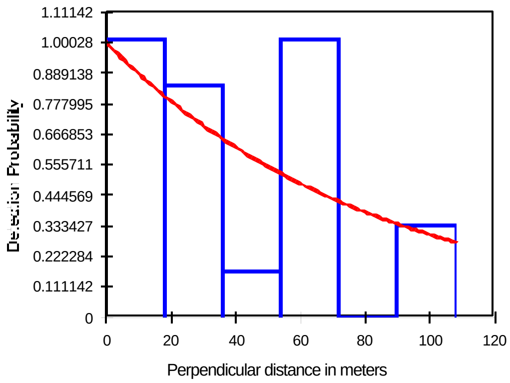
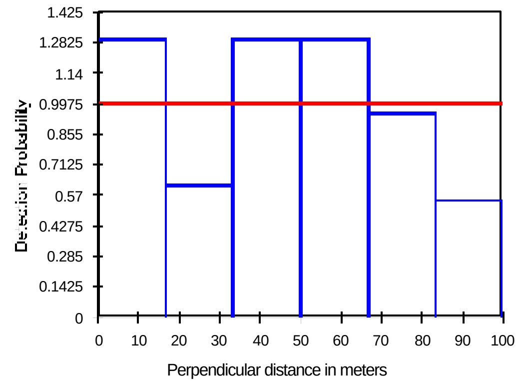


Figure 2.2. North study area of Way Canguk Research Station, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Line transect surveys were conducted on each of vertical lines on monthly basis

A. 1998, 10 intervals, half normal/cosine



B. 1999 data, grouping set by program, uniform/cosine



C. 2000 data, grouping set by program, half normal/cosine

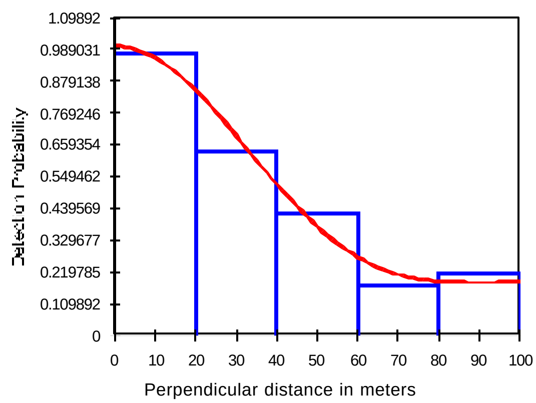
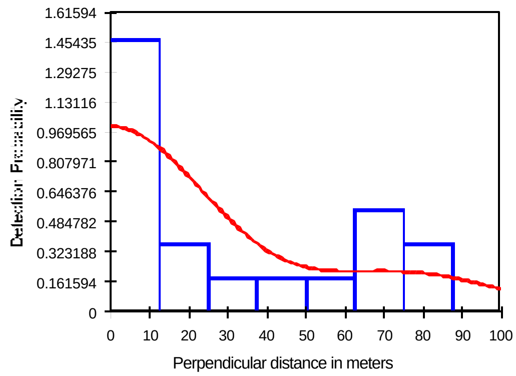
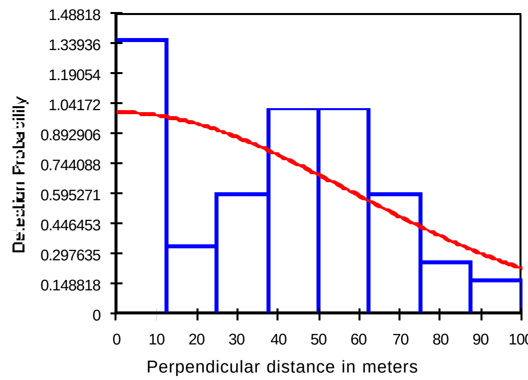


Figure 2.3. Histograms of detection probability over perpendicular distances of best heaping models applied to Great Argus pheasant 1998, 1999, 2000 data from South study area, Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Line transect were conducted on 12 lines surveyed once a month.

A. 1998 data, 8 intervals, half-normal/cosine



B. 1999 data, 8 intervals, half-normal/cosine



C. 2000 data, 5 intervals, half-normal/cosine

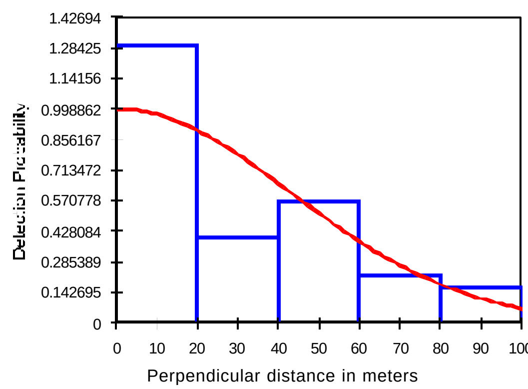
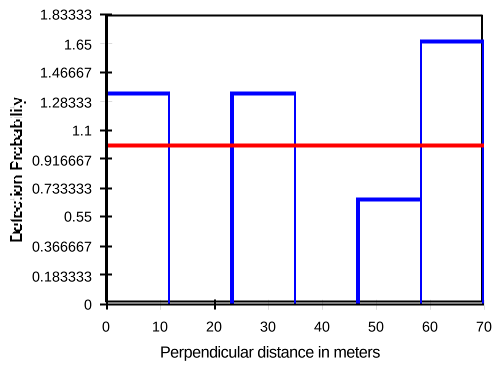
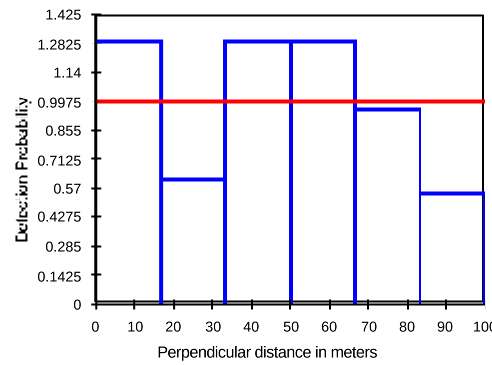


Figure 2.4. Histograms of detection probability over perpendicular distances of best heaping models applied to Great Argus pheasant 1998, 1999, 2000 data from North study area Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Line transect were conducted on 6 lines surveyed once a month.

A. 1998 data, 10% truncation,
uniform/cosine



B. 1999 data, no truncation,
uniform/cosine



C. 2000 data, no truncation,
uniform/cosine

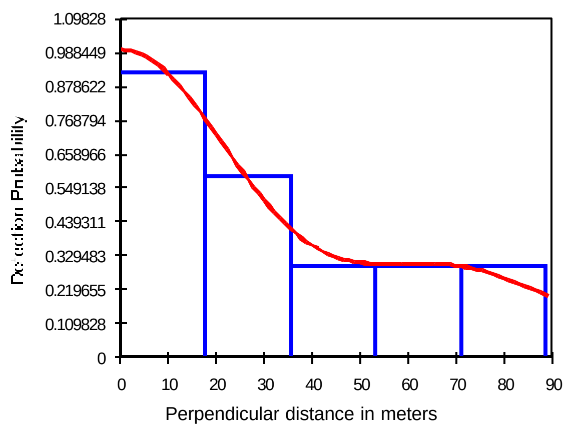


Figure 2.5. Histograms of detection probability over perpendicular distances of best truncation models applied to Great Argus pheasant 1998, 1999, 2000 data from South study area Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Line transect were conducted on 12 lines surveyed once a month.

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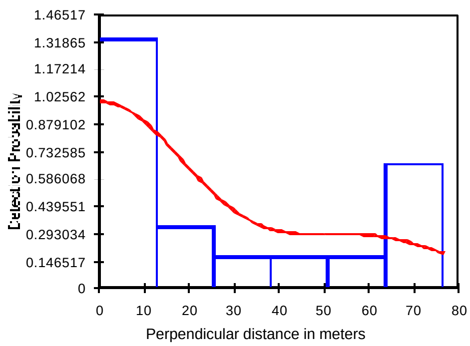
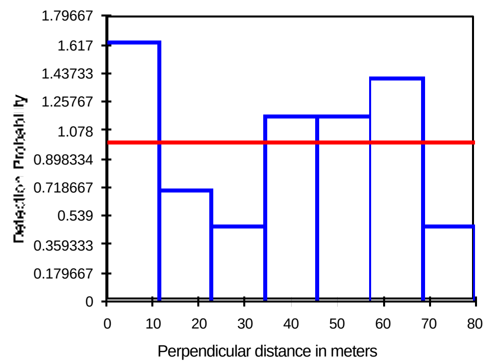
A. 1998 data, 5% truncation, half-normal/cosine



B. 1999 data, 5% truncation, Uniform/cosine



C. 2000 data, 5% truncation, half-normal/cosine

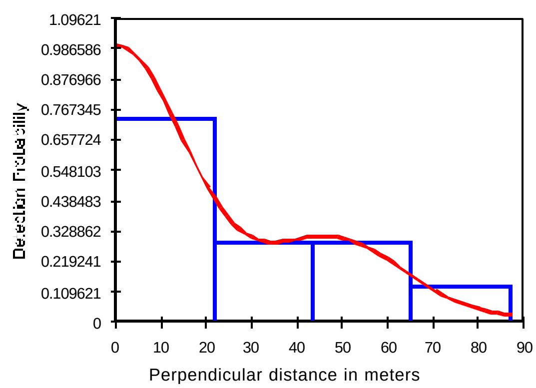


Figure 2.6. Histograms of detection probability over perpendicular distances of best truncation models applied to Great Argus pheasant 1998, 1999, 2000 data from North study area Way Canguk, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Line transect were conducted on 6 lines surveyed once a month.

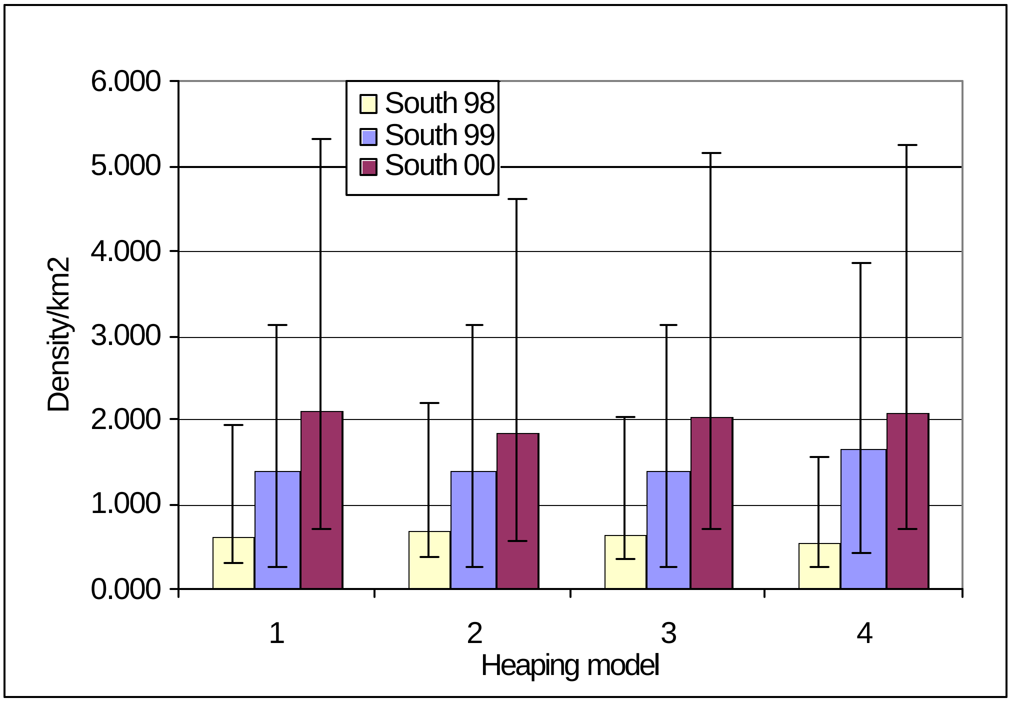


Figure 2.7. Density of Great Argus pheasant (numbers/km^2 with lower and upper confidence interval) in South study area, Bukit Barisan Selatan National Park, Sumatra, Indonesia, using four different heaping models (1= no heaping, 2 = 5 intervals, 3 = 8 intervals, 4 = 10 intervals)

