Effects of forest patch size on Galliformes in southern Sumatra, Indonesia

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ABSTRACT

We evaluated the status of five species of Galliformes in 16 forest patches within two National Parks in Lampung Province, southern Sumatra, Indonesia. We surveyed pheasants during January-August 2003 using variable radius circular plots, line transects, and *ad libitum* sampling. We categorised forest blocks into large (5,000-10,000 ha), medium (1,000-5,000 ha), and small (<1,000 ha) patches and considered the Bukit Barisan National Park (260,384 ha) as the source from which we measured patch isolation. We detected five of the six species known to occur in southern Sumatra during our surveys, great argus pheasant *Argusianus argus*, Sumatran peacock-pheasant *Polyplectron chalcurum*, crested fireback *Lophura ignita*, red junglefowl *Gallus gallus* and crested partridge *Rollulus rouloul*. The number of these species recorded in each forest patch varied between none and all five. The most common species was Sumatran peacock-pheasant, which was recorded in six patches and great argus pheasant, which was recorded in four forest patches. In general, more species occurred in the larger patches that were less isolated from other forests. All forest patches were highly disturbed by encroachment and illegal logging. Although our results are preliminary, the absence of Galliformes from patches less than 4,400 ha suggests that all surveyed species require large forest patches for persistence. Consequently, conservation of habitats is crucial for their long-term survival.

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INTRODUCTION

Indonesia is home to 22 species of Galliformes of which 15 are found in Sumatran forests (MacKinnon & Phillipps, 1993; Johnsgard, 1999). Most of the species are dependent on forested habitats which make them vulnerable to deforestation and habitat degradation. Many galliform species are threatened by hunting for food and trade, and their feathers are used for ornamentation in Indonesia. As a consequence, the status of many Galliformes in Indonesia is considered threatened (Fuller & Garson, 2000).

In Sumatra, the status of Galliformes is poorly known. Most records are restricted to forests within protected areas. The 2000-2004 Pheasant Action Plan indicated the need to assess the populations of Asian Galliformes within protected areas and to survey for threatened pheasants and partridges in Sumatra in particular (Fuller & Garson, 2000). Lampung, as the southern most province of Sumatra and has two National Parks, Bukit Barisan Selatan and

Way Kambas, which are known to support Galliformes. Other, largely unknown populations are scattered in remaining forest patches in the province (WCS unpublished reports; Parrot & Andrew, 1996). This limited information is consequently leading to a potentially misguided conservation efforts.

In Sumatra, more than 60% of the forest habitat that would formerly have been available to forest galliform species appears to have been lost (McGowan & Gillman, 1997). McGowan and Gillman (1997) also concluded that not only is the lowland forest habitat being reduced in size, but it is also being fragmented, resulting in blocks of habitat that may be too small to support viable populations of forest specialists. This is particularly true for lowland forest areas. From an overall total of 168,200 km^2 of forested area in Sumatra, only 13% of lowland forest remains, much of which is fragmented (Holmes & Rombang, 2001). Between the late 1950s and 1989, much of Lampung's forest was cleared as part of the Indonesian Government's Transmigration Program (Benoit *et al.* 1989). This was followed by a period of spontaneous migration of people leaving the overcrowded, neighbouring island of Java. Between 1985 and 1997, forest cover declined by approximately 44.2%, the second highest rate of any Sumatran province (World Bank, 2001). The protection given to National Parks and Nature Reserves is not sufficient to stop forest clearance. The expansion of agricultural lands across park boundaries continues to occur in most Nature Reserves (MacKinnon & Phillipps, 1993; O'Brien & Kinnaird, 1996), and fire, as a result of illegal logging, is becoming a major threat (Holmes & Rombang, 2001).

Previous research has shown that local extinction of birds often occurs when the population is isolated in forest fragments (Newmark, 1991; Arango-Vélez & Kattan, 1997). Understorey birds such as Galliformes are particularly vulnerable to forest disturbance due to their intolerance of canopy gaps (Wong, 1985; Bierregaard & Lovejoy, 1992). Their poor flight ability further limits their foraging opportunities in fragmented forest as they are reluctant to move across non-forested areas. Thus, conservation of Galliformes relies heavily upon the protection and management of large blocks of suitable habitats.

