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Short Communication

Influence of Matrix Habitats on the Occurrence of Terrestrial Mammals in Planted Forest Landscapes

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SK and TM conceived the idea. KM, SK and TM contributed to the study design. KM, SK. MM, TI and SH collected the data. MS and TN analyzed the data and wrote the manuscript with input from all authors.

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Camera trap, forest fragmentation, forestry plantation, temperate forest,

A B S T R A C T

We studied the responses of terrestrial mammal community to high levels of habitat fragmentation caused by forestry plantations in central Japan. Our aim was to understand how terrestrial mammals select remnant natural forest (broad-leaved forest) patches in a fragmented forestry plantation landscape. Camera traps monitored remnant 12 broad-leaved forest patches for 7 months. These patches differed in the ratio of broad-leaved forest to the surrounding forestry plantation matrix area. In total, 144 photographs captured. A positive relationship was found between the number of photographs of mammals and the area of broad-leaved forest around the remnant broad-leaved forest. Hierarchical variation partitioning also showed that BF had a substantially greater independent explanatory power than CF. Future studies of landscapes resulting from different matrix types are needed to help land managers understand the influences of habitat configuration on patterns of species persistence and community dynamics.

Forest loss and fragmentation are two important interacting processes that may negatively affect biodiversity (Fahrig, 2003). They both isolate remnant patches, increasing the risk of extinction for some mammal species (*e.g.*, Bodmer *et al*., 1997) and reducing mammal species richness (*e.g*., Cullen *et al*., 2000). Recent studies on the effects of forest fragmentation showed that fragmented landscapes are complex and variable systems, because the quality of remnants or the affinity to the matrix, the dominant component in the landscape, often strongly influences their functional connectivity (*e.g*., Laurance and Bierregaard, 1997; Bierregaard *et al*., 2001). Additionally, several studies have described how the surrounding matrix influences populations in forest fragments (*e.g*. Hinsley *et al*., 1995; Stouffer and Bierregaard, 1995).

The matrix can be important because it both influences mammal movement through the landscape (Revilla *et al*., 2004; Bender and Fahrig, 2005) and provides potential food resources (Tubelis *et al*., 2007; Harper *et al*., 2008). Thus, knowledge of the effects of anthropogenic disturbances and matrix quality and structure on ecological processes are crucial to understanding patterns of mammal species distribution and community dynamics in fragmented landscapes (Santos-Filho *et al*., 2012).

The area covered by planted forest landscapes, forestry plantations, is one of the common landscapes in several countries such as Japan and Australia (Forest resource assessment, 2010). Therefore, understanding how to conserve native biodiversity in the remnant natural forest patches within planted forest landscapes is an increasingly important issue. The common matrix environments under this land-use type may provide new food sources and some shelter for some animal species that do not use mature natural forest, allowing them to occupy the matrix or disperse through it (Anderson *et al*., 2007). Thus, management of the planted forest landscape matrix for biodiversity is easier than that of other matrix types such as urban or agricultural landscapes. Nevertheless, the responses of highly mobile medium-sized and large-bodied vertebrates to habitat disturbance and matrix quality are not completely understood.

In this study, our objective was to understand how terrestrial mammals select remnant natural forest (broad-leaved forest) patches in a fragmented forestry plantation landscape in Japan. We used the camera traps because it was useful noninvasive monitoring tool (*e.g.*, Wang *et al*., 2014). We investigated the effect of matrix habitat structure on mammalian communities in a hyper-mosaic

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landscape between broad-leaved forests and conifer forestry plantations of Japanese cedar (*Cryptomeria japonica*), Japanese cypress (*Chamaecyparis obtusa*), and Japanese larch (*Larix kaempferi*) in central Japan.

Methods

Study area

This study lies within the southern part of the Abukuma Mountains, Honshu, Ibaraki Prefecture, central Japan (36°56′N, 140°35′E, 610–660 m a.s.l.). The mean annual precipitation and temperature are about 1,910 mm and 10.7°C, respectively, with mean monthly temperature ranging from −0.9°C in January to 22.6°C in August, based on data from the Ogawa meteorological station (36°54′N, 140°35′E) (Moriguchi *et al*., 2002). The maximum winter snow depth is about 50 cm.

