博 士 論 文 の 要 約

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学 位 論 文 題 名

Wildlife responses to naturally altered and human-modified landscapes in Malaysia and Japan

（マレーシアならびに日本の自然および人為的景観における野生動物の応答解析）

The growing demand on forestry resources and development leads to the expanding of settlements or agricultural land that contributed to the global forest decline. Major natural forest is threatened by timber extraction and conversion into more profitable land-use such as conifer plantation forest, oil palm plantation and other agriculture plantation. Moreover, alteration on natural forest habitat give a great influence on most of the wildlife species. The response of wildlife species on habitat modification are depending on the taxa and the group they belong to i.e., generalist and specialist. Focusing the study area on the tropical rainforest in Malaysian Borneo and boreal forest ecosystem in Northern Japan, the thesis aimed to assess the response of wildlife on the modified landscape in regard to the forestry and wildlife management system between the two regions.

1. Camera-trapping assessment of terrestrial mammals and birds in rehabilitated forest in INIKEA Project Area, Sabah, Malaysian Borneo

The establishment of Innoprise-IKEA (INIKEA) Forest Rehabilitation Project to rehabilitate degraded forest affected by conventional logging and forest fires that occurred during an El-Nino event (1982–1983) drives the attention to investigate the responses of ground-dwelling mammals and birds to the different rehabilitation practices i.e., gap-cluster planting, line planting and liberation, where enrichment planting was applied in both gap-cluster and line planting.

As part of the effort to evaluate wildlife diversity in this study area, camera-trapping survey was used to achieve the objectives, i.e., (1) to record the species occurrence of medium-to-large mammals and birds, (2) to compare species richness and composition of terrestrial mammals and birds among different planting techniques and natural regeneration (control), and (3) to assessed rehabilitation methods and natural recovery alter forest structures and, subsequently, wildlife diversity.

At least a total of 74 camera traps were successfully deployed at random locations across reforested INIKEA plots, including plots in control areas comprising naturally regenerated forest. Relative abundance index (RAI) calculated for the trapping success of each recorded species. The species richness patterns, and composition was analysed by using sample-based rarefaction curve and Jaccard's similarity index. Besides, to assess the general forest structures and wildlife response, 14 microhabitat variables were recorded from each of the camera-trapping point. Canonical correspondence analysis (CCA) was conducted to find out the relationship between species occurrence and the 14 recorded micro-habitat variables.

As a results, a total of 6534 independent photographs of medium-to-large vertebrates from 7266 camera-trap nights representing 33 species from 14 families and 7 orders were obtained. Species that listed on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species were also documented in the study where 2 are listed as Critically endangered, 5 as Endangered, 8 as Vulnerable and 6 as Near threatened. The group living animals are the most frequently photo-captured with the mousedeer (*Tragulus sp*.) as the highest species, followed by muntjac (*Muntiacus* sp.), bearded pig (*Sus barbatus*), sambar deer (*Rusa unicolor*), pig-tailed macaque (*Macaca nemestrina*) and crested fireback (*Lophura ignita*). Species accumulation curve shows no significant different in species richness between gap-cluster planting, line planting, liberation and control area. There is a high percentage of similarity in term of species composition between treatments. For the general forest structure, the results indicate that there is no clear distinction in the forest characteristics between the treatments and natural regeneration area. The wildlife response to forest characteristics shows that sambar deer preferred the area with dense ground vegetation, while the ground-dwelling birds preferred the area with tall and dense canopy cover as well as an abundance of large and climax tree species. Muntjac and bearded pig species were found to be abundant in the

area with dense understorey vegetation, pioneer tree species, medium-sized trees and thick leaf litter cover. The other species such as mousedeer, Malay civet, banded civet and pig-tailed macaque preferred the habitat with abundant of lianas and medium-to-large trees.