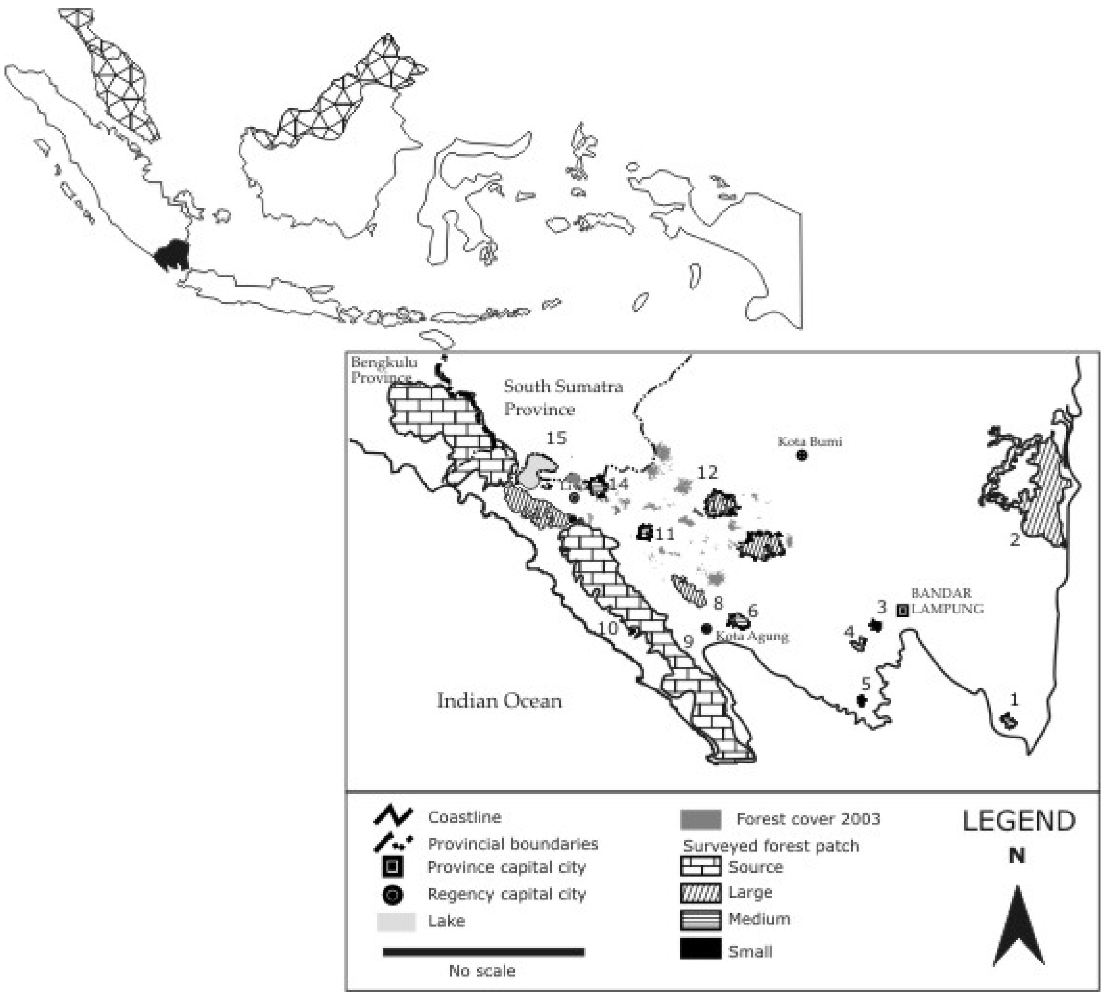
This paper reports the preliminary status of six galliform species in Lampung Province, Sumatra, and investigates the effect of forest fragmentation on population size. We compiled data from two different surveys in forest patches across Lampung Province to assess the species richness and to study how particular species were influenced by the fragmentation process.