In Japan, forests cover 67% of the land area, including 40% covered by forestry plantations (Forest Agency, 2012). Most forestry plantations and natural forests form a mosaic and complex structure within the landscapes of Japan. Conifer forestry plantations cover more than 60% of forest area in Ibaraki Prefecture (Forest Agency 2012). In our study area, forestry plantations was dominant vegetation type, however natural forests were remain partly. Thus, conifer plantations and natural forests of broad-leaved trees form a complex mosaic landscape. *Fagus japonica*, *Castanea crenata*, *Quercus serrata*, *Carpinus laxiflora*, and *Prunus verecunda* dominate the natural forests. To investigate effect of the amount of natural forests among the forestry plantation matrix on mammal fauna, we measured the amount of forest (forest area) surrounding the remnant broad-leaved forest at radii of 126, 178, 252, 309, 357, and 399m from the mapped points, which correspond to 5, 10, 20, 30, 40, and 50ha, respectively. We selected 12 natural forest patches in our 10 km × 15 km study area depend on the matrix condition. Each patch was separated from at least 1.3km (Fig. 1). Among the matrix (surrounding area of the selecting 12 patches), forestry plantations were dominant vegetation type, however natural forests were also part of the matrix. These selected patches differed in the ratio of natural forest to the surrounding matrix area (Supplementary Table I).

Fig. 1. Location of 12 forest patches in Ibaraki Prefecture, Japan, indicated by numbers. Black, gray, and white denote broad-leaved forest, conifer plantations, and other land uses, such as farmland or pasture, respectively (Modified from Ministry of the Environment Japan, 1999).

Camera trapping

The presence of mammals in 12 forest patches was assessed from May to November, 2012 using infra-red triggered cameras (5.0 Megapixel Infrared Digital Motion-detection Camera, National Geographic Store, Margate, FL, USA) in each forest patch. Because the species differed in birthing, pregnancy, and dispersal seasons, we monitored mammals for several months using a total of 214 camera days per study site (1 camera × 214 d). Each photograph was stamped with the time and date. The time delay between photographs was set to a minimum of 1 minute. However, we decided that photographs less than 1 hour apart would not be independent. Only independent data should be entered into the analysis. At each site, the camera trap was tied to a tree 50 cm above the ground to take a picture of terrestrial medium-large size mammals, we have not targeted small mammals such as rodents. At each patch, we placed the camera traps near the center of each patch calculating by GIS where the probability of mammal detection was high (*e.g*., animal trails) but we did not use baits. The vegetation of each camera setting was representative type of each forest patch. We checked each camera and changed the batteries monthly. Photo results were logged into a computer with frame number, date, time, and contents. Mammal species were identified by body size and body color.

Table I.- Results of camera trapping.

Plot No	Number of photographs						
	Badger	Boar	Hare	Fox	Raccoon dog	Marten	Squirrel
1	0	1	0	0	0	0	0
2	11	26	1	2	5	1	4
3	0	11	0	0	0	0	1
4	1	16	0	0	0	0	0
5	1	7	0	0	2	1	3
6	0	10	0	0	1	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0
10	0	1	0	0	0	0	0
11	0	4	1	0	0	0	4
12	0	0	0	0	0	0	0

Statistical analysis

In this study, there was a significant correlation between broad-leaved forest area surrounding matrix area (BF) and conifer plantation area surrounding matrix area (CF) (5ha: r = -0.84; 10ha: r = -0.90; 20ha: r = -0.93; 30ha: r = -0.93; 40ha: r = -0.92; 50ha: r = -0.90, for all P < 0.001, see Table I). We therefore used a hierarchical variance partitioning analysis in order to compute independent contributions of BF and CF accounting for correlation between these variables. In doing so, we used the 'hier.part package' version 1.0–4 in R statistical software (ver. 3.2.1, R Core Team, 2015). Hierarchical variation partitioning was conducted for each spatial scale (5, 10, 20, 30, 40, 50ha). In the analysis, we analyze mammal community as a whole rather than by species because few animals were recorded.