In overall, the total number of species recorded in this study was almost correspond to that recorded in the well-managed commercial forest of Deramakot Forest Reserve and higher than in the primary forest of Imbak Canyon Conservation Area. Though the differences in the total number of species recorded was due to the different sampling effort, the results indicate that the study area still support a high diversity of terrestrial mammals and birds. The occurrence of three largest mammals in Borneo i.e., the critically endangered Orangutan, the endangered Bornean pygmy elephant and Bornean banteng, including the five species of wild felids, i.e., clouded leopard, bay cat, flat-headed cat, marbled-cat and leopard cat, suggesting that this area is an important conservation area to protect these species. Additionally, the non-significant in species richness and high similarity in species composition between treatments and control might be due to the less differences in the characteristics of forest habitat among gap-cluster, line planting, liberation and control area. It was also suggested that most of the wildlife species that inhabit in this forest were able to utilize the habitat after the rehabilitation. Though liberation method could facilitate the growth of remaining natural tree species, the implementation of the method might reduce the variation in food availability from the fast-growing climbers and pioneer tree species.

Therefore, the findings revealed that rehabilitation methods applied in INIKEA have aided the forest recovery, providing habitat for the ground-dwelling mammals and birds in Sabah. As long as it is well-managed, the secondary forest habitat could still provide suitable habitat for the wildlife species, especially in term of hunting restrictions. However, it is recommended for a long-term monitoring of wildlife population in the area to reduce hunting activity due to the easy access from the road near to the forest edge. The sensitivity of specific species should also be evaluated to understand their sensitivity towards the different rehabilitation techniques. Therefore, it is suggested to remain the disturbed forest to undergo natural recovery when the major of the forest components still remain after the disturbance.

2. Seasonal home range and habitat selection patterns of sika deer *Cervus nippon* in southern Hokkaido, Japan

In 1980 and 1981, eight and nine individuals of sika deer *Cervus nippon* were reintroduced in southern Hokkaido, Japan, to cope with population decline in a few decades ago. As recent population growth has led to human–wildlife conflicts, this study investigated the responses of sika deer to resource availability and geomorphic factors during the summer and winter seasons. To achieve the aimed of this study, two objectives was generated, (1) to find out the core area and home range size of sika deer in summer and winter and (2) to assess the habitat selection by sika deer in summer and winter in relation to the resource availability and topographic factors.

The study was conducted in two area i.e., Mount Esan and Shiriuchi, the mountainous coastal forest environment located in southern Hokkaido. Global positioning system-collared (GPS) was applied to monitor 14 female sika deer (5 individuals in Mount Esan; 9 individuals in Shiriuchi). The data was collected between 2016 to 2018. In prior to the analysis, the data was classified into summer (June – October) and winter (January – March). Sika deer behaviour was grouped into resident and migratory deer. The core area and home-range sized of each sika deer was analysed by using the Kernel density estimation (KDE), with 50% KDE and 95% KDE respectively. Home range analysis was conducted with "*adehabitHR*" package in R statistical software. Comparisons of home range size between summer and winter was analysed with *t-test* and 2-way ANOVA.

To assess the habitat selection of sika deer, 11 variables of the land cover characteristics, topography and distance to covariates were recorded from the High-Resolution Land Use and Land Cover (HRLULC) map. The variables included deciduous forest, coniferous forest, natural grassland, distance to forest edge, cropland, human settlement, river and road as well as elevation, slope angle and south aspect. The raster images were standardized to $10m^2$ resolution. All GIS analysis was conducted in ArcMap (ver. 10.7.1). To model the sika deer habitat selection in summer and winter, the Resource Selection Function (RSF) was fitted using the generalized linear mixed model (GLMM) with the logit link function. The response variable was assigned for the deer selection, while the 11 landscape variables as the predictor variables. Interaction effects was

included to understand how the deer utilized the landscape with respect to the variation of habitat type and resources in summer. The habitat selection model was selected based on the lowest AIC values. The analysis was conducted with the "*lme4*" package using R statistical software.