STUDY AREA AND METHODS

Study area and identification of forest patches

The study was conducted between January and August 2003. Forest patches within Lampung Province were identified from a 2000 Landsat map, using a definition of a forest patch as any area of forest greater than 1 km^2. Principal Component Analysis (PCA) was used to classify these forest patches according to size, distance from nearest neighbouring forest patch, the number of forest patches that function as as stepping stones between source forests, and the distance from source forests. An area was considered as source forest when its size was greater than 500 km^2. Bukit Barisan Selatan National Park (BBSNP) was considered as a source. The PCA grouped 34 forest patches into six different size/isolation categories: small (<10 km^2), medium (10 km^2 – 50 km^2), large (>50 km^2) with each being considered near or far from the source park. Then, we randomly selected 16 of 34 forest patches and one source forest for sampling (Figure 1; Hadiprakarsa *et al.*, 2004). The other National Park in Lampung, Way Kambas National Park was considered as a patch due to its size.

Figure 1. Forest patches and National Parks in Lampung Province (1. Mt. Rajabasa; 2. Way Kambas National Park; 3. Mt. Betung; 4. Mt. Pesawaran; 5. Mt. Tanggang; 6. Mt. Tanggamus; 7. Batu Tegi; 8. Bukit Rindingan; 9. Bukit Barisan Selatan National Park; 10. Mulang Mayang; 11. Mt. Sekincau; 12. Air Naningan Kecil; 13. Tangkit Tebak; 14. Mt. Pesagi; 15. Mt. Seminung; 16. Lombok; 17. Lima Kunci).



METHODS

The aim of the surveys was primarily to generate presence/absence data for the Galliformes in remaining forest patches in Lampung Province. Galliformes were recorded as part of surveys targeted at sampling hornbills *Bucerotidae* and lesser apes *Hylobatidae*. For these surveys point and line transect methodologies were used as well as any incidental encounters (*ad lib*) during the surveys. The length of line transects walked (approximately, small = 8 km, medium = 16 km, large = 24 km, and source 96 -144 km) and numbers of points (small = 1 point, medium = 2 points, large = 3 points, source = 7 points) visited were adjusted proportionally with size of patches or source. The line transects were surveyed in the morning (06:00 - 10:00) and afternoon (13:00 - 17:00) for at least two days at each transect (Hadiprakarsa *et al.*, 2004). Observations using point counts was conducted from 05:00 - 12:00. Due to the difficulty of detecting Galliformes all *ad hoc* encounters, either visual or audible, during these surveys were recorded. No systematic data collection was employed during the surveys.

Rapid habitat assessments data from the hornbill survey (Hadiprakarsa *et al.*, 2004) was used to quantify habitat suitability for Galliformes. Habitat assessments were only conducted along the transect surveys. Habitat disturbance was evaluated by counting the number of trees cut by humans, the number of large trees that were logged, and by determining canopy openness at 200 m intervals along transects using a spherical densiometer. In addition, reproductive-sized semi-epiphyte fig trees (number of figs/km^2) and large trees (number of large trees/km^2) within 15 m on each side of the transect at 200 m intervals were also counted. Hadiprakarsa *et al*. (2004) considered large trees as any trees with diameter above 65 cm, which are usually used by hornbills as nesting trees. We used Spearman rank correlation to see whether patch size category and number of Galliformes found were associated with habitat parameters.

We used stepwise multiple regressions to evaluate whether galliform species richness was influenced by patch size, class of patch size, distance to nearest neighbours, size of nearest neighbours, as well as habitat parameters (fig density, canopy openness, human disturbance, natural disturbance, and large tree density). We excluded distance to source and degree of isolation in the regression model, assuming that Galliformes residence at each patch was not affected by both variables, due to their sedentary nature. The number of galliform species and patch size were log-transformed before regression. Then, we plotted the species-area relationship following Arrhenius equation (1921): $S = CA^z$,where S = number of species, C = fitted constant, A = Area, Z = fitted constant; which is often presented in a linear form $\log_{10} S = \log_{10} C + z \log_{10} A$.

Furthermore, we used binary logistic regression to test whether the presence-absence of individual galliform species was influenced by patch size, proximity to source, degree of isolation, as well as habitat parameters. This test was only applied to great argus peasant, Sumatran peacock-pheasant, and red junglefowl due the sparse data for other species. All statistical tests were performed using SPSS 11.5 (SPSS, 1999).