Results

In total, 144 independent photographs were taken of seven species: wild boar (*Sus scrofa*), Japanese badger (*Meles meles*), red fox (*Vulpes vulpes*), raccoon dog (*Nyctereutes procyonoides*), Japanese marten (*Martes melampus*), Japanese hare (*Lepus brachyurus*), and Japanese squirrel (*Sciurus lis*) (Table I). All camera-traps functioned fully throughout the whole study period. Individuals could not be recognized for all seven species.

A positive relationship was found between the number of photographs and the area of broad-leaved forest around the remnant (only area within 50ha) (Spearman's correlation, area within 5 ha: r = 0.40, P=0.2, area within 10 ha: r = 0.54, P=0.07, area within 20 ha: r = 0.43, P=0.3, area within 30 ha: r = 0.45, P=0.14, area within 40 ha: r = 0.48, P=0.15, area within 50ha: r = 0.59, P < 0.05). Hierarchical variation partitioning showed that BF had a substantially greater independent explanatory power than CF for each spatial scale (Table II).

Table II.- The independent contribution (given as the percentage of the total explained variance) of BF and CF from hierarchical variation partitioning.

Variables	% independent contribution
50ha	
BF: Area of broad-leaved forest	95.6
CF: Area of conifer plantation forest	4.4
40ha	
BF: Area of broad-leaved forest	67.7
CF: Area of conifer plantation forest	32.3
30ha	
BF: Area of broad-leaved forest	93.5
CF: Area of conifer plantation forest	6.5
20ha	
BF: Area of broad-leaved forest	62.4
CF: Area of conifer plantation forest	37.6
10ha	
BF: Area of broad-leaved forest	95.2
CF: Area of conifer plantation forest	4.8
5ha	
BF: Area of broad-leaved forest	99.1
CF: Area of conifer plantation forest	0.9

Discussion

Human land uses that displace and fragment forest habitats serve as important factors in the decline of forest-dependent fauna (*e.g.*, McAlpine and Eyre, 2002; McGarigal and McComb, 1995; Rochelle *et al.*, 1999). However, fragmentation by forestry plantations does not necessarily decrease the total forest area in a landscape. However, our results indicate forestry plantations around the remnant broad-leaved forest cannot be a substitute for remnant natural forest.

In our study, a positive relationship was found between the number of photographs, especially wild boar, and the area of broad-leaved forest around the remnant broad-leaved forest, especially more large scale. And, there may be ecological threshold values of natural forest area around the remnant natural forest within a forestry plantation matrix for the mammal abundance. For example, very few mammals were recorded when natural forest is less than 22 ha in the case of the area of broad-leaved forest around the remnant natural forest within 50 ha (Table I). However, there are several exceptive patches such as No.1 or No. 11. Several plausible reasons may explain these phenomenons. Firstly, major photographed species are mid- to large-sized mammals, these species have large home ranges, which are 116 ha for wild boar, 5–407 ha for badger, and 10–600 ha for raccoon dog (Ohdach *et al*., 2009). Thus, because these three species are highly mobile, they may move through much broader areas. Secondary, the matrix may act as some functions such as food resource. For example, in particular, the wild boar mainly eat earthworms (Ohdach *et al*., 2009). However, the amounts of earthworms do not differ between broad-leaved forests and conifer plantation forests (Ichikawa *et al*., 2008). Third, our study design has some problems; camera traps do not provide large amount of data (low number of camera sites and no repeat measures over a number of study years) and individual recognition is impossible. Thus, it is possible that some individuals (especially the larger species) could have moved/disperse between patches (especially ones close together). For the future, we plan to investigate how these animals move between fragments using telemetry.

However, we can provide several important suggestions. Previous studies identified matrix quality as an important factor that determines the persistence of species in fragmented habitats (Bentley *et al*., 2000; Knight and Fox, 2000), it may also affect habitat quality via edge effects, although exotic species and altered climatic conditions at patch boundaries affect habitats (Saunders *et al*., 1991). However, in this study, the conifer forestry matrix may provide additional food sources and some shelter for mid- and large sized mammals. We cannot discuss this concept in detail. Thus, studies of landscapes resulting from different matrix vegetation structure are needed to aid our understanding of the effects of habitat configuration on patterns of species persistence and community dynamics in the future.

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Statement of conflict of interest

Authors have no conflict of interest.