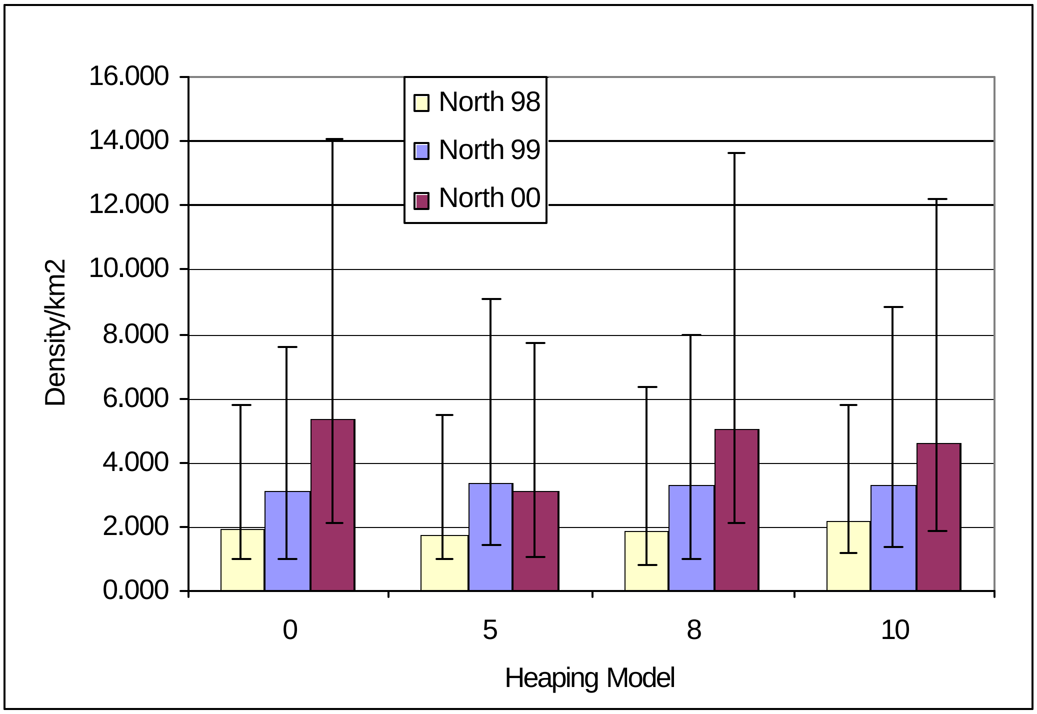


Figure 2.8. Density of Great Argus pheasant (numbers/km^2 with lower and upper confidence interval) in North study area, Bukit Barisan Selatan National Park, Sumatra, Indonesia, using four different heaping models (1= no heaping, 2 = 5 intervals, 3 = 8 intervals, 4 = 10 intervals).

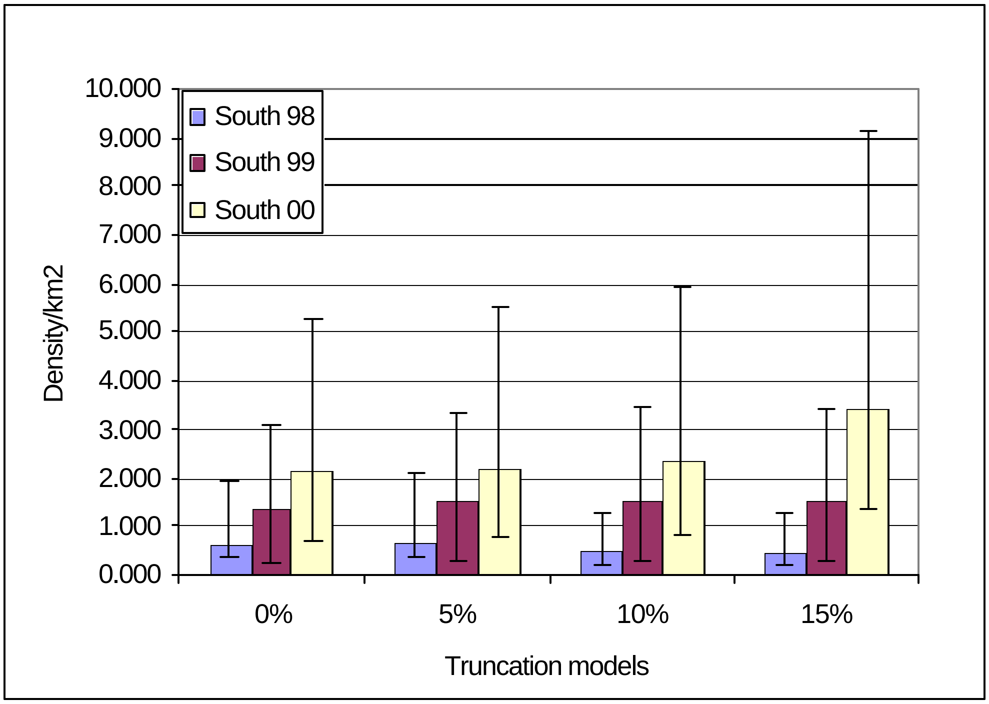


Figure 2.9. Density of Great Argus pheasant (numbers/km^2 with lower and upper confidence interval) in South study area, Bukit Barisan Selatan National Park, Sumatra, Indonesia, using four truncation models.

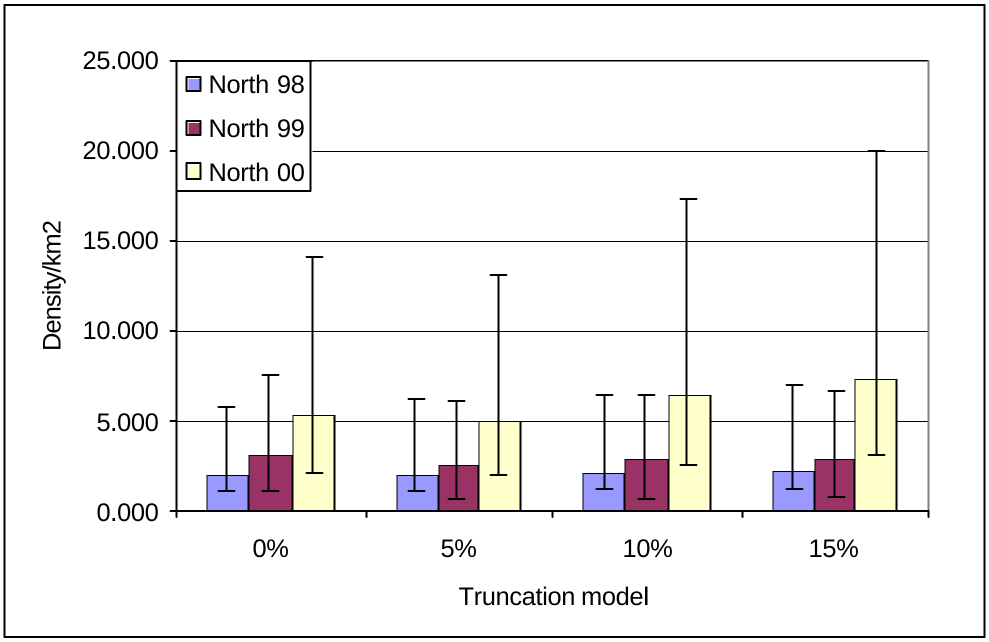


Figure 2.10. Density of Great Argus pheasant (numbers/km^2 with lower and upper confidence interval) in North study area, Bukit Barisan Selatan National Park, Sumatra, Indonesia using four truncation models.

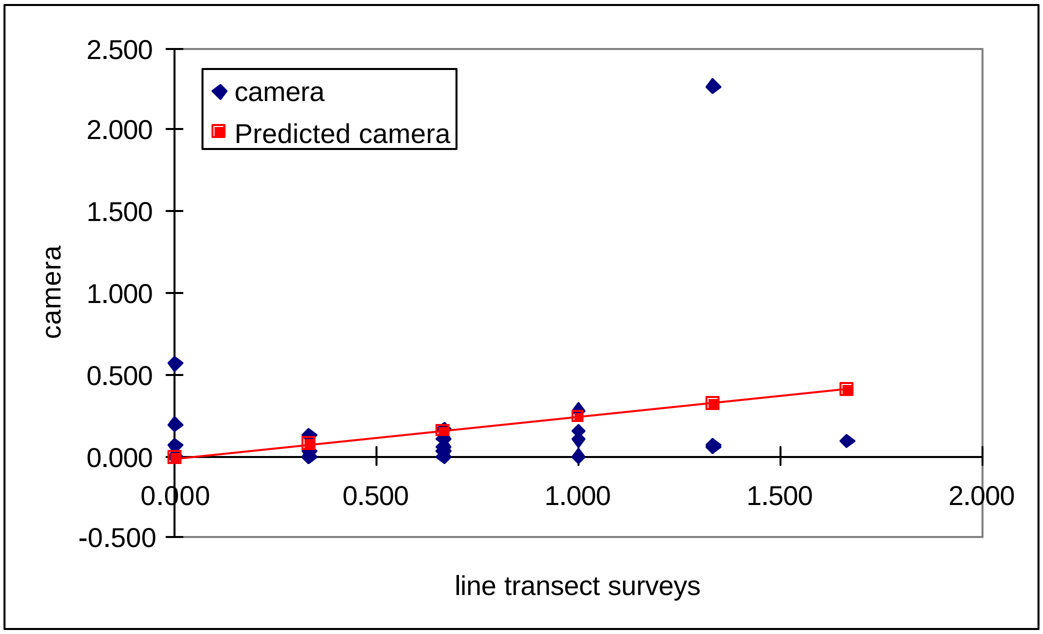


Figure 2.11. Regression line of camera traps and line-transect surveys based on detection rate, showing camera traps data and predicted data over line transect surveys

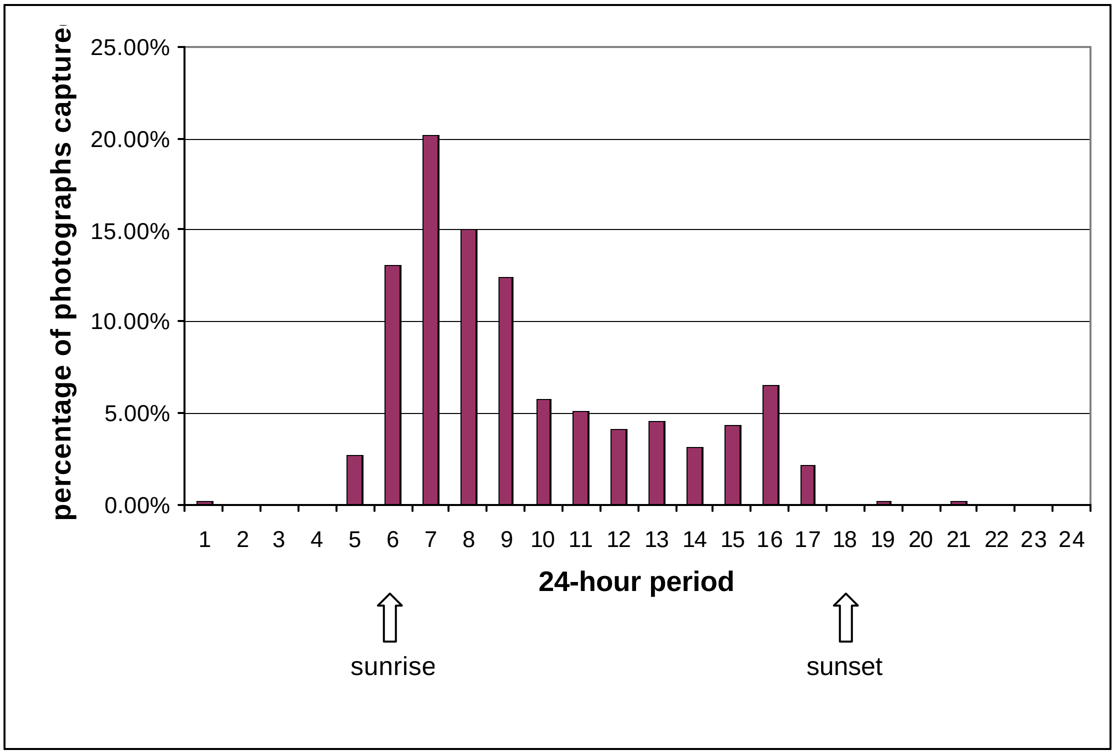


Figure 2.12. Percentage of Great Argus photographs captured in 24-hour period in Bukit Barisan Selatan National Park, Sumatra during 1999-2000. Sunrise is about 6:00 and sunset is about 18:00.

CHAPTER 3

LEK SITE SELECTION AND HABITAT USE BY THE GREAT ARGUS PHEASANT (*Argusianus argus*) IN SOUTHERN SUMATRA, INDONESIA

INTRODUCTION

The Great Argus pheasant is known to be associated with lowland dipterocarp forest where trees of family Dipterocarpaceae dominate (Davison 1981b). On the Malay Peninsula, Great Argus pheasant is common in hilly areas, but absent in montane forests, coastal forests, and highly disturbed and fragmented areas (Davison 1981a, Johnsgard 1999). This species seems to prefer tall primary forest and is less common in secondary forest (Nijman 1998).