RESULTS

The average elevation of forest patches in Lampung Province ranged between 300 and 2,200 m above sea level and the dominant forest type varied from lowland to mountain dipterocarp forest, with gradients varying from flat to slopes greater than 30^o. Most of the forest patches were highly disturbed with illegal logging and agricultural clearings. Patch size correlated with density of large trees (Spearman $\rho = 1$, N = 4, $P < 0.001$). However, smaller patch size contains higher semi-ephyfite fig density (Spearman $\rho = -1$, N = 4, $p < 0.001$). Overall, habitat condition of forest patches did not show any patterns based on number of galliform species found as well as patch size (Table 1 and 2).

Table 1. Galliformes species presence in relation to various measures of habitat condition in Lampung Province forest patches. Mean values are given.

Total species	Fig density (trees/km²)	Canopy openness (counts)	Human disturbance (counts)	Natural disturbance (counts)	Large tree density (trees/km²)
0	193.3	6.3	0.0	0.0	1.2
1	147.2	11.5	0.2	0.2	0.7
2	34.5	6.5	0.2	0.1	1.0
3	97.2	5.3	0.1	0.0	1.9
4	100.1	8.3	0.1	0.0	0.3

Table 2. Habitat condition in Lampung Province forest patches based on size patch size. Mean values are given.

Size category	Fig density (trees/km²)	Canopy openness (counts)	Human disturbance (counts)	Natural disturbance (counts)	Large tree density (trees/km²)
Small	161.1	6.7	0.1	0.0	0.8
Medium	159.4	9.5	0.2	0.2	1.0
Large	112.7	7.6	0.1	0.0	1.1
Source	112.4	7.8	0.1	0.0	1.6
Average	**141.8**	**7.9**	**0.1**	**0.1**	**1.0**

Our surveys detected five out of the six galliform species known to occur in Southern Sumatra, these were great argus pheasant *Argusianus argus*, Sumatran peacock-pheasant *Polyplectron chalcurum*, crested fireback *Lophura ignita*, red junglefowl *Gallus gallus*, and crested partridge *Rollulus rouloul*. The number of forest patches in which each was recorded is given in Table 2. The Sumatran peacock-pheasant was commonly found in six forest patches whereas great argus pheasant was recorded in four (Table 3).

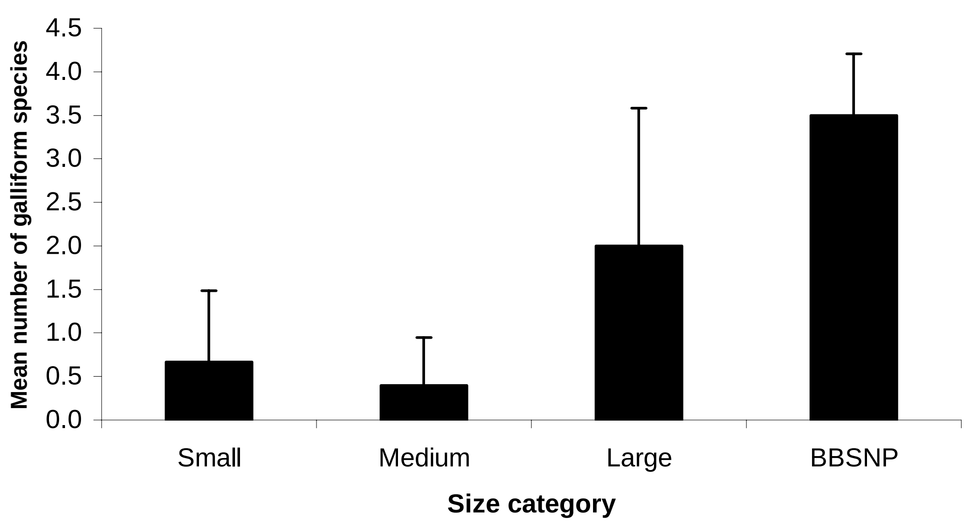
Of the 17 forest patches surveyed, no galliform species were found in seven patches, six patches had one species, two patches had two species, and only one patch had three species. In BBSNP, one of the sources, we recorded five galliform species (Table 3). In general, most species were recorded in the large, less isolated patches with the highest number of species recorded in the source forests (BBSNP, Figure 2). Comparisons between the three different methods (point counts, line transect, and *ad lib*) revealed that the highest rate of detection is generated by *ad lib*, followed by line transect and point counts (Table 4).