Supplementary Table I is available on Weblink: http://www.zsp.com.pk/pdf48/907-911%20(41)%20QPJZ-219-2015%2019-4-16_skR.pdf

References

Anderson, D.R., Rowcliffe, J.M. and Cowlishaw, G., 2007. *Biol. Conserv*., **135**: 212-222.

Bentley, J.M., Catterall, C.P. and Smith, G.C., 2000. *Conserv. Biol*., **14**: 1075-1087.

Bender, D.J. and Fahrig, L., 2005. *Ecology*, **86**: 1023-1033.

Bierregaard, Jr. R.O., Gascon, C., Lovjoy, T.E. and Santos, Dos, A., 2001. *Lessons from Amazonia: The ecology and conservation of a fragmented forest.* Yale University Press, New Haven, Connecticut.

Bodmer, R.E., Eisenberg, J.F. and Redford, K.H., 1997. *Conserv. Biol*., **11**: 460-466.

Cullen, L. Jr., Bodmer, R.E. and Padua, C.V., 2000. *Biol. Conserv*., **95**: 49-56.

Driscoll, D.A., 2004. *Ecol. Appl*., **14**: 220-240.

Fahrig, L., 2003. *Annu. Rev. Ecol. Syst.*, **34**: 487-515.

Forestry Agency, 2012. *Annual report on trends in forest and forestry.* Association of Agriculture and Forestry Statistics, Tokyo.

Forest Resources Assessment, 2010. *Key findings: global forest resources assessment.* FAO, Rome, Italy.

Harper, M.J., McCarthy, M.A. and Van Der Ree, R., 2008. *Austral. Ecol*., **33**: 243-252.

Hinsley, S.A., Bellany, P.E., Newton, I. and Sparks, T.H., 1995. *J. Avian. Biol*., **26**: 94-104.

Ichikawa, T., Takahashi, T. and Kobayashi, T., 2008. *J. Jap. Soc. Reveget. Tech.*, **34**: 15-20 (in Japanese with English Abstract).

Knight, E.H. and Fox, B. J., 2000. *Austral. J. Zool*., **48**: 577-595.

Laurance, W.F. and Bierregaard, R.O., 1997. *Tropical forest remnants – Ecology, management, and conservation of fragmented communities*. University of Chicago Press, Chicago.

McAlpine, C.A. and Eyre, T.J., 2002. *Landsc. Ecol*., **17**:711-728.

McGarigal, K. and McComb, W.C., 1995. *Ecol. Monogr*., **65**: 235-260.

Ministry of The Environment Japan, 1999. *The 2nd-5th natural survey on the natural environment.* Ministry of the

Enviroment Japan, Tokyo, Japan (in Japanese).

Moriguchi, Y., Morishita, T. and Ohtani, Y., 2002. In: *Ogawa Forest Reserve of Japan* (eds. T. Nakashizuka, and Y. Matsumoto), Springer, Tokyo, pp. 11–18.

Ohdachi, S.D., Ishibashi, Y., Iwasa, M.A. and Saitoh, T. (eds) 2009. *The wild mammals of Japan.* Shoukadoh, Kyoto.

Revilla, E., Wiegand, T., Palomares, F., Ferraras, P. and Delibes, M., 2004. *Am. Nat.*, **164**: E130–E153.

Rochelle, J.A., Lehmann, L.A. and Wisniewski, J., (eds.) 1999. *Forest fragmentation: Wildlife and management implications*. Brill, Leiden, The Netherlands.

Santos-Filho, M., Peres, C.A., Silvia, D.J. and Sanaiotti, T.M., 2012. *Biodiv. Conserv*. **21**: 1127-1147.

Saunders, D.A., Hobbs, R.J. and Margules, C.R., 1991. *Conserv. Biol*., **5**: 18-32.

Stouffer, P.C. and Bierregaard, R.O., 1995. *Conserv. Biol*., **9**: 1085-1094.

Stratford, J.A. and Stouffer, P.C., 1999. *Conserv. Biol*., **13**: 1416-1423.

Tubelis, D.P., Lindenmayer, D. and Cowling, A. 2007. *Landsc. Ecol.*, **22**: 1045-1058.

Wang, K., Wang, Y., Tao, S., Chen, X., Kong, Y., Shah, A., We, C. and Pang, M., 2014. *Pakistan J. Zool.*, **46**: 725-731.