A Scientific report of Field Science Course:

Effects of vegetation and elevation on distribution of Japanese Macaque (*Macaca fuscata yakui*) in Yakushima Island

[1] Danhe YANG, [2] Momoko OKA, [2] Moe YANAGI, [3] Takayuki SAKURAI, [3] Taku OHTSUBO, [2] Yutaro SATO, [4] Mikaze KAWADA, [5,6] Christopher Chai Thiam WONG

[1] Department of Anthropology, Sun Yat-sen University, China. [2] Wildlife Research Centre, Kyoto University, Japan. [3] Plant Molecular Biology, Kyoto University, Japan. [4] lab of Anthropology, Kyoto University, Japan. [5] School of Biological Sciences, Universiti Sains Malaysia, Malaysia. [6] WWF-Malaysia.

Abstract

We conducted route censuses in Yakushima Island in order to investigate the current island-wide distribution of Japanese macaques (*Macaca fuscata yakui*). In particular, we focused on two factors, namely vegetation and elevation. During censuses, monkeys were detected by direct observation, feces, or vocalizations. In total, we detected 460 feces, 10 calls, and 42 direct sighting during our route censuses. We analyzed detection frequency in relation to the altitude and vegetation. Our results suggest that monkeys were more likely to be detected in natural forests compared with other vegetation areas including grassland, plantation,or village areas, implying that forests were more suitable habitats for them. Monkeys were less likely to be detected around village areas. This might be because of methods to keep them away by farmers. When it comes to the elevation, higher percentage of signs of monkeys were detected at low to mid altitude (‘0-400’ m and ‘401-800’ m a.s.l) whereas lower percentage of signs of monkeys were detected at high altitude areas (‘>1200’ m a.s.l). The results are simplistically hypothesised to be affected by the habitat quality or possibly due to the uneven sampling effort in different elevational classes during the survey.

Introduction

Yakushima Island lies about 60 km south of Cape Sata on the Ohsumi Peninsula, the southern tip of Kyushu mainland, covering an area of 503 km². Due to a large scale volcano eruption about 7300 years ago (Fukuzawa, 1995), biodiversity in the island was severely affected (Okano & Matsuda, 2013). Nonetheless, a wide range of plants and animals can be seen in Yakushima, with more than 1900 species and subspecies of flora, 16 mammal species of which 4 subspecies are endemic to Yakushima and 4 subspecies are endemic to Yakushima and Tanegashima island to the north east.

Among the broad range of animals, the Yakushima macaques (*Macaca fuscata yakui*), subspecies of Japanese macaque indigenous to Yakushima, have long been the topic of research (Fig. 1). Another indigenous subspecies to Yakushima are the Yakushima deer (*Cervus nippon yakushimae*). As with the Yakushima monkey, the deer are also smaller than the mainland species. In Yakushima, the largest animals are the deer and the monkeys which can be seen all year around, particularly on the hiking courses and the Seibu-Rindo —— the western forest road.

Studies were conducted, mainly focusing on the western lowland forest and upper areas of Yakushima (1975-2000). Previous studies were more about the habituation and individual-identification of multiple groups and the population and social dynamics in the coniferous forest and western lowland forests. The study showed that in the highland forest (2008-2010), inter-group competition in the highland forest in Yakushima is weaker than in the lowland. And, group distribution changed considerably in the lowland site between 1998 and 2010. Also, group distribution is more stable in the highland site between 2000 and 2010. Moreover, the problems of human-monkey conflicts such as crop raiding have been also discussed (Yoshihiro, 1998). Monkey's population has decreased in the lowland in the past twenty years (Miyata et al., 2017). And Crop-raiding by monkeys decreased as well. However, the number of captured monkeys as a pest control increased till 2014.