Using stepwise multiple regressions, we found that species richness was only affected by patch size in a linear relationship (R^2 = 0.551, $F_{1,\ 9}$ = 11.058, p = 0.009; Figure 3). The regression rejected the other variables from the model. On average, Galliformes were not found in forests less than 4000 Ha (Table 5).

Table 3. Galliform species richness in Lampung Province forest patches (patch size: small: <1,000 ha, medium: 1,000-5,000 ha, large: 5,000-10,000 ha).

Site name	Size	Isolation category	*A. argus*	*L. ignita*	*P. chalchurum*	*G. gallus*	*R. rouloul*	Total
Batu Tegi	Large	Most isolated	1			1		2
Tangkit Tebak	Large	Most isolated			1			1
WKNP	Large	Most isolated	1	1		1	1	4
Bukit Rindingan	Large	Least isolated	1		1	1		3
Lima Kunci	Large	Least isolated						0
G. Pesawaran	Medium	Most isolated						0
G. Pesagi	Medium	Least isolated			1			1
G.Rajabasa	Medium	Most isolated						0
G. Tanggamus	Medium	Most isolated						0
G. Sekincau	Medium	Least isolated			1			1
G. Tanggang	Small	Most isolated	1					1
G. Betung	Small	Most isolated	1		1			2
G. Seminung	Small	Least isolated						0
Air Naningan Kecil	Small	Most isolated			1			1
Lombok	Small	Least isolated				1		1
Mulang Mayang	Small	Least isolated						0
BBSNP	Source		1	1	0	1	1	4
BBSNP	Source		1	0	1	0	1	3

Figure 2. Distribution of Galliformes in forest patch categories compare with source (BBSNP)



Percentage of occurrence of each species in the 16 patches and one source forest showed that the Sumatran peacock-pheasant was highest at 38.9%, followed by great argus pheasant (33.3%), red junglefowl (27.8%), and both crested fireback and crested partridge (11.1%). Using binary logistic regression, we found that the occurrence of great argus pheasant was affected by patch size (χ^2_4 = 9.031, p = 0.001, 100% correctly classified), then canopy openness (χ^2_2 = 5.938, p = 0.004, 93.8% correctly classified), and fig density (χ^2_1 = 4.906, p = 0.027, 62.5% correctly classified). Red junglefowl was affected by number of natural disturbance (χ^2_3 = 5.004, p = 0.001, 100% correctly classified) and patch size (χ^2_2 = 12.991, p = 0.002, 93.8% correctly classified). The occurrence of Sumatran peacock-pheasant did not show any significant relationships to the measured variables.

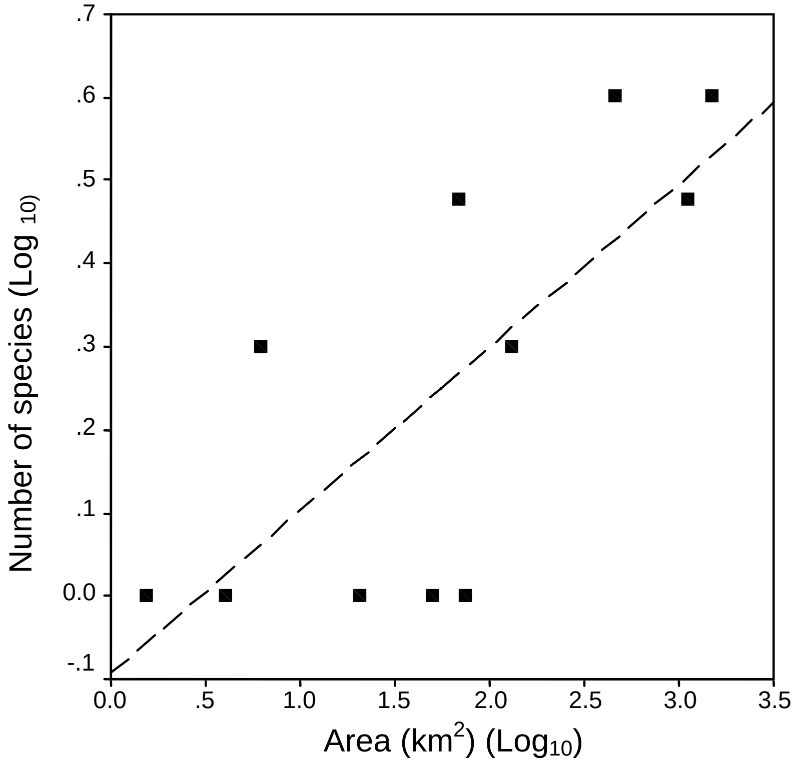
Table 4. Comparison of Variable Circular Plot (PC), Line Transect (LT), and *ad lib* (AL) methods in detecting Galliformes (0 = no detection, 1 = detection).