A total of 50,479 location of sika deer were used to assess the home range and habitat selection patterns of sika deer population in Mount Esan and Shiriuchi. The overall fix success rate was 99.4%. As a results, the core area (50% KDE) and home range (95% KDE) size of all sika deer was smaller in summer compared to the winter seasons. Only the comparisons of core area and home range size between summer and winter for the resident deer in Mount Esan was significantly different, but not the deer in Shiriuchi. The habitat selection in summer showed a variation between resident deer of Mount Esan and Shiriuchi, as well as migratory deer in Shiriuchi. Resident deer in Mount Esan and migratory deer in Shiriuchi preferred coniferous forest and forest edge habitats in summer, and both resident deer in Mount Esan and Shiriuchi selected habitats closer to croplands in the summer. Interaction effects revealed that sika deer in Mount Esan preferred cropland and grassland away from the forest edge, whereas both resident and migratory deer in Shiriuchi selected cropland closer to the forest edge, and migratory deer selected grassland habitats closer to the forest edge and croplands, which reveals a tactic to avoid humans. In winter, forest edge habitat, southing, low elevation, and being away from the river were important habitat features for all deer across the study area.

The findings reported on the preliminary home range and habitat selection of sika deer population that was reintroduced in southern Hokkaido in 1980 and 1981. It was suggested that the availability of various resources grown within the summer habitat affected on the smaller home range of sika deer in summer. Calving might also influence the small summer home range by female sika deer during the reproductive stage. Sika deer exposing large home range in winter could be due to increasing in movement to adjust with the fluctuating weather conditions as well as searching for available food resources that was scarce in winter.

In term of habitat selection, the presence of crops area and natural grassland in the study area appeared to attract the deer in summer seasons. The proximity from the forest edge to utilize the open area seems to be an important selection to easily escape from human. During winter season, topographic factors i.e., south slope and low elevation area

was preferred by all deer in the study area. This is due to the south slope tend to have less snow due to greater amount of sunlight, while less snow cover at the low elevation area. The selection on coniferous forest in winter was less important in this area which could probably be due to the predominant effects by snow cover were more influenced by topographic factors in southern Hokkaido. The present study reported on the new findings on the habitat selection of sika deer wintering closer to the coastal cliff environment.

Thus, sika deer habitat selection depends on resource availability and human interference in summer while topographic factors in the winter. The present study suggested on the management efforts to control the sika deer population density to focus on the area between the forest edge habitat and open area such as grassland and crops area. As the present study could only infer the important habitat selection of sika deer, it was suggested for further study particularly in estimating the deer density in this area as there is still very limited of literature to prevent the overestimation of deer density in this area.

3. Patterns of seasonal habitat selection of sika deer *Cervus nippon* on the largest wetland in Japan, Kushiro-Shitsugen National Park, Hokkaido

The Kushiro-Shitsugen National Park is one of the largest wetland and important conservation area in Japan. It was a protected basin that gazetted as Ramsar site and National Park in 1987. The area was covered by diverse wetland vegetation, including the endemic and endangered plant species. However, the overabundant of sika deer population density in this area has been a major concern due to the alteration in vegetation species diversity from deer trampling and overgrazing. The present study was designed to assess the home range and habitat selection patterns of the deer population that wintering in the wetland area.

The study area was located in eastern of Hokkaido, that consists of flat topography and covered mostly by large agriculture land of pasture plantation towards the east of Kushiro wetland. At least 30 individuals of female sika deer that wintering in the wetland was monitored with Global positioning system-collared (GPS). The capturing location can be divided into three area in the wetland i.e., Ugan (the right embankment), Takkobu Lake and Kottaro. The sika deer captured in Takkobu was monitored between 2014 –

2016, while in Ugan and Kottaro was monitored between 2015 – 2017. Dataset was classified into summer (June – September) and winter (January – March), while the behavioural classification as resident and migratory deer. To assess the core area and home range size, Kernel density estimation (KDE) was analysed for each deer as 50% KDE (core area) and 95% KDE (home range). Home range analysis was conducted with "*adehabitHR*" package in R statistical software. The Wilcoxon's signed ranked test was used to analyse the comparisons for summer and winter home range size.