The relationship between distribution of Japanese macaque and environments such as vegetation and elevation have long been studied in this island (Hanya, 2004 & 2006; Yoshihiro, 1999). Yakushima has a variety of vegetation, ranging from coastal warm-temperature broad-leaved forest to subalpine grassland (Hanya, 2004). Yakushima mountains are divided into the lower lying Maedake range that rises sharply from the village up to about 800 meters and the upper Okudake range thereafter reaching almost 2000 m. The highest point, Mt.Miyanoura, stands 1935 m above sea level (a.s.l) (Yoshihiro, 1998). Vertical change of vegetation preserved from coast to summit of more than 1900 m above sea level.

This study aims to investigate the current island-wide distribution of macaques, focusing on the vegetation and altitude by analyzing the detection frequency in relation to the two factors. We also took into consideration the effects of human activities such as hunting.

Figure 1. The Yakushima macaque (*Macaca fuscata yakui*)

Methods

Our study was performed in Yakushima Island, Kagoshima prefecture, Japan. Research of monkeys in this site was firstly done in 1952 and it was not until mid-1970s that field studies resumed (Yamagiwa, 2008). Since monkeys there are not food provisioned, they mainly feed natural food resources such as tree leaves, fruits, or flowers, etc (cf. Hanya, 2004).

Data collection

We conducted route censuses between 0700 to 1630 hrs in May 14-16, 2017 (in total 3 days). During censuses, monkeys were detected by direct observation, feces, or vocalizations. We geotagged the locations where monkeys were detected using handheld GPS (Garmin Etrex 20x, US). Also, we noted the condition of feces (new or old).

Data Analyses

Vegetation on detection

We classified the vegetation into five categories; forest, grassland, plantation, village and others. Also, we divided the whole Yakushima into 3 parts; “highland” which altitude is over 400 m, “lowland–hunt” which altitude is under 400 m and where hunting is approved, and “lowland–no hunt” which altitude is under 400 m and where hunting is not allowed. These data were processed with QGIS software.

For the fecal samples, to avoid the overlap counting of the same individual, we removed fecal samples which were found within 20 m from the adjacent sample. The criteria was defined as follows: first, using data from Seibu, where we found feces the most, we calculated the distance between adjacent fecal samples and the average of them. From that distance, we made a histogram and a density curve graph (Fig. 2). The incline of the density curve changed at the point of 20 m. Considering that the distance between individuals in a given group is relatively stable, we regarded 20 m as the largest distance between individuals in a group and counted fecal samples which were more than 20 m far from the previous one as a new data.