Site name	*PC*	*LT*	*AL*
Batu Tegi	0	1	1
Tangkit Tebak	0	1	1
TNWK	1	1	1
Bukit Rindingan	0	1	1
Lima Kunci	0	0	0
G. Pesawaran	0	0	0
G. Pesagi	1	0	1
G.Rajabasa	0	0	0
G. Tanggamus	0	0	0
G. Sekincau	0	1	0
G. Tanggang	0	0	1
G. Betung	1	1	0
G. Seminung	0	0	0
Air Naningan Kecil	0	1	0
Lombok	0	0	1
Mulang Mayang	0	0	1
TNBBS	0	1	1
TNBBS	0	1	1
Detection rate	0.17	0.50	0.56

Table 5. Number of galliform species found in mean relation to patch size (ha ± s.e.).

Number of species	*Average size (ha ± s.e.)*
0	4414.1 ± 2232.4
1	2653.4 ± 1392.7
2	6871.7 ± 6255.2
3	58895.9 ± 51983.1
4	97828.6 ± 51676.6

Figure 3. Relationship between number of galliform species and forest patch area (km^2), showing prediction line of number of galliform species.



DISCUSSION

Of all species recorded during survey, we found no new records of galliform species. Many galliform species in Sumatra reside in higher elevation and survey areas in Lampung have elevations between 300 and 2,200 m. Higher elevation of sampling areas was mostly close to the Barisan Mountain ranges. The Way Kambas National Park was only represented by four species. Parrot & Andrew (1996) accounted for at least seven species in the National Park.

Many Galliformes possess cryptic plumage colouration and subdued calls which decreases detection probability (Bibby *et al.*, 2000; Carroll & Conroy, 2000). Restricted visibility in the tropical rainforest adds to the low detection of galliform species and field methods have to be modified to accommodate the species behaviour (Winarni, 2002). In addition, the small sample size would also be likely to contribute to the low encounters. The data used in this paper were generated from specific survey of canopy birds and primates and thus, methods were adjusted to target species. Search effort was not systematic or focused towards finding galliform species, which may also affect encounter rates. In consequence, *ad lib* methods provided the highest detection rate because any incidental encounters are noted. However, line transect seems promising as appropriate method to survey Galliformes in tropical rainforest as long as sample sizes are large.

Compared to other birds, galliform species are sedentary and have poor flight ability, which makes them unlikely to disperse to other forest patches. Consequently, their presence is dependent on the proximity to sources and the degree of isolation. Three forest patches, Bukit Rindingan, Batu Tegi, and Gunung Betung are of particular interest. These three patches hold more than one species and two of the areas, Batu Tegi and Gunung Betung, are both located far from the two protected areas in Lampung Province. However, Galliformes may still be able to move between patches as long as patches are connected with suitable habitat. Although it mainly utilises primary forest, great argus pheasant is known to use secondary forest or agroforest (Wilson & Johns, 1982; Thiollay, 1994; Nijman, 1998), and red juglefowl uses forest edge and rubber tree plantations (Thiollay 1994).

With regard to island biogeography theory (MacArthur & Wilson, 1967), the size of an area appears to be the ultimate factor in supporting different species of Galliformes. The smaller an area predicts lower species richness. Winarni (2002) has shown that great argus pheasant needs a relatively large area of between 7 and 32 ha. Considering that the southern Sumatran population of great argus pheasant prefers the flat lowland areas (Beebe, 1926), the remaining suitable habitat for great argus pheasant and other lowland specialist has declined as a consequence of small patch size. Camera trap data revealed that great argus pheasant was less often found in association with other galliform species and was never found with Sumatran peacock-pheasant (Winarni *et al.*, this volume), which indicates habitat partitioning among medium to large-bodied Galliformes. If available habitat is small, then fewer species can co-exist. When an area becomes smaller and isolated the chance of inbreeding would be greater and food resource would be diminished (Thomas, 1991). Although Galliformes may still use small patch size, on average Galliformes were absent in areas less than 4000 ha, indicating the need for larger forests.