During breeding season, an adult male Great Argus pheasant will clear its dancing ground and perform its "kow-wow" short call. A male will keep its display court clean of litter or any herbaceous materials. It is considered a lekking species (Johnsgard 1994, Hoglund and Atalalo 1995, Jiguet et al. 2000). A lek breeding system occurs in only 1% of all bird species (Johnsgard 1994, Jiguet et al. 2000). General characteristics of a lek include the lack of male parental care, an arena in which some degree of displaying males occur, and visitation of females to display sites to select a male (Bradbury 1981, Jiguet et al. 2000). Due to the importance of male display in lekking species, previous studies suggested that particular habitat types are required for display territory placement and are sometimes limited (Boyd and Sumanik 1969, Westcott 1993, Endler and Théry 1996, Tello 2001). Even within its general habitat, birds often select special features of vegetation (Cody 1985). Nevertheless, detailed information on lek sites is still lacking in many species.

Great Argus pheasant do not have a traditional lek, but something called an exploded lek, where the members of display sites are invisible of one another, but are still in auditory range (Bradbury 1981, Johnsgaard 1994, Ligon 1999). As occurs in many lekking species (Gibson and Bradbury 1987, Johsgaard 1994, Höglund and Alatalo 1995), traditional display sites are often preferred for dancing ground placement (Davison 1981a, Gibbons et al. 1996). Preliminary observation by Davison (1981b) revealed that topography of area could be important as a site selection factor. In the previous study in Malaysia, dancing grounds were never far from water, always had an adjacent perch, and were associated with palms *Eugeissona tristis* and *Arenga westerhoutii* (Davison 1981b). This display court was usually located on top of a hill or ridge (Beebe 1926, Davison 1981b). In Kalimantan, Nijman (1998) found that most dancing grounds of Great Argus pheasant were located in primary forest.

Foraging behavior of Great Argus pheasant (Davison 1981a), which mainly involved pecking items on the surface litter, suggested that Great Argus pheasant might prefer habitats with a low density of undergrowth. However, based on the diet of Great Argus pheasant observed in the Malay Peninsula (Davison 1981a), fruit derived from vines and climbers, suggests that Great Argus pheasant might be more often found where there are larger numbers of these plant types. Greatest number of detections of Great Argus pheasant in East Kalimantan was correlated to tree diameter, tree height, height of the first bough, and canopy cover (Nijman 1998).

So far, relatively little information has been obtained regarding habitat use and habitat availability of many pheasant species, including the Great Argus pheasant. Although most pheasants possess elaborate wing or tail plumage, their coloration is cryptic within the dense forest. Thus, these species are difficult to observe in the field and that leads to difficulty in studying the ecology of pheasant species. In addition, habitat selection is influenced by many factors such as inter-specific competition and degradation of preferred resources (Ericson et al. 2001). However, expanded knowledge on habitat preference can be critical to management actions (White and Garrott 1990). The persistence of lowland specialist depends on the ability to utilize the suitable habitat (Webb and Shine 1997), as well as their biological attributes (Smyth and Pavey 2001). Thus, species that depend on a specific habitat types may be more vulnerable to habitat loss (Loiselle and Blake 1992). Lowland forests in Sumatra and in nature reserves in Indonesia are being lost through expansion of agriculture lands and illegal logging (MacKinnon and Phillips 1993, McGowan and Garson 1995, O'Brien & Kinnaird 1996). Therefore, to understand the lek placement of male Great Argus pheasant in Bukit Barisan Selatan National Park, in this study we assessed dancing ground habitat characteristics, and their habitat use in relative to availability.

STUDY AREA

I studied Great Argus pheasant in Bukit Barisan Selatan National Park (BBSNP), Sumatra during July 2001 to November 2001. This park is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien and Kinnaird 1996, Sunarto 2000). BBSNP contains some of the largest tracts of lowland rain forest remaining in Sumatra and functions as the primary watershed for southwest Sumatra (O'Brien and Kinnaird 1996).

Research was carried out in the Wildlife Conservation Society (WCS) Conservation and Training Research Center in Way Canguk area (5^o 39' S; 104^o 24' E), which is located in the southwestern part of the park. The station is located in lowland forest and has a high diversity of wildlife (Sunarto 2000) including a number of high profile endangered mammals, such as Sumatran Tiger (*Panthera tigris*), Sumatran rhino

(*Dicerorhinus sumatrensis*), and 187 species of birds including 3 species of Phasianidae (Winarni 1999). The study area encompasses an 800 ha forest with a grid of trails at 200 m intervals. The study area is bisected by the Canguk River and the two sections are referred to as North and South sides. All transects are permanently marked at 50 m intervals. The study area contains a mosaic of lowland habitat types, including primary forest (50%), lightly disturbed forest (27%), and previously burned forest (23%). The latter category resulted from fires during 1992/1993 and during a 1997 drought (O'Brien et al. 1998). Tall canopy trees of the Dipterocarpaceae family dominate the primary forest (WCS-IP 2001), which become the character of most lowland forest in Sumatra (Whitmore 1975).

METHODS

<u>Radio telemetry</u>

I snared Great Argus using traditional ground snares modified to reduce injury. These were set in the vicinity of active dancing grounds and on trails. Each snared bird was fitted with a 164 MHz necklace type radio transmitter (Advanced Telemetry System, model A3960), leg-band, and numbered collar. I conducted standard measurements and then, the bird was released nearby. All snares were removed and human activity reduced for several days before tracking to reduce the stress on collared birds.

Birds were tracked for 3 to 5 months during July-November 2001 depending on times of capture. I used triangulation with two teams of observers. The two teams tracked the birds using intersections of the grid transect system spaced 50-150 m apart. Observers simultaneously collected pairs of bearings on the collared birds. Therefore, triangulation bearings were almost always taken from distances less than 150 m from the bird. For the purpose of estimating daily home range, I conducted intensive daily tracking twice per month from 6:00 to 17:00 hours for each bird with locations taken at 1-hour intervals. In addition to the analysis of total home range, I also conducted seasonal tracking with 12 radiolocations taken for each bird per month.

<u>Dancing ground habitat characteristics</u>

I attempted to locate all dancing grounds throughout the study site. I compared macrohabitat) of leks with expected values based on proportion of each habitat category on the study area. Then, I paired active dancing grounds and random sites within recognized home range for comparison. On each of the active dancing grounds and random sites, a 10-m radius circular plot was laid out. Within this circular plot, I counted number of trees and measured the DBH of five nearest trees with DBH ? 10 cm, measured the distance to the center of dancing ground and recorded the size of leaves of these five trees. Size of leaves was divided into 3 types, based on average measurement of 5 leaves: small (length ? 20 cm, width ? 10 cm), medium (20>length? 35 cm, width ? 15 cm), and large (length >35 cm, width >15 cm). I also counted the number of fallen logs and the distance to the center of dancing ground. At 4 different bearings, I took measurements of understory density, canopy openness, and litter thickness. Understory density was estimated using coverage of a 1x1 m sheet divided into 25x25 cm grids. I used a spherical densiometer to measure canopy openness at the center and at 4 random locations within the plot. I also recorded position of dancing ground, general topography, and the density score of dominant understories (seedlings/saplings, lianas or climbers, grass/other herbs, gingers). Scoring of understory density was divided into 4 scales based on percent coverage of each type of plant within the plot: score 1 (0-25 %), score 2

(25-50 %), score 3 (50-75 %), and score 4 (75-100 %). A 100% coverage indicated an expected maximum coverage of plant types within the plot.

Habitat variables measured on dancing grounds as well as random sites were modeled using binary logistic regressions with SPSS version 10 (SPSS Inc. 1999). Variables were divided into 9 continuous and 9 categorical variables.

Habitat use

Macrohabitat data were provided by the Wildlife Conservation Society – Indonesia Program. Using the grid system intersections, cells of 4 ha were created on the study area (Figures 3.1 and 3.2). All trees with DBH $\geq$ 10 cm, and saplings were counted and measured. Measurements of understory density and canopy closure using spherical densiometers were also recorded. And as an indication of disturbance, presence of rattan, palms (Palmae), lianas, bamboo and wild ginger (Zingiberaceae) were noted. Habitat types of the study area are divided into four types based on exposure to sunlight and mean DBH (Hadiprakarsa and O'Brien *unpublished data*):

1. Undisturbed forest with large trees
2. Undisturbed forest with small trees
3. Disturbed forest with large trees
4. Disturbed forest with small trees.

Habitat use and availability of radio-tagged Great Argus pheasants were analyzed using compositional analysis (Aesbischer et al. 1993). Individual male Great Argus pheasant was used as the experimental unit. Minimum Convex Polygon (MCP) home ranges of each individual were analyzed using GIS Arc View version 3.2 with Animal Movement extensions (Hooge and Eichenlaub 1997). In addition, I also analyzed Kernel home ranges based on 30%, 50%, and 70% probability of use (Hooge and Eichenlaub 1997). I constructed a GIS map of habitat types overlaid with Great Argus pheasant 100% MCP home ranges and radiolocations using Arc View. I used Spatial Analyst extensions to estimate percentage of use based on radiolocations and availability from raster data. Compositional analysis was done in two steps following Aesbischer et al. (1993). First, I analyzed the proportion of MCP versus study area, and second, proportions of radiolocations within the home ranges. SAS (SAS Institute 1999) with MACOMP.SAS program (Ott and Hovey 1997) was used to conduct compositional analysis of pooled data from South and North study area. Zero values, which are unutilized habitat, were replaced by smallest value 0.001%.

RESULTS

Dancing ground habitat characteristics

I measured habitat characteristics of 15 active dancing grounds and 15 random sites. Only active dancing grounds were used. Most dancing grounds were located on Habitats 1 and 2, which indicated the use of undisturbed forests (Table 3.3). However, there was no difference between dancing grounds and expected (?^{2} = 5.541, 3 df, P = 0.134). Using forward-stepwise logistic regressions, my results revealed that the model retained 2 habitat variables, lianas (?^{2} = 24.375, 3 df, $P<0.005$) and leaf size (?^{2} = 38.816, 4 df, $P<0.005$). The model indicated that there were more lianas (climbers) and higher leaf size in random sites than occupied sites (Tables 3.1 and 3.2). The model then correctly classified 29 of the 30 sites used to create the model.

Habitat use

Between July and mid-September 2001, I captured 9 males during a total of 410 trap-hours (17.07 trap-days). During trapping, there was no indication that the birds were injured by the snares or died due to the stress. However, one bird was killed by an unknown predator while in the snare and poachers attempted to steal another bird. Therefore, only 8 birds were fitted with radio transmitters during this study. During the study, one bird died of an unknown cause, presumably predator. Therefore, only 7 birds were included in the analyses. As of November 2001, I recorded 82-122 radiolocations per bird depending on time of capture.

In both study areas, most of the habitat consisted of Habitat 1 (large trees and undisturbed), follow by Habitats 3 and 4 (large and small trees, and disturbed) in the South study area, and Habitat 2 (small trees and undisturbed) in the North study area. Percentages of habitats in home range and radiolocations were variable among Great Argus pheasants, but were mainly Habitat 1 followed by Habitat 2 (Table 3.4, Figures 3.1 and 3.2). In the comparison between MCP home ranges in proportions to habitat available in the study area, I found that rank in order: Habitat 1> Habitat 2> Habitat 3> Habitat 4 (Table 3.5). However, there was no overall difference between availability and use of habitat. Compositional analysis also identified the same rank order when I compared the radiolocations in proportion to habitat available within the home range. Estimated use in habitat 1 was significantly different from Habitat 2 ($t = 2.71$, 3 df, $P = 0.04$) and Habitat 4 ($t = 2.73$, 3 df, $P = 0.02$). Comparison on percentage of use using 100% MCP home ranges and Kernel home ranges with different probability of use suggests that areas of concentrated use by male Argus was most common in Habitat 1 (Table 3.6).

DISCUSSION

Dancing ground habitat characteristics

In ruffed grouse (*Bonasa umbellus*), display site selection has been shown to occur in stages (Johnsgard 1994). The first stage was to select an area sparse in ground and shrub vegetation and secondary selection would be the actual display sites, which consisted of fallen logs (Johnsgard 1994). Display site selection of Great Argus pheasant also seemed to follow this model where general characteristics would be selected as the first stage, which may be linked to vocalization transmission to attract females, followed by particular habitat characters correspond to mating behavior, although which factor plays the most important role is still questionable.