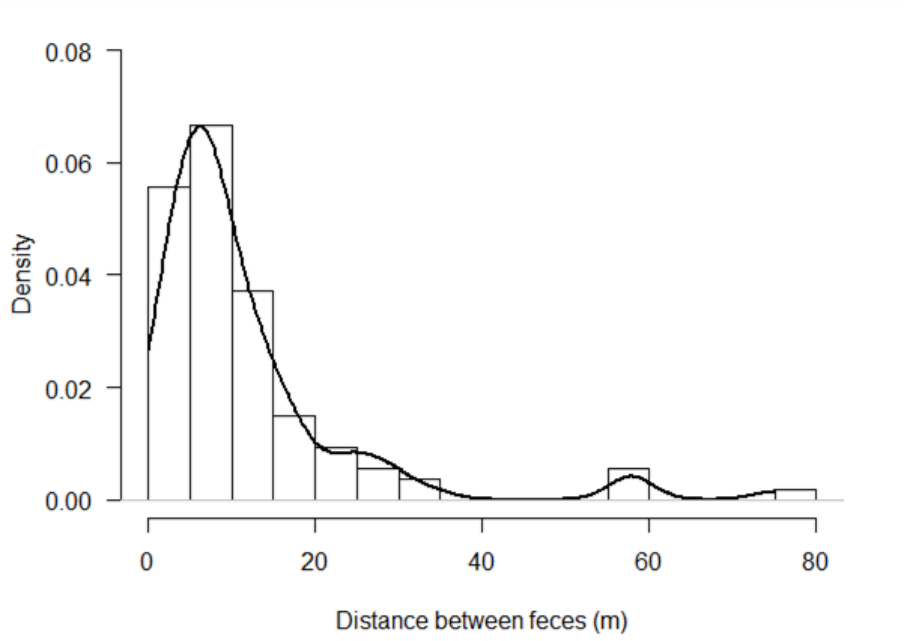

Figure 2. The average distance between feces and its density

We used some points from the census routes automatically recorded by GPS at intervals of 500 m as a control (highland: n = 480; lowland-hunt: n = 283; lowland-no hunt: n = 57). Specifically, we compared the proportion of each vegetation in areas within a radius of 100 m from these control points (hereafter, environment areas) and in areas within a radius of 100 m from points where monkeys were detected (hereafter, detected areas: highland: n = 139; lowland-hunt: n = 57; lowland-no hunt: n = 77).

For the following statistical analyses, the statistical package, R was applied. The proportion of vegetation between detection / environment for each area was compared by the Welch's t-test (two-tailed, $\alpha = 0.05$).

Elevation on detection

Routes from the monkey survey were segmented into 500 meters replicates. Elevation of the mid-point of each segments was estimated as the proxy for environment to be compared with the elevation of detection points for the monkeys. Both recorded elevations were categorized into four categories namely 0-400m, 401-800m, 801-1200m and >1200m. Using R statistical software, Welch's t-test was performed to compare the detections of monkey and environment in each elevational class. For the analysis, only fresh feces, direct sightings and calls were used; old feces and other secondary signs such as feeding signs were removed to prevent inflation of detection of the same individual/group.

Results

We detected 460 feces, 10 calls, and 42 direct sighting for a total during our route census. The route of our census and the place of detection is shown in Figure 3.

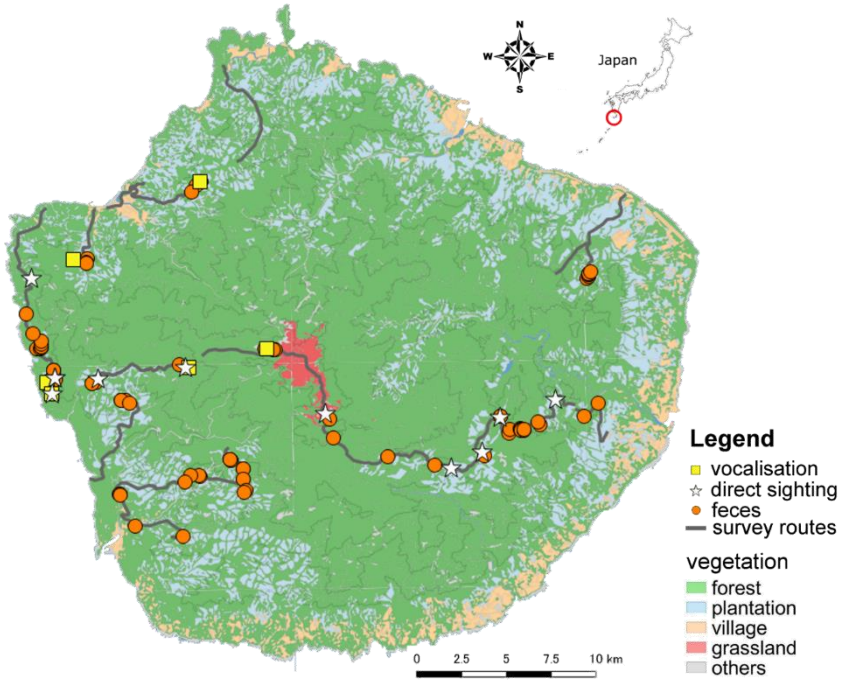

Figure 3: Census route and all detection in this study

Vegetation on detection

There were some significant differences in the proportion of each vegetation between detected and environment areas (Fig. 4). The percentage of forest in detected areas was significantly higher than that of environment areas in all places (highland: t = -3.55, df = 307.1, $p < 0.001$; low-hunt: t = -5.91, df = 127.7, $p < 0.001$; low-no hunt: t = -6.85, df = 60.75, $p < 0.001$). The vegetation of grassland was only seen in highland areas, and its percentage in detected areas was significantly lower compared with that in environment areas (t = 8.42, df = 604.69, $p < 0.001$).