Both the occurrence of great argus pheasant and red junglefowl was affected by patch size and were mostly found in larger forest patches. The red junglefowl also occurred in areas with less natural disturbance. Although the red junglefowl prefers areas of secondary forests associated with abandoned clearings (Johnsgard, 1999), it seems that the bird was more tolerant of natural disturbance rather than clearings caused by humans. The absence of many galliform species in the medium-sized forest patches was probably due to limited resource availability. Great argus pheasant occurrence was also affected by the density of figs. Great argus pheasant is known to be omnivorous and has been observed scratching dung of primates containing figs (A. Nurcahyo, *pers. obs*.). Lambert (1989) recorded that crested fireback ate figs, indicating that Galliformes species are likely to consume figs. Fig trees also have large and dense canopies that provide protection to many under-storey animals.

Patch size did not seem to affect the Sumatran peacock-pheasant. Little information is available on the ecology of this bird. However, the Sumatran peacock-pheasant is usually confined to higher elevations between 800 and 1700 m (MacKinnon & Phillipps, 1993) and its occurrence is probably more correlated to elevation than other habitat parameters (Winarni *et al.*, this volume). Remnant hill-top forest patches in Lampung are usually located at the centre of the forest patch, suggesting that edge effect has little consequences on birds dependant on high elevations. Great argus pheasant and other lowland specialists would be adversely affected by fragmentation.

Birds that live in the upper canopy have a better chance of extending their foraging area and avoiding disturbance (Wong, 1985). Galliformes species, as other under-storey birds have restricted opportunities to move between patches. Although Galliformes may use secondary habitat and agroforest, they are mainly forest interior specialist and are more affected by fragmentation before other groups of birds (Bierregard & Dale, 1996). When a patch is isolated and natural habitats are not maintained, under-storey birds like pheasants are vulnerable to local extinction because there are no compensatory invasions of the same species due to their limited dispersal ability (Bierregard & Dale, 1996). Smaller patch size will also lead to diminishing interior forest area as edge width increases (Ranta *et al*., 1998) signifying the importance of patch size to Galliformes. Under-storey birds are usually adapted to low light intensity, low heat stress, and high humidity, which makes them susceptible to large scale disturbance (Wong 1985). However, fragmentations increase edge effect, which increase light intensity and winds that affect edge-living trees (Schelhas & Greenberg, 1996; Bierregard & Dale, 1996).

Nest predation is correlated with fragment size (Arango-Vélez & Kattan, 1997) and a study in Brazil revealed that under-storey birds avoided crossing narrow gaps of clear-cut forest (Bierregard & Lovejoy, 1992). Under-storey birds in Tanzania experienced local extinction when fragmentation occurred (Newmark, 1991) suggesting that tropical rainforest may be susceptible to fragmentation effect (Bierregard & Dale, 1996). This sensitivity of under-storey birds makes them good indicators of habitat disturbance. Thus, the need for large forest areas and the sensitivity to changes in the habitat can be used as the basis of forest patch management particularly when linked to the occurrence of other wildlife species.

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REFERENCES

Arango-Vélez, N. & Kattan, G.H. 1997. Effect of forest fragmentation on experimental nest predation in Andean cloud forest. Biological Conservation 81: 137-143.

Arrhenius, O. 1921. Species and area. Journal of Ecology 9:95-99.

Beebe, W. 1926. Pheasant: their lives and homes. Volume II. New York Zoological Society, New York: 309 pp.

Benoit, D., Pain, M. & Levang, P. 1989. Transmigration en spontanees en Indonesie/ Transmigration and spontaneous migrations in Indonesia: Lampung Province. Orstom & Transmigration Department, Jakarta.

Bibby, C.J., Burgess, N.D., Hill, D.A. & Mustoe, S.H. 2000. Bird census technique. Second Edition. Academic Press, London.