Beebe (1926) and Davison (1981b) found that display sites of Great Argus pheasant were always located on top of a hill. As in my study, man-made trails were also found to be preferred with several sites correlated to the presence of low branch in Malaysia (Davison 1981b). Although there were variations on the random sites, based on categorical variables measured, my result suggests that dancing grounds are always located where animal trails and low branches are present. Flat topography also seemed important for site selection as well as the lowest density of seedling/sapling, lianas (climbers), herbs, and gingers. This kind of position may be correlated to the promotion of vocalization transmission (Westcott 1993). However, both studies were conducted in Malaysia and Borneo, which are more hilly than BBSNP. In Borneo, Great Argus pheasant inhabits the hilly terrain (Nijman 1998) and the bird is even called as slope specialist (Wells 1985), although this may be due to the high degree of human disturbance at lower sites. Beebe (1926) noted the exception to this for populations that inhabit the Southern part of Sumatra where the area is flat. Our study area would seem to be included in this exception (Iqbal 1999). However, the low density of understory would probably contribute to signal transmission, as well as the presence of low branch utilized by males during calls.

During the breeding season, maintaining display sites is important for lekking species such as Great Argus pheasant where the display can be performed to attract females. Habitat constraints have been known as one of the factors influence lek sites (Johnsgaard 1994). Hence, secondary stage of display site selection played a role, which would be the most important step in site selection correspond to mating behavior. In this study, my result reveals that males of Great Argus pheasant selected areas with less lianas (climbers) and smaller leaf size. Both variables seemed to be very important factors in relation to display and cleaning behavior of Great Argus pheasant. The density of particular vegetation structure may influence the selection of display sites of lekking species. Ochre-bellied flycatcher (*Mionectes oleaginous*) showed preference to place display sites on area with less sapling due to the extensive flights during display (Westcott 1993).

Display of male Great Argus pheasant includes elaborate movement and utilization of secondaries and tail feathers. Some of this behavior can include stamping by walking slowly around the perimeter of the dancing ground and ending with frontal display by fanning the primaries and secondaries (Davison 1982). Thus, these elaborate actions need a sufficient amount of space. Higher liana density would restrain male display.

Based on previous study, < 1% time of male Great Argus pheasant was spent on cleaning the dancing ground (Davison 1981b). Cleaning behavior includes series of cleaning flaps using wings and tails, leaf throwing, high pecking, and bill scraping, which utilized the bill. Scraping the leaf litter with feet was never observed (Davison 1981b). Thus, the bill is the main tool to carry out this cleaning behavior. Therefore, smaller leaf size of the nearest trees, which later become litter would be easier to assist this behavior. Larger leaf size would restrain the males in cleaning their dancing grounds.

Davison (1981b) suggested that mating system of Great Argus pheasant depends on the meeting of both sexes at the display site where the male perform the loud call to attract the females. Thus, during breeding season, possession of dancing ground and the amount of time spent there is critical to a male's fitness (Davison 1981b). Defense of and maintenance of the dancing ground, thus, is also important during breeding season. During observation, I found that a male may maintain more than one display sites. Although usually only one was kept clean at all times during breeding season, my radio telemetry data indicated that checking other sites were performed by several males. My random sites suggested that areas selected for dancing ground may be limited in the study area. I believe that human impacts, such as illegal logging and land conversion, which reduce the amount of habitat available, might negatively affect the distribution of lek sites and outside reserves.

Habitat use of Great Argus pheasant

One of the features of radio telemetry studies is to provide understanding on animal's resource use (Erickson et al. 2001). Particular habitat used by an animal does not, however, necessarily indicate that the habitat is preferred (Johnson 1980). Availability of habitat on study area should be considered in resource selection studies (McClean et al. 1998). My results indicate that male Great Argus pheasant placed their home ranges randomly distributed within the study area even though rank order suggested that, undisturbed forests were used first followed by other habitat types consecutively.

Undisturbed forest with large trees was identified as the most important habitat for Great Argus pheasant within the home range. This forest type may be used differently than forests with small trees, either in an undisturbed or disturbed condition. Thus, large trees maybe play an important role in influencing the distribution of Great Argus pheasant. This result in general corresponds with previous research in Kalimantan (Nijman 1998). Nijman (1998) found that the greatest density of Great Argus pheasant correlated with tree diameter and tree height. Although large trees do not necessarily indicate a direct relationship with Great Argus pheasant distribution, larger trees constituted the emergent stratum of tropical rainforest canopy. Forest with large, emergent trees usually have more open understory, which provide easier access to move around for understory bird. Large, tall trees of Dipterocarpaceae dominate the Way Canguk study area (WCS-IP 2001). Trees of this group do not emerge singly but form extensive groups consisting of different species creating a contiguous canopy (Whitmore 1975), which provide cover for Great Argus pheasant. Furthermore, canopy provides a different microclimate between outside and within the canopy due to the low light intensity and high humidity (Whitmore 1975). Adapted to low light intensity, low heat stress, and relative high humidity, understory bird such as Great Argus pheasant is usually sensitive to large-scale disturbance (Wong 1985). Existence of gaps in the canopy may change the microclimate and resulting ground vegetation (Richards 1996). Understory birds were observed to avoid crossing narrow gaps of clear-cut forest (Bierregard and Lovejoy 1992) and nest predation is correlated to fragment size (Arango-Vélez and Kattan 1997). Studies on lekking species suggested that the sunlight from the sun-flecks is important to male display, which depends on the reflection of light to bird's body part (Endler and Théry 1996). Leks also found to be located on areas with similar wavelength (Stutcbury and Morton 2001).

Kernel home range (Worton 1987) analysis produced the same rank order of habitat type used by Great Argus pheasant using MCP. As core use areas were restricted, percentage of used in forest with large trees increased, but decreased in habitats with small trees. Great Argus pheasant may choose different habitat types for different reasons (Cooper and Milspaugh 2001), such as feeding, roosting and dancing ground placement. Suitable habitat may provide suitable microclimate, foraging substrates, food resources, nest sites, and coverage (Terborgh 1985). Great Argus pheasant seemed to use large trees with a first branch at approximately 10 m from the ground for roosting, indicating the use of large trees as well (N. Winarni *personal observation*). The breeding season of Great Argus pheasant occurs during July through February. During this time of the year, male Great Argus pheasant spent more time around dancing ground for territory advertisement and mating behavior. Female movement is also known to influence the lek locations of lekking species (Westcott 1997). Although this has not been proved, Great Argus pheasant movement during breeding season may correlate with female habitat use.

These finding suggest that, although Great Argus pheasant males will use areas with small trees and disturbances, lek sites and most use of habitat was on undisturbed forest with large trees. Habitat loss and degradation is identified as the largest threat to pheasant survival (Fuller and Garson 2000). Even in this relatively protected forest, undisturbed forest with large trees roughly comprised only 40% of the study area. In consequence, Great Argus pheasant distribution is restricted to a small proportion of the total forest.

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Table 3.1. Continuous variables habitat characteristics of Great Argus leks (n = 15) and random sites (n = 15) with standard deviations in Bukit Barisan Selatan National Park, Sumatra, Indonesia, during 2002.

Variables	***Dancing grounds***		***Random locations***	
	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Canopy (counts)	2.70	0.78	2.93	0.97
Center canopy (counts)	3.41	3.66	3.85	3.50
Understory density (counts)	36.27	12.13	36.37	11.21
# of trees (counts)	12.00	3.59	9.53	3.68
Average DBH (centimeters)	21.53	5.58	23.22	6.40
Average tree distance (meters)	4.03	0.80	4.02	1.17
Average leaf size (scale-centimeters)	1.15	0.19	1.32	0.22
# of fallen log (counts)	1.20	1.01	1.33	0.82
Average log distance (meters)	3.78	3.05	4.52	3.07
Litter thickness (centimeters)	2.43	1.01	2.03	1.11

Table 3.2. Categorical variables habitat characteristics of Great Argus pheasant leks (n = 15) and random sites (n = 15) in Bukit Barisan Selatan National Park, Sumatra, Indonesia during 2002.

Categorical Variables	**Scoring**	**Dancing Ground (N=15)**					**Random locations (N=15)**				
		0	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**
Location	0-1 (0=on trail, 1=off trail)	10	5				8	7			
Animal Trail	0-1 (0=absence, 1= presence)	0	15				4	11			
Presence of low branch	0-1 (0=absence, 1= presence)	0	15				2	13			
Topography	1-2 (1=flat, 2=ridge)		14	1				10	5		
Seedling/sapling density	1-4 (1=0-25%, 2=25-50%, 3=50-75%, 4=75-100%)		15	0	0	0		11	4	0	0
Climbers (lianas) density	1-4 (1=0-25%, 2=25-50%, 3=50-75%, 4=75-100%)		13	2	0	0		1	8	5	1
Herbs density	1-4 (1=0-25%, 2=25-50%, 3=50-75%, 4=75-100%)		15	0	0	0		12	3	0	0
Ginger density	1-4 (1=0-25%, 2=25-50%, 3=50-75%, 4=75-100%)		15	0	0	0		7	8	0	0

Scoring of understory density (seedling/sapling, climbers, herbs, and ginger) was divided into 4 scales based on percent coverage of each type of plant on the plot: score 1 (0-25 %), score 2 (25-50 %), score 3 (50-75 %), and score 4 (75-100 %). A 100% coverage indicated an expected maximum coverage of plant types within the plot.

Table 3.3. Distributions of lek sites (n=15) and expected sites (n=15) within habitat types in Way Canguk study area. Way Canguk habitat types are divided into 4 categories: Habitat 1, undisturbed forest with large trees; Habitat 2, undisturbed forest with small trees; Habitat 3, disturbed forest with large trees; and Habitat 4, disturbed forest with small trees.

	habitat 1	***habitat 2***	***habitat 3***	***habitat 4***
dancing grounds	6	6	3	0
expected	5.96	2.71	3.23	3.07

Table 3.4. Percentage of habitat availability in Way Canguk study area during 2001, habitat use of male Great Argus pheasant within the MCP home range, and radiolocations in proportion to habitat availability within the home range. Number 1-4 indicates the habitat types: 1) undisturbed forest with large trees; 2) undisturbed forest with small trees; 3) disturbed forest with large trees; 4) disturbed forest with small trees.

Individuals	**Study area**				**MCP home range**				**Radio locations**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Eno	37.8%	14.6%	23.3%	24.4%	28.0%	47.8%	24.2%	0.0%	28.6%	39.3%	32.1%	0.0%
King	37.8%	14.6%	23.3%	24.4%	37.6%	22.2%	3.4%	36.8%	56.9%	19.0%	0.0%	24.1%
Indy	37.8%	14.6%	23.3%	24.4%	46.2%	53.7%	0.0%	0.0%	56.1%	43.9%	0.0%	0.0%
Mandra	37.8%	14.6%	23.3%	24.4%	40.8%	0.0%	43.5%	15.8%	31.4%	0.0%	57.0%	11.6%
Iyar	42.7%	23.3%	19.0%	15.1%	21.8%	23.0%	45.4%	9.8%	54.5%	27.3%	10.7%	7.4%
Erros	42.7%	23.3%	19.0%	15.1%	81.2%	0.0%	0.0%	18.8%	97.3%	0.0%	0.0%	2.7%
Inam	42.7%	23.3%	19.0%	15.1%	30.4%	36.0%	26.4%	3.3%	53.3%	29.5%	16.2%	1.0%
$\bar{x}$	39.9%	18.3%	21.4%	20.4%	40.8%	26.1%	20.4%	12.1%	54.0%	22.7%	16.6%	6.7%
SD	0.03	0.05	0.02	0.05	0.20	0.21	0.20	0.13	0.23	0.17	0.21	0.09

Table 3.5. Simplified ranking matrices of Great Argus pheasant based on (a) comparing habitat use within 100% MCP home range in proportions to habitat availability in the study area, and (b) comparing habitat use based on radiolocations in proportions to habitat availability within the MCP home ranges. Large rank indicates more preferred and triple signs indicate significant difference between habitat types. Way Canguk habitat types are divided into 4 categories: Habitat 1, undisturbed trees with large trees; Habitat 2, undisturbed forest with small trees; Habitat 3, disturbed forest with large trees; Habitat 4, disturbed forest with small trees.

A. MCP home ranges vs. study area

Habitat type	***Habitat type***				***Rank***
	1	**2**	**3**	**4**	
1		+	+	+	3
2	-		+	+	2
3	-	-		+	1
4	-	-	-		0

B. Radiolocations vs. MCP home range

Habitat type	***Habitat type***				***Rank***
	1	**2**	**3**	**4**	
1		+++	+	+++	3
2	---		+	+	2
3	-	-		-	1
4	---	-	+		0

Table 3.6. Percentage of Great Argus pheasant habitat use at different home range size using 100% MCP, 70% Kernel, 50% Kernel, and 30% Kernel in Bukit Barisan Selatan National Park, Indonesia during September-November 2002. Way Canguk habitat types are divided into 4 categories: Habitat 1, undisturbed trees with large trees; Habitat 2, undisturbed forest with small trees; Habitat 3, disturbed forest with large trees; Habitat 4, disturbed forest with small trees.