As for the proportion of plantation, that of detected areas was significantly higher than that of environment areas in highland (t = -3.33, df = 188.93, p = 0.001). We could not find a significant difference in the proportion of plantation between detected and environment areas in lowland-hunt area (t = 1.63, df = 101.42, p = 0.11). In lowland-no hunt area, the proportion of plantation was significantly lower in detected areas than in environment areas (t = 6.00, df = 61.69, $p < 0.001$).

Regarding to the village, we could not find a significant difference in its proportion between detected and environment areas in highland (t = -1, df = 138, p = 0.32). However, it was significantly

lower in detected areas than in environment area in lowland-hunt (t = 7.60, df = 337.92, p < 0.001) and lowland-no hunt area (t = 2.24, df = 56, p = 0.03).

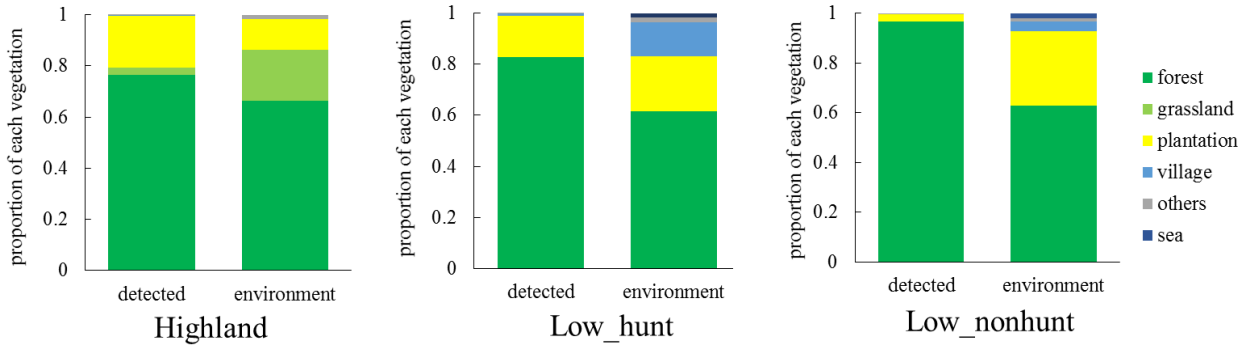

Figure 4. The proportions of each vegetation in detected areas and environment for Highland (left), Low hunt (center), and Low non-hunt area (right). The vegetation were classified as forest (green), grassland (light green), plantation (yellow), village (sky blue), others (gray), or sea area (blue).

Table 1. The result of Welch's t-test compared vegetation between detection / environment for each area

	Forest	Grassland	Plantation	Village
Highland	＋	－	＋	NS
Lowland – hunt	＋	NA	NS	－
Lowland – no hunt	＋	NA	－	－

＋: detected ＞environment, －: detected ＜environment, NS : no significant difference, NA : not available

Elevation on detection

For all four categories, two of the elevational classes show no significant difference in detections – '0-400' m and '801-1200' m. While detection was significantly higher than the environment for elevational class 401-800 (p = 0.007), the environment is significantly higher than the detection for elevational class >1200 (p = 0.021: Fig.5).