Bierregard Jr., R.O. & Dale, V.H. 1996. Islands in an ever-changing sea: the ecological and socioeconomic dynamics of Amazonian rainforest fragments. In: Schelhas, J. and R. Greenberg. 1996. Forest patches in tropical landscapes. Island Press, Washington DC & Covelo: 187-204.

Bierregaard Jr., R.O. & Lovejoy, T.E. 1992. The biological dynamics of tropical rainforest fragments. Bioscience 42: 859-867.

Conroy, M.J. & Carroll, J.P. 2001. Estimating abundance of Galliformes: tools and application. In: Carroll, J., Musavi, A. & Zhang, Z-W. Proceedings of the 7th International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal: 204-215.

Fuller, R.A. & Garson, P.J. (eds.). 2000. Pheasants. Status survey and conservation action plan 2000-2004. WPA/BirdLife/SSC Pheasant Specialist Group. IUCN, Gland: 68 pp.

Hadiprakarsa, Y., Iqbal, M. & Wijayanto, U. 2004. Status and threats to hornbills across the Southern Sumatra landscape. The Wildlife Conservation Society Indonesia Program, Bogor.

Holmes, D.A. & Rombang, W.M. 2001. Daerah penting bagi burung: Sumatra. PKA/Birdlife International-Indonesia Programme, Bogor.

Johnsgard, P.A. 1999. The pheasants of the world: biology and natural history. 2nd ed. Smithsonian Institution Press, Washington. 398 pp.

Lambert, F. 1989. Fig-eating by birds in a Malaysian lowland rain forest. Journal of Tropical Ecology 5: 401-412.

MacArthur, R.H. & Wilson, E.O. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

McGowan, P.J.K. & Gillman, M. 1997. Assessment of the conservation status of partridges and pheasants in South East Asia. Biodiversity and Conservation 6: 1321-1337.

MacKinnon, J. & Phillipps, K. 1993. A field guide to the birds of Borneo, Sumatra, Java, and Bali. Oxford University Press, New York.

Newmark, W.D. 1991. Tropical forest fragmentation and the local extinction of understory birds in the Eastern Usambara mountains, Tanzania. Conservation Biology 5: 67-78.

Nijman, V. 1998. Habitat preference of Great Argus Pheasant *Argusianus argus* in Kayan Mentarang National Park, East Kalimantan, Indonesia. Journal of Ornithology 139: 313-323.

O'Brien, T.G. & Kinnaird, M.F. 1996. Birds and mammals of the Bukit Barisan Selatan National Park, Sumatra, Indonesia. Oryx 30: 207-217.

Parrot, S. & Andrew, P. 1996. An annotated checklist of the birds of Way Kambas National Park, Sumatra. Kukila 8: 57-85.

Ranta, P., Blom, T., Niemelä, J., Joensuu, E. & Siitonen, M. 1998. The fragmented Atlantic rain forest of Brazil: size, shape and distribution of forest fragments. Biodiversity and Conservation 7: 385-403.

Schelhas, J. & Greenberg, R. 1996. The value of forest patches. In: Schelhas, J. and R. Greenberg. 1996. Forest patches in tropical landscapes. Island Press, Washington DC & Covelo: xv-xxxvi.

SPSS Inc. 1999. SPSS for windows release 10.0.5. SPSS Inc., Chicago.

Thiollay, J.M. 1995. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. Conservation Biology 9: 335-353.

Thomas, C.D., 1991. Ecological Corridors: an assessment. Department of Conservation, Washington.

Wildlife Conservation Society. 2003. Status and threats to Lesser Apes across the Southern Sumatran Landscape. A report to Disney Conservation Fund, Bogor.

Wilson, W.L. & Johns, A.D. 1982. Diversity and abundance of selected animal species in undisturbed forest, selectively logged forest and plantations in East Kalimantan. Indonesia. Biological Conservation 24: 205-218.

Winarni, N.L. 2002. Distribution and movement patterns of Great Argus pheasant (*Argusianus argus*) in Bukit Barisan Selatan, Sumatra, Indonesia. MS Thesis. University of Georgia, Athens.

Wong, M. 1985. Understorey birds as indicators of regeneration in a patch of selectively logged West Malaysian rainforest. ICBP Technical Publication 4: 249-263.

World Bank, 2001. Indonesia: environment and natural resource management in the time of transition. Washington DC: World Bank.