Home range	Habitat 1	Habitat 2	Habitat 3	Habitat 4
100% MCP	40.8%	26.1%	20.4%	12.1%
70% Kernel	66.3%	18.4%	14.1%	1.2%
50% Kernel	70.1%	14.3%	15.6%	0.0%
30% Kernel	71.5%	10.5%	17.9%	0.0%

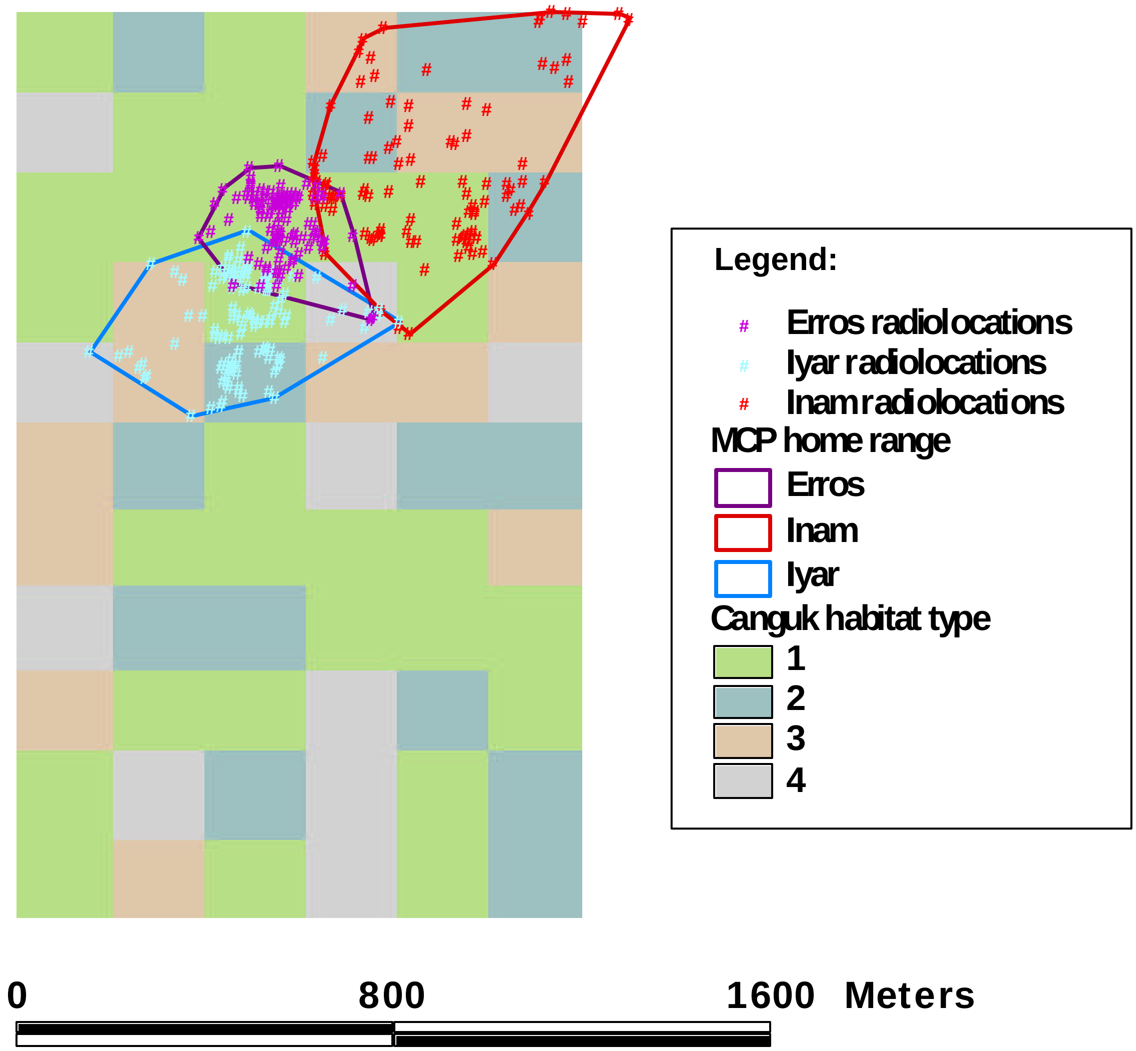

Figure 3.1. MCP home range of 4 males Great Argus pheasant on North study area overlaid on available habitats, during September-November 2001. Way Canguk habitat types are divided into 4 categories: Habitat 1, undisturbed forest with large trees; Habitat 2, undisturbed forest with small trees; Habitat 3, disturbed forest with large trees; Habitat 4, disturbed forest with small trees.

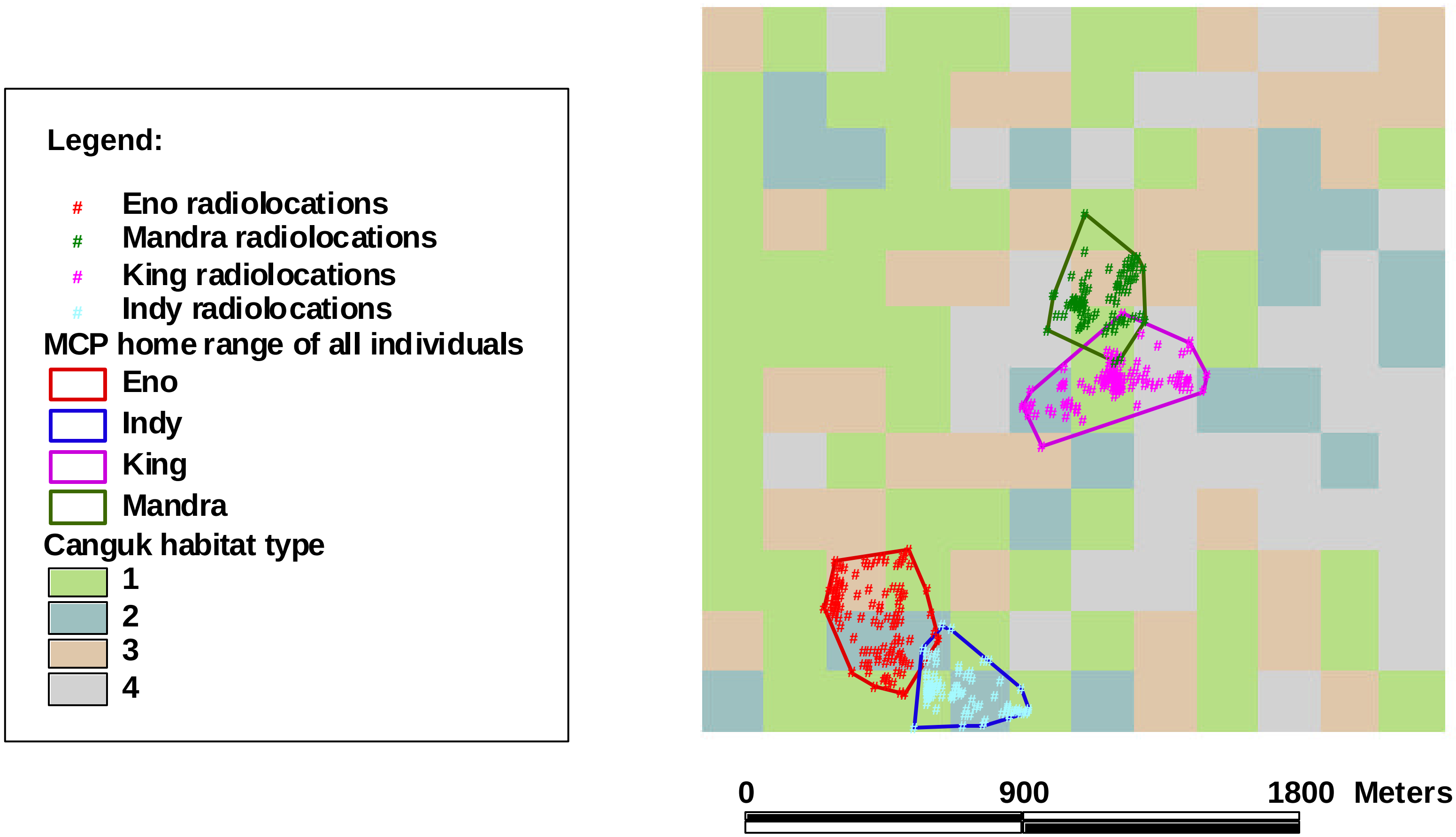

Figure 3.2. MCP home range of 3 males Great Argus pheasant on South study area overlaid on available habitats, during September-November 2001. Way Canguk habitat types are divided into 4 categories: Habitat 1, undisturbed trees with large trees; Habitat 2, undisturbed forest with small trees; Habitat 3, disturbed forest with large trees; Habitat 4, disturbed forest with small trees.

CHAPTER 4

HOME RANGE AND MOVEMENT PATTERNS OF GREAT ARGUS PHEASANT (*Argusianus argus*) IN SOUTHERN SUMATRA, INDONESIA

INTRODUCTION

Despite a rather long history of description, our understanding of the natural history of tropical rainforest pheasants is inadequate. To date, comprehensive studies on Asian pheasants have been confined to the Green Peafowl *Pavo muticus* (van Balen et al. 1995), Crested Wood-partridge *Rollulus rouloul* (McGowan 1992), Malaysian Peacock-Pheasant *Polyplectron malaccense* (Davison 1983, McGowan 1994), Crested Argus *Rheinardia ocellata* (Davison 1977) and Great Argus pheasant *Argusianus argus* (Davison 1981a, 1981b, 1982, Nijman 1998). Early field studies of Great Argus pheasant presented more on general description of the bird and its general habitat. For example, Beebe (1926) described general habits and habitats of Great Argus pheasant in the wild. A study in Malaysia provided some understanding on the Great Argus pheasant behavior and mating system (Davison 1981a, 1981b, 1982). Nijman (1998) studied the abundance and habitat use of Great Argus pheasant in Kalimantan.

Understanding animal movement in time and space is important since it is linked to the dynamics of populations. Animal spatial use is related to both the internal and external pressures of populations (Kernohan et al. 2001). Study of home range as the core of spatial use analyses can be very important for management applications. For example, home range size or territory size can be regulated by energetic requirements (Greenwood and Swingland 1983). Thus, home range size information is valuable to answer questions on energy expenditure among individuals and may also correlate with individual performance (Kenward 2001). Daily movement is useful in providing information on energy expenditure especially if data are collected on regular interval (Kenward 2001). Furthermore, intensity of use within the home range is important to describe how an animal utilizes its home range (Hayne 1949, Worton 1987).

Although pheasants are often found where they spend foraging time due to their correlation to food supply, Beebe (1926) argued that this situation does not fit Great Argus pheasant. He suggested that home ranges of male Great Argus pheasant become extremely small during breeding season and closely associated with its dancing ground. His observation was supported by Davison (1981a), who observed 2 adult males fitted with radio transmitters. Davison (1981a) found that Great Argus pheasant maintained a small home range, approximately 1-3 ha on a hillside. He (1981a) found that daily travel of Great Argus pheasant was 800-900 m and a visit to the hilltop would add 300-400 m to daily travel. In his study, which also focused on the dispersion pattern of Great Argus pheasant linked to food supply, Davison (1981a) doubted that dispersion and population density was influenced by food availability.

In his observations, Beebe (1926) stated, "during non-breeding season the Great Argus pheasant would go into a more closed forest". This was supported by the fact that the "Dayak", the indigenous people of Borneo never trapped the bird at the same place more than once (Beebe 1926). Nevertheless, whether movements are associated to food supply is still in question. Although this bird is no longer regarded as an endangered species (Fuller and Garson 2000), more information is needed to ensure the long-term survival of this lowland forest specialist. Here, I present an overview on home range size as a comparison for what has been done previously, the differences among individual males, spatial patterns within the home range, and movement pattern of individual males. This is done in context of movement relative to the dancing ground and food availability.

STUDY AREA

This research was conducted in Bukit Barisan Selatan National Park (BBSNP), Sumatra during July to November 2001. This park is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien and Kinnaird 1996, Sunarto 2000). BBSNP contains some of the largest tracts of lowland rain forest remaining in Sumatra and functions as the primary watershed for southwest Sumatra (O'Brien and Kinnaird 1996).

Research was carried out in the Wildlife Conservation Society (WCS) Conservation and Training Research Center in Way Canguk area (5^o 39' S; 104^o 24' E), which is located in the southwestern part of the park. The station is located in lowland forest and has high diversity of wildlife (Sunarto 2000) including a number of high profile endangered mammals, such as Sumatran Tiger (*Panthera tigris*), Sumatran rhino (*Dicerorhinus sumatrensis*), and 187 species of birds including 3 species of Phasianidae (Winarni 1999). The study area encompasses an 800 ha forest with a grid of trails at 200 m intervals. The study area is bisected by the Canguk river and the two sections are referred to as North and South sides. All transects are permanently marked at 50-m intervals. The study area contains a mosaic of lowland habitat types, including primary forest (50%), lightly disturbed forest (27%), and previously burned forest (23%). The latter category resulted from fires during 1992/1993 and during a 1997 drought (O'Brien et al. 1998).