Habitat selection was assessed from 11 variables of the land cover characteristics, topography and distance to covariates recorded from the High-Resolution Land Use and Land Cover (HRLULC) map. The variables included deciduous forest, coniferous forest, natural grassland, distance to forest edge, agriculture, human settlement, river and road as well as elevation, slope angle and south aspect. The raster images were standardized to $10m^2$ resolution. The Geographic Information System (GIS) analysis was conducted in ArcMap (ver. 10.7.1). Resource Selection Function (RSF) model was built using the generalized linear mixed model (GLMM) with logit link function. Deer selection was assigned as response variables, while the 11 landscape variables as the predictor variables. The best model was selected based on the lowest AIC value. Analysis was conducted with the "*lme4*" package using R statistical software.

A total of 81,762 locations of female sika deer was used to assess the home range and habitat selection patterns of sika deer in eastern Hokkaido. The total GPS-fix success rate for all deer was 97.7%. As a result, both core area and home range size of all sika deer in summer was smaller compared to the winter. Only the comparisons of core area and home range size between summer and winter for resident deer shows significantly different. The habitat selection patterns reveal that in summer both migratory and resident deer selected coniferous forest and grassland habitats that were close to a road, south-facing and flat terrain. In winter, habitats closer to the forest edge and agriculture were selected by both migratory and resident deer. The results also shows that resident deer selected the similar habitat characteristics in summer and winter, except for the distance to agriculture. Migratory deer was observed to shift the habitat selection away from the forest edge, toward a road and south-facing aspects in summer, with less selection in winter.

The present study documented the home range and habitat selection patterns of sika deer population that wintering within the Kushiro wetland. Habitat heterogeneity which includes forest cover, grassland and agricultural crops might provides a sufficient of resources for the deer in summer. Thus, the deer exhibits small home range during summer. In contrast during winter, limited grazing availability and unstable weather condition i.e., snow cover, strong wind and low temperature might force the deer to increase their range to find for suitable shelter and available graze.

In term of habitat selection, the selection of coniferous forest and natural grassland by both resident and migratory deer might be due to the preferences on open native grassland with less human interference compared to the agricultural plantation area. The presence of planted pasture grass on the embankment area within the wetland attracted the resident deer to utilize the area seasonally. However, the migratory deer travel outside of the wetland and used the open pastureland in summer seasons which explain on the selection closer to agriculture by migratory deer. In winter, migratory deer will return to the wetland for wintering, while resident deer remained in the wetland seasonally. These results explain to the changes in the habitat selection by migration deer as well as similar habitat selection by resident deer in summer and winter. Thus, the high utilization of the wetland area by the high density of deer could lead to the alteration in vegetation species diversity. Additionally, migratory deer shows less selected on the south aspect in winter though this area were covered with less snow. This factor may be less important to the deer population in the wetland due to the flat topographic condition of the area. The highest elevation selected by the deer is up to 100 m a.s.l. which is a low elevation for wintering. It was also documented that resident deer use coniferous forest habitat in winter as the habitat could provide a shelter from the deep snow and strong wind during winter. Furthermore, the presence of natural springs at the bottom hills surrounding the wetland melt the snow easily which allowing some ground vegetation to emerge in winter. This habitat was favoured by the sika deer in winter due to the less snow cover and easily access to available browse.

In overall, the present study reported on the sika deer population in Kushiro wetland shifted the habitat selection to benefits the available resources, avoid from hunter and as a response to unstable winter condition. It was recommended of the replacement of pasture grasses alongside the embankment of the wetland with native plants that are

unfavourable to sika deer. The population control management should also focus on the embankment area where the resident deer utilized in both summer and winter seasons. Since hunting activity might be prohibited and difficult within the wetland, using enclosure trapped was suggested, particularly at the embankment area. As the forest edge habitat was utilized by the migratory deer in summer to reach the open agriculture land, it was suggested to focus on the management at the forest edge closer to the agricultural plantation area.