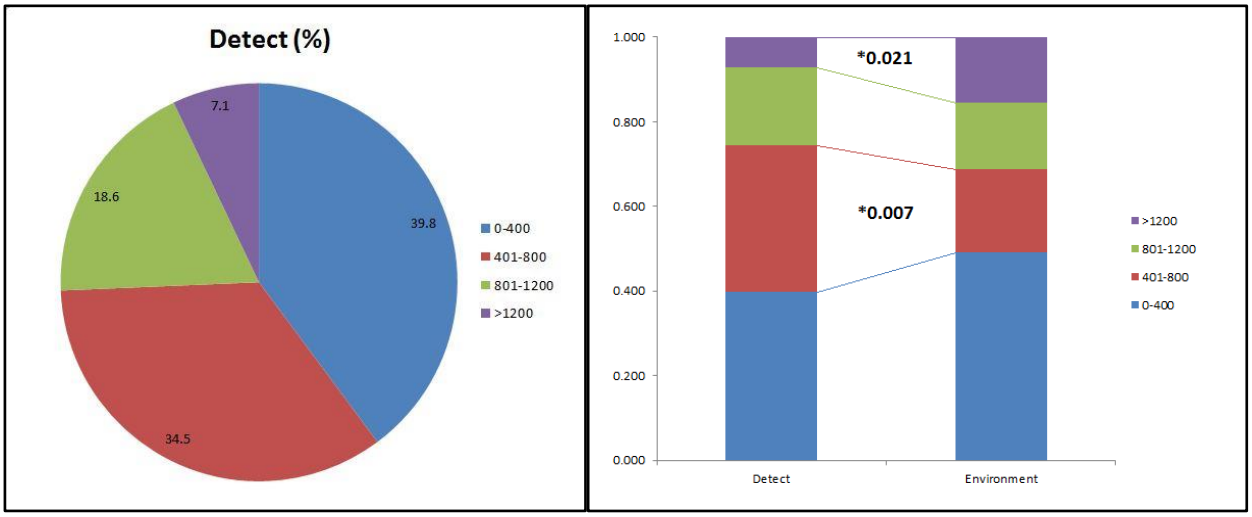

Figure 5: Comparison between detection of monkey to the environment;*P-Value <0.05.

Discussion

Vegetation on detection

Our results suggest that monkeys are more likely to be detected in natural forests, implying that monkeys in Yakushima depend on natural forests. Since a past study reported the total annual food abundance was one of the important determinants of the density of Japanese macaques in this island (Hanya, 2004), this study suggests that forests are more suitable habitats for them especially in terms of their diet.

We also found that monkeys were less likely to be detected around village areas. This might be because of methods to keep them away by farmers. However, crop raiding by monkeys is still continued in some areas (Yamagiwa, 2008). To prevent it, conservation and restoration of natural forests should be enforced.

Elevation on detection

Overall, higher percentage of signs of monkeys were detected at low to mid altitude (‘0-400’m and ‘401-800’ m a.s.l). Simplistically, the result is hypothesized to be affected by the differences in habitat quality depending on elevation (Hanya et al., 2004) or possibly due to the uneven sampling effort in different elevational classes during the survey.

Beehner & McCann (2008) revealed that the high altitude affects the population of primates, by measuring the stress level using glucocorticoid metabolites. Even though the altitude of that study was much higher (>3000 m a.s.l), the effect of high altitude on the stress of primates could be in the consideration for further understandings of the distribution of the Japanese macaque in the Island. Addition to that, inclusion of detection probability (MacKenzie et al., 2002) could also improve the model, by considering factors such as human-induced (e.g. surveyor, distance to human settlement), weather (e.g. rain) and geographical (e.g. types of surfaces) ones.

Acknowledgement

We would like to thank Prof. Hanya, Dr. Hongo, Dr. Kurihara, and Mr. Honda for their kind cooperation and valuable lectures in Yakushima. We also thank a staff who cooked for us during the stay in Yakushima. This work was conducted under the supports of Primatology and Wildlife Science leading program (PWS) and the CETBio project.

References

Beehner, J. C., & McCann, C. (2008). Seasonal and altitudinal effects on glucocorticoid metabolites in a wild primate (Theropithecus gelada). *Physiology & behavior*, *95*(3), 508-514.

Fukusawa, H. (1995). Non-glacial varved lake sediment as a natural timekeeper and detector on environmental changes. *The Quaternary Research (Daiyonki-kenkyu)*, *34*(3), 135-149.

Hanya, G., Kiyono, M., Yamada, A., Suzuki, K., Furukawa