METHODS

Capture Methods

All birds used were captured using a modification of traditional leg-snares. First attempts of capture were focused on males with active dancing grounds. Usually 5 to 7 snares were set on sites around dancing grounds that the bird tended to use as entrances. Typically, males with dancing grounds use 2 or 3 entrances (Davison 1981b; N. Winarni *personal observation*). Snares were constructed a day prior to deployment. I checked the snares based on calling behavior of the bird. Usually, I let the bird to perform its first morning call. During preliminary observation, I found that the birds usually call from a branch adjacent to dancing ground before entering it. By waiting until after the first morning call, I allowed the bird to enter the trap area before disturbing them. In addition, checking the snares soon would lessen stress and minimizing time the bird spent in the snare. In addition to placing the snares around a dancing ground, I also set the snares along the trail system.

Each snared bird was fitted with a 164 MHz necklace type radio transmitter (Advanced Telemetry System, model A3960), leg-band, and numbered collar. I conducted standard measurements and then, the bird was released nearby. All snares were removed and human activity reduced for several days before tracking to reduce the stress.

Radio tracking

Birds were tracked for 3 to 5 months during July-November 2001 depending on times of capture. I used triangulation with two teams of observers. The two teams tracked the birds using intersections of the grid transect system spaced 50-150 m apart. We collected pairs of bearings of the bird at the same time. Therefore, triangulation bearings were almost always taken from distances less than 150 m from the bird. For the purpose of daily home range, I conducted intensive daily tracking twice/month from 6:00–17:00 hours for each bird with locations taken at 1-hour intervals. In addition to the analysis of total home range, I also conducted seasonal tracking with 12 radiolocations taken for each bird per month.

Fallen food abundance

I plotted daily Minimum Convex Polygon (White and Garrot 1990) home ranges based on the intensive daily tracking. Through each home range, I placed several 100-m transects spaced 50 m apart. I used marking trails of existing grid trail as the start point of transect. I attached a 1-m stick on a 100 m measuring tape along each transect. Data on fallen fruits, flowers, seeds, and mushrooms present beneath the stick were recorded every 1 m. Thus, each time after tracking, fallen food abundance on transects within home range were measured. I only recorded fresh fallen fruits and flower, and fresh mushroom on the litter surface.

Statistical Analyses

Home range size was analyzed using 100% Minimum Convex Polygon (White and Garrot 1990). Kernel Home Range is used to determine utilization distribution within the home range, which was then used to determine centers of activities based on a 50% probability. All home range analyses were performed using Arc View version 3.2 with animal movement extensions (Hooge and Eichenlaub 1997).   To test whether there is significance time effect on home range, repeated measures ANOVA were performed. Movement pattern and distance of travel were also analyzed using Animal Movement Extensions in Arc View (Hooge and Eichenlaub 1997). Mean distances of radiolocations to dancing ground and mean daily travel were tested using repeated measures ANOVA to determine if there were differences among months.

I used multiple regressions to test whether fallen food abundance affects home range size using flower, food, and mushroom as predictor variables. All statistical analyses were performed using SPSS version 10 (SPSS Inc. 1999).

RESULTS

Between July and mid-September 2001, I captured 9 males during a total of 410 trap-hours (17.07 trap-days). This trapping success is noteworthy compared to the study on this species in Malaysia (Davison 1981a) where only 2 males of Argus were equipped with radio transmitters, although there was no information on trapping success nor how long he deployed the snares. In the study of Malaysian peacock-pheasant, McGowan (1992) captured 11 individuals in a total of 5845 trap-days.

During trapping, there was no indication that the birds were injured by the snares or died due to the stress. However, one bird was killed by an unknown predator while in the snare.   Therefore, only 8 birds were fitted with radio transmitters during this study. Tracking was performed and all birds seemed in good condition without obvious effect of the transmitters. During the study, one bird died of an unknown cause, presumably predator. Therefore, only 7 birds were included in the analyses. As of November 2001, I recorded 82-122 radiolocations per bird depending on time of capture. During November, two of the radio transmitters malfunctioned, therefore, one of the two radio-tagged birds could not be tracked during November.

Home range and movement patterns

Results show that home range size was about 7–32 ha (Table 4.1), and means daily home range was about 1-4 ha (Figure 4.3). Home range size was not different among months (Table 4.2, F = 1.889; 2, 17 df; P = 0.1816). Although, I only had one sample of a sub-adult male, it appears that the sub-adult male without a dancing ground had a larger home range (32 ha). The other males with dancing grounds had home ranges between 7–16 ha in size. This sub-adult male's home range overlapped with another male who occupied a dancing ground. Daily home range, however, was about the same between sub-adult and adult individuals (Figure 4.3).

Distribution of radiolocations in home ranges was concentrated around dancing ground. Kernel analysis showed that core areas (50% of use) of Great Argus pheasant ranged between 6–12% of total home ranges (Figure 4.4). I found that 3 of 6 adult males centered their activities close to the dancing grounds and that these areas based on 50% probabilities were mostly located close to the boundaries of home range. All males had multiple centers of activities.

When I tested the mean distance of radiolocations taken each month to the dancing ground, I found that there were no patterns of mean distance over month (F = 1.386; 1, 4 df; P = 0.985). Individual mean distances to a dancing ground were varied between approximately 67-200 m (Figures 4.5). Movement patterns of male Great Argus pheasant revealed that mean daily travel ranged between 412-1145 m and varied among months ($F = 2.072$; 1, 11 df; $P = 0.618$, Table 4.3). Most of the males, however, increased their travel in October. During all these months, dancing grounds remained active.

Correlation of fallen food abundance and home range

I found that food availability was not related to home range size (fruit, $t = -0.77$, 1 df, $P = 0.45$; flower, $t = 0.88$, 1 df, $P = 0.38$; mushroom, $t = 1.40$, 1 df, $P = 0.17$). Food abundance was low and did not seem to show any particular pattern over time (Figure 4.6). From overall fallen food data that I collected, only mushroom showed high abundance. Fallen fruits and flowers were low during all 3 months.

DISCUSSION

Movement pattern of Great Argus pheasant

The concept of home range as first defined by Burt (1943) has been discussed by many biologists. In this study, home range is simply defined as the area with a probability of occurrence of an animal during a specified time period (Kernohan et al. 2001). Males of Great Argus pheasant exhibited more variable and larger home ranges in the current observations compared to previous study in Malaysia, where home range size of 2 males ranged between approximately 1-3 hectares (Davison 1981a). Factors that may have influenced home range size between the different geographic regions may be weather, land use/cover, topography, population densities, and methodology (Smith et al. 1999). Topography may be of particular importance since Davison (1981a) reported that the males visited a hilltop adjacent to their home range while my study area had flat topography.

Male Great Argus pheasant had variable home range size among months. This finding, however, were not surprising since data were taken during the bird's breeding season. In Davison's (1981a) study, his 2 males only moved occasionally and not far from their display sites. Home range size increased from November to January, which was suggested that the bird became adapted of carrying transmitter (Davison 1981a). Breeding time of Great Argus pheasant in my study area starts in July/August where the males performed their long calls preceding territory establishment. Thus, this result suggested that Great Argus pheasant were never far from their display sites during this period. However, since data were collected only during September through November during the breeding season, I cannot make any comparison whether area around display sites was the center of activities all year round. Most studies on home range were applied to higher latitude pheasants, which show larger home range in spring (Johnsgard 1999). Tropical areas, however, showed a more stable climate all year, which lead to greater length of breeding season and greater variability among individuals (Stutchbury and Morton 2001).

Compared to previous study (Davison 1981a), my birds again had more variable core areas. Of 6 adult males with dancing grounds, only 3 males focused their activities around their display sites. Since I placed the snares around active dancing ground, most males captured abandoned their display sites. Of the 5 males captured on their dancing ground, only one came back to the old site early during data collection. Thus, for the other 4 males, until the end of the study I failed to find their new display sites. These males might just have started to clear another site or sites were inconspicuous. However, there was indication that some males re-occupied their display sites later (N. Winarni *personal observation*). I also found that 3 individuals maintained more than one dancing ground, even though only one site was clean at any particular time.

Most centers of activities were not located in the center of the home range but somewhere close to the boundaries of the home range. A similar situation occurred in Eurasian capercaillies (*Tetrao urogallus*), which placed the territory center near the territory boundaries (Muller 1979). This situation is probably related to the purpose of territory advertisement where display sites are located in such a way so that competitive situations are occurred among males (Johnsgard 1994).

Movement of Great Argus pheasant, when associated to dancing ground, did not show particular patterns over time. This would probably due to individual variation since there was not a significant effect among months. However, all males with dancing grounds showed relatively short distance movement from dancing ground suggesting the importance of dancing ground as the center of activities during the breeding season. Movement was also likely affected by females. However, since no females were fitted with transmitters, it is difficult to relate the movement pattern of these males to females. Comparison to previous study (Davison 1981a) suggested that daily travel is somewhat similar, which indicate energy expenditure on foraging of Great Argus pheasant.

Correlation of fallen food abundance and home range size

Breeding season is usually correlated to rainfall pattern and food availability (Stutchbury and Morton 2001). Thus, it is likely to link the home range size during breeding season with food availability. In this study, however, home range size was not affected by fallen food abundance. Stutchbury and Morton (2001) suggested that territory size is determined more by food availability during non-breeding season. Although as a lekking species, Great Argus pheasant defends display territory, home range of this bird is small during breeding season and most of the males concentrated their activities around the dancing ground. During breeding season, since display sites are limited and have to be defended, there should be a trade-off between foraging versus defending a territory. Davison (1981b) suggested that during breeding season, possession of dancing ground and the amount of time spent there is critical to male's fitness. He also suggested that Great Argus pheasant is able to minimize their energy expenditure during low food availability (Davison 1981a).

The abundance of fruits, flowers, and mushrooms did not show any particular pattern during my study. In the tropics, fruit supply tends to be clumped and unevenly distributed in space and time (Herrera 1985). Since I laid the transects at 50 m intervals, my transects might not have distinguished clusters of fruit or flower. In this study, I found that mushroom abundance was higher than fallen fruits and flowers. During observation, I saw a male Great Argus pheasant eat mushrooms only in one occasion. Previously, mushrooms were never mentioned in the previous research (Beebe 1926; Davison 1981a, 1981b, 1982).

Great Argus pheasant can be considered as a generalist in terms of range of food resources, where low resource availability resulted in few competitors (Bell 1991). Each individual of Great Argus pheasant has its own home range, which slightly overlapped. Thus, competition for food is less intense and in the case of Great Argus pheasant, competition for mate is more likely.

Great Argus pheasant diet items comprise a wide-variety of foods, including invertebrates, parts of fruits, flowers, and leaves (Beebe 1926, Davison 1981a, Johnsgard 1999). Davison (1981a) conducted a comprehensive study on the leaf litter invertebrates abundance in relation to Great Argus pheasant diet. His result suggested that Great Argus pheasant do not develop particular foraging paths. Great Argus pheasant also showed an irregular movement patterns and peck at food occasionally (Davison 1981a). My observations concur with these. When using random search strategy, only probability distribution of its position can be predicted over time (Bell 1991). If a particular tree is flowering or fruiting, one might expect that Great Argus pheasant would spend more time and frequently visit this patch. However, this situation did not appear in Great Argus pheasant. Even though one particular area contained large amounts of particular fruit (*Alangium javanicum*, family Alangiaceae), the observed bird stayed only for a short time to peck at the pericarp and did not come back even the next day (N. Winarni *personal observation*). Davison (1981a) also observed that pecking was directed to scattered items on the surface of leaf litter. Thus, Great Argus pheasant seem to be opportunistic foragers.

Other factors may be playing a role in affecting the home range size. Habitat heterogeneity may limit the area available for home range. My study area is located at the southwestern tip of Sumatra, which is close to the sea and exposed to the strong seasonal monsoon wind from the Indian Ocean. The monsoon wind speed is increased when there are breaks in the Barisan Mountains (Whitten et al. 1984). With the heavy rain that comes along, these will create forest gaps. Sumatra still experienced the continuing uplift of the Barisan Mountains that cause regular earthquakes (Whitten et al. 1984). Both of these factors create a very dynamic forest habitat.

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Table 4.1. Total home range (in hectares) of each individual male Great Argus pheasant during September-November 2001, in Bukit Barisan Selatan National Park, Sumatra, with comparison to previous research by Davison (1981a)

Individual	Age	Dancing ground	Total (ha)	# of radio locations
Iyar	Adult	yes	16.09	122
Eno	Adult	yes	12.58	112
King	Adult	yes	14.47	116
Erros	Adult	yes	7.65	113
Indy	Adult	yes	8.27	82
Mandra	Adult	yes	9.97	86
Inam	Subadult	no	32.30	105
Davison (1981a)				
Male 1	Adult	yes	1.09-2.71	905
Male 2	Adult	yes	1.39-2.84	1200

Table 4.2. Monthly home ranges (in hectares) of each individual male Great Argus pheasant during September-November 2001, in Bukit Barisan Selatan National Park, Sumatra, Indonesia.

Individuals	Age	Dancing ground	Home range (hectares)		
			September	October	November
Iyar	Adult	yes	9.180	7.980	6.650
Eno	Adult	yes	7.370	9.420	6.960
King	Adult	yes	4.650	9.460	7.460
Erros	Adult	yes	2.940	4.890	1.840
Indy	Adult	yes	6.300	5.890	
Mandra	Adult	yes	2.740	9.510	2.210
Inam	Subadult	no	13.840	8.380	7.600

Table 4.3. Means of daily travel (meters) of males Great Argus pheasant during September-November 2001, in Bukit Barisan Selatan National Park, Sumatra, with standard error. Daily trackings were conducted 2 times/month for each bird (n=2), except for Mandra during September (* indicate that only one daily tracking conducted).

Individuals	**September**		**October**		**November**	
	$\bar{x}$	**SE**	$\bar{x}$	**SE**	$\bar{x}$	**SE**
Iyar	1145.05	126.95	1084.54	253.18	907.12	484.14
Eno	648.96	69.96	1001.52	139.29	821.73	119.82
King	412.69	86.80	1024.19	84.96	924.20	327.02
Erros	629.19	122.88	733.70	26.77	626.35	86.87
Indy	978.97	184.80	847.09	240.66	no data	
Mandra	578.40*		1041.98	422.13	595.33	5.48
Inam	815.76	24.30	1087.41	170.08	1073.39	25.56

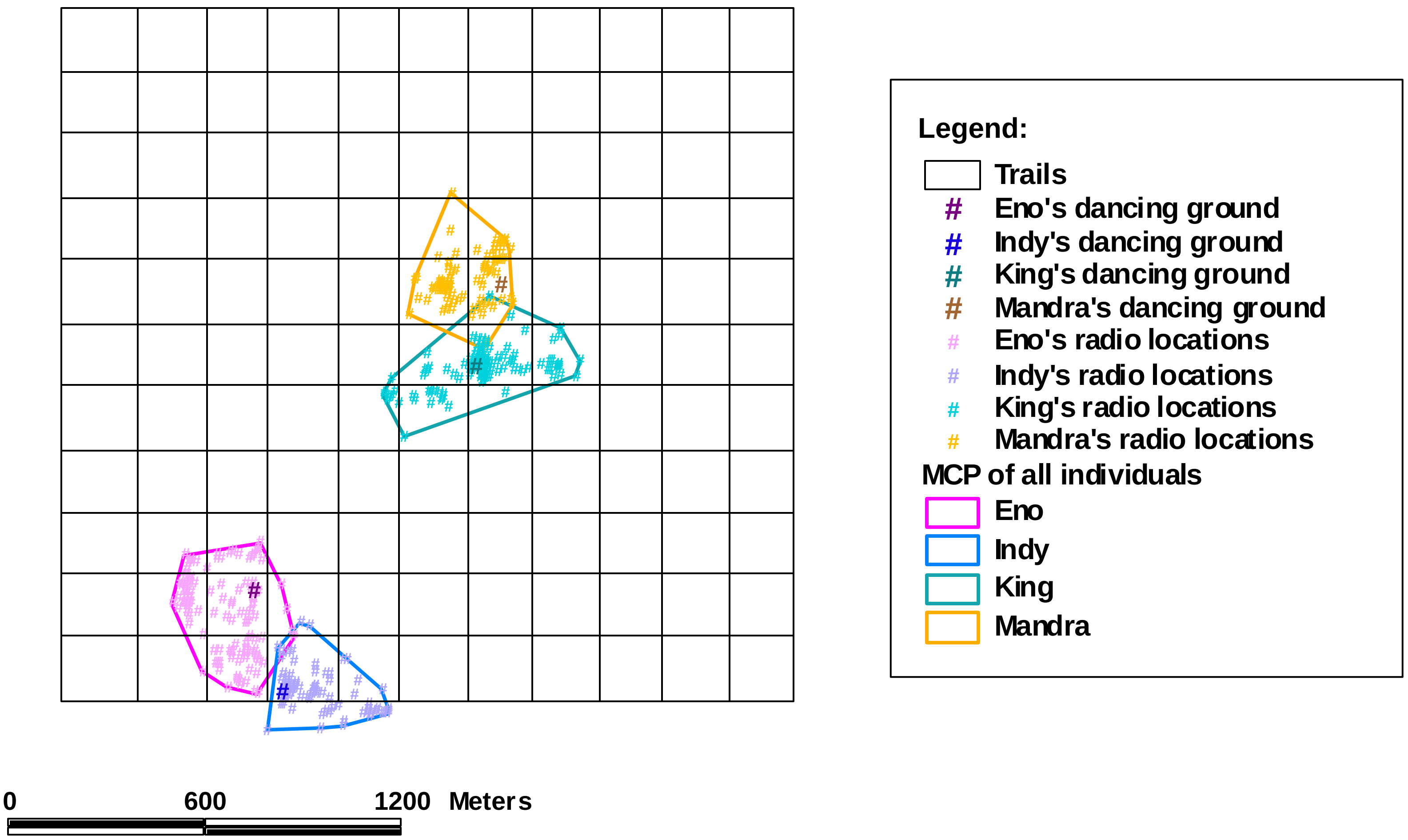


Figure 4.1. Home range of 4 males of Great Argus pheasant on South study area of Bukit Barisan Selatan National Park, Sumatra, depicting radiolocations, dancing ground, and MCP home range for each individual

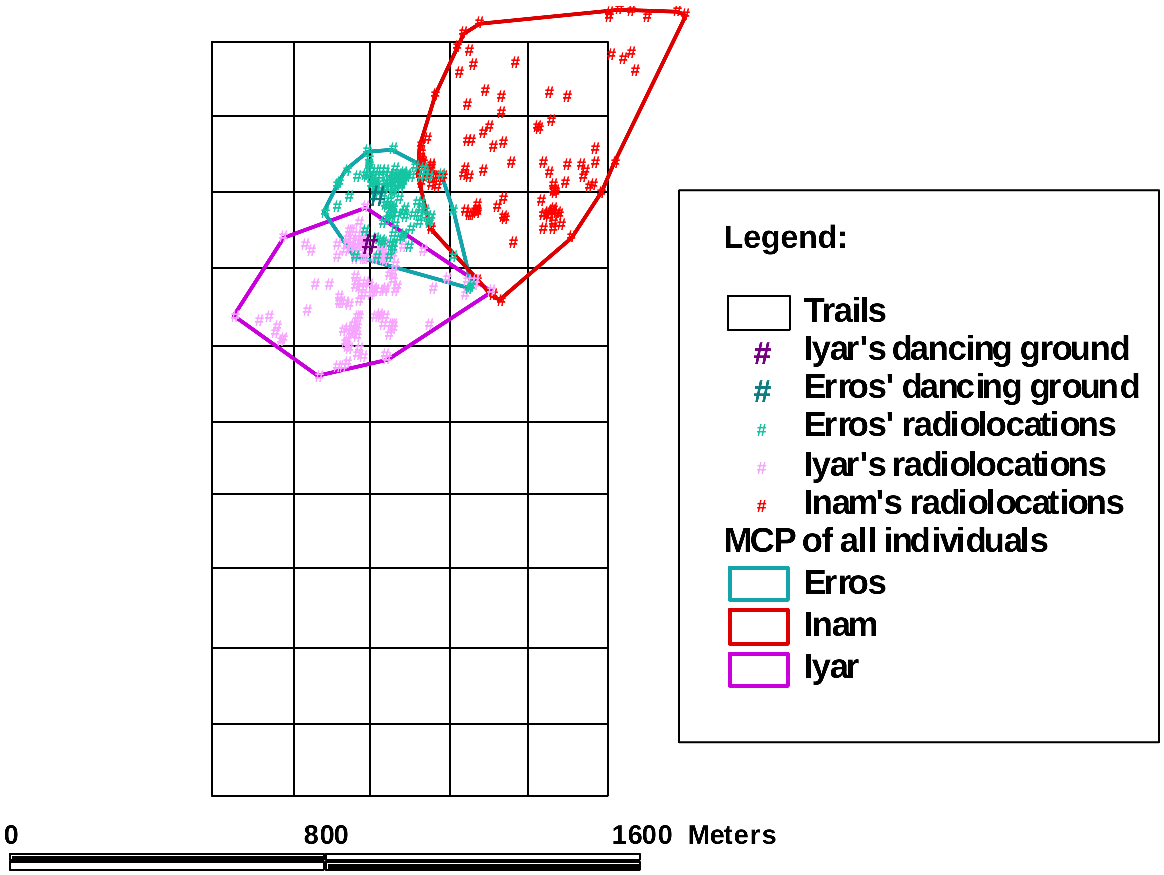


Figure 4.2. Home range of 3 males of Great Argus pheasant on North study area of BukitBarisan Selatan National Park, Sumatra, depicting radiolocations, dancing ground, and MCP home range for each individual

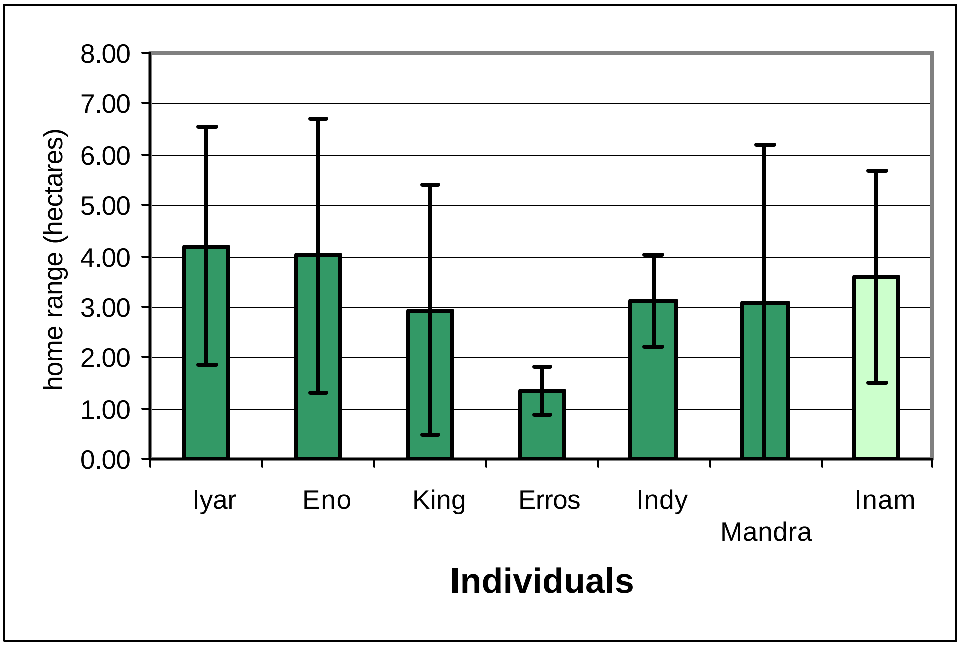


Figure 4.3. Mean daily home range (± SD) of males Great Argus pheasant in Bukit Barisan Selatan National Park, Sumatra, Indonesia (Adult: Iyar,Eno, King, Erros, Indy, Mandra; Sub-adult: Inam)

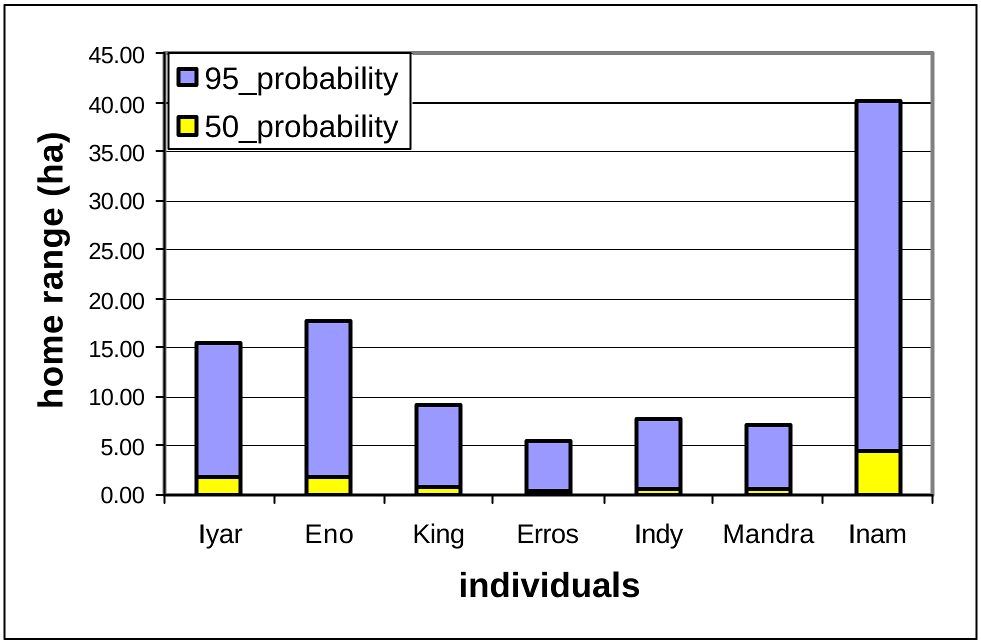
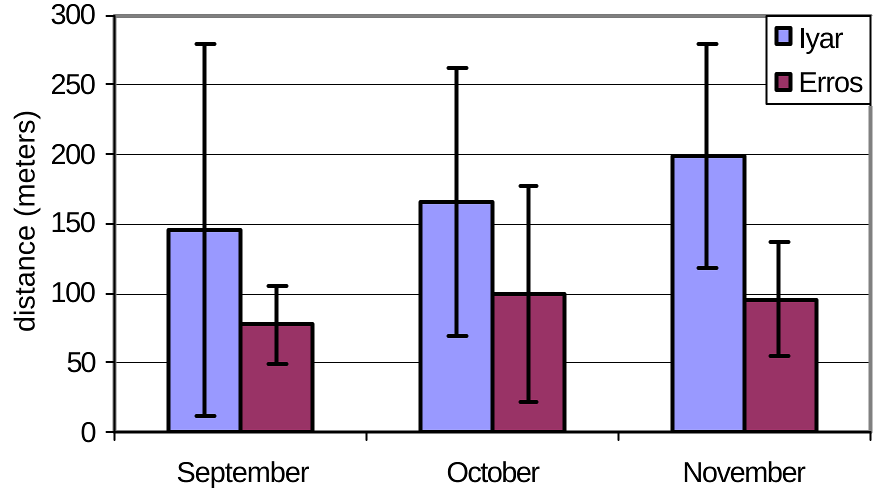


Figure 4.4. Kernel home range of male Great Argus pheasant in BBSNP, Sumatra, Indonesia, showing 95% probability and 50% probability of home range use (Adult: Iyar,Eno, King, Erros, Indy, Mandra; Sub-adult: Inam)

A. North study area



B. South study area

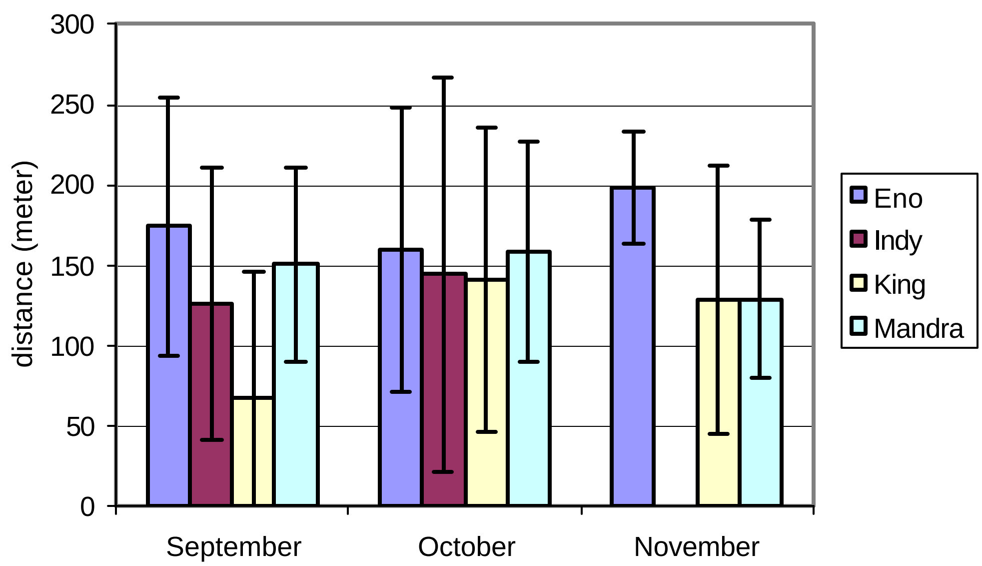


Figure 4.5. Monthly mean distances to dancing ground (± SD) of adult males Great Argus on North and South study area during September-November 2001, Bukit Barisan Selatan National Park, Sumatra, Indonesia.

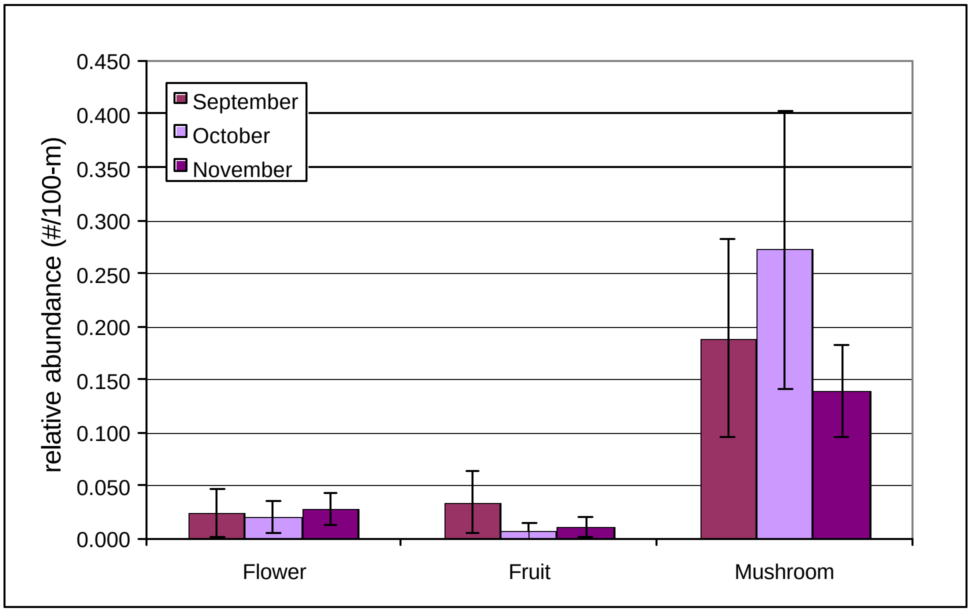


Table 4.6. Means of fallen food abundance within home ranges (± SD) of male Great Argus pheasant during September to November in Bukit Barisan Selatan National Park, Sumatra, Indonesia

CHAPTER 5

MANAGEMENT IMPLICATIONS ON

GREAT ARGUS PHEASANT CONSERVATION

MANAGEMENT IMPLICATIONS

This study suggests that Great Argus pheasant population density is greater than reported elsewhere and might have increased during 1998 through 2000. This study, however, may not be comparable to previous studies on Great Argus pheasant population estimates, which were unverified indices, based on vocalizing individuals (Davison 1981b) or vocalizing males (Nijman 1998). In this study, we recorded both males and females through sighting and calling encounters, and applied Distance sampling methodology. Females of Great Argus pheasant are less vocal than males, but are known to give "long calls" as do males, which may confuse identification in the field.

Detection of Great Argus pheasant can be influenced by several different factors, such as species behavior, and habitat (Bibby et al. 2000). First, as most of other pheasants, Great Argus pheasant is sensitive to human disturbance. Most detection came from aural cues, therefore, estimating distance from aural cues is a difficult task and observers need to be experienced. Knowledge on Great Argus pheasant dancing ground sites was very helpful in practicing distance estimation. Second, detectability is influenced by habitat type or habitat condition. Dense understory vegetation may limit the visibility for observers. Changes in habitat, such as fire, will obviously affect the understorey species in terms of distribution in space and time. Third, other factors such as weather and season may also affect the detectability. Male Great Argus pheasant usually starts to perform its call during pre-establishment of the dancing ground and during the breeding season to attract the females (Davison 1981b). Therefore, calling is not performed all year round, which means that probability of detection during non-breeding season will be lower.

Bennett and Dahaban (1995) found that the number of calls was correlated to hunting pressure, where there was a decline as hunting pressure increased. Nevertheless, the increase of Great Argus pheasant density in the study area does not necessarily correlate to less hunting pressures. Hunting pressures in the area have not been measured, even though hunting of Great Argus pheasant for local consumptions does occur (O'Brien and Kinnaird 1996).

Although, population estimates are considered basic in ecological studies, understanding the natural history is also important especially if we want to understand trends in the population. These studies suggest that observers need to practice their distance estimation so that population estimation can be improved. Improving population estimates, eventually will lead to a better management. By knowing the accurate abundance of this species, more advance studies can be pursued and conservation management of Great Argus pheasant can be enhanced.

Our study on Great Argus pheasant with camera traps revealed that camera trapping offers an alternative method to study secretive and elusive pheasant such as Great Argus pheasant. Although they have lower rates of detection, the camera trapping method is less time consuming than the line transect method and can detect animals at all times.

In this study, we were constrained by the small sample size. However, once standardized, a double sampling approach for both methods maybe applicable to get an index of abundance and maybe applied in concur with camera trapping projects in other areas designed to assess abundance of Sumatran tigers.

A number of studies on density and abundance suggested that Great Argus pheasant is more abundant in primary lowland forest than secondary forest or agroforest (Wilson and Johns 1982, Thiollay 1994, Nijman 1998). The observed distribution of Great Argus pheasant in Way Canguk corresponded with previous findings suggesting that undisturbed forest with large trees was used more than other forest types. In Sumatra, trees from the family of Dipterocarpaceae predominate the largest trees in lowland forest (Whitmore 1975). Trees of this group are renowned as timber trees, but notoriously slow in reaching maturity (Whitmore 1995, Richards 1996). Clusters of Dipterocarpaceae, consisting of different species, form a contiguous canopy reflecting the high density of top canopy trees in this Malesia region, which is unique in the world (Whitmore 1975). Contiguous canopy provide cover and specific microclimate suit to understory species such as Great Argus pheasant.

This study suggested that males of Great Argus pheasant selected sites with more open understory for their dancing grounds. Although males may maintain more than one dancing ground within the home range, our data revealed that sites appropriate for dancing ground are limited in the study area. Dancing grounds are precious and are being maintained for long period during the breeding season. Any disturbance during this period would lead the male to abandon its dancing ground and find a new one, which is costly. Males of Great Argus pheasant have larger home ranges than the same species in Malaysia (Davison 1981a), although in neither case size correlated to food abundance. Large animals typically have larger ranges, which make them less likey to recover when population decrease (Loiselle and Blake 1992).

Way Canguk Research and Conservation Training Center was built in 1997. A path connecting the Way Haru enclave to the outside of the park bisects the study area. This path can become extremely busy with human traffic each week during market day. Although, typically villagers would not go into the study area, this path will increase the chance of poachers and illegal loggers. Even though Great Argus pheasant is a sensitive bird, we found that this bird can become habituated to humans (N. Winarni *personal observation*), which would increase the chance of being hunted.

Considering that this part of the park is one of the last intact lowland rainforest in Sumatra, Way Canguk is critical habitat to ensure the preservation of lowland inhabitants. During 1997, forest fires damaged approximately 165 ha of the study area (O'Brien et al 1998). Understory birds like Great Argus pheasant are the most vulnerable taxa susceptible to forest disturbance due to their intolerance of canopy gaps (Wong 1985, Bierregaard and Lovejoy 1992). The decline of canopy trees due to fires (Kinnaird and O'Brien 1998) provides less cover for understory birds. Fires also affected wildlife in terms of food supply, territoriality, and shelter needs. Flowering and fruiting trees are less within and next to the burn area than in the forest (Kinnaird and O'Brien 1998).

Wilson and Johns (1982) found that Great Argus pheasant exists in old logged forest and primary forest, but not in recently logged forest, suggesting that there is immediate response to logging. With the high density of Great Argus pheasant compare to other areas such as West Malaysia (Davison 1981) and Kayan Mentarang in Borneo (Nijman 1998), Way Canguk revealed as good representation of Great Argus pheasant habitat. Although Great Argus pheasant is no longer regarded as a Vulnerable species (Fuller and Garson 2000), conservation of habitat is still important for other species that show preference to intact forest. Sumatra is identified as one of the highest priority areas for pheasant conservation. High in pheasant diversity, Sumatra holds the long list of threatened species due to habitat loss (Fuller and Garson 2000). The degree of illegal logging in the area has increased for the past 2 years, as well as the increase of land conversion to agriculture near the boundary of the park (O'Brien and Kinnaird 1996, WCS-IP *unpublished reports*). Consequently, preservation of this part of the park, as well as other areas similar should become a higher priority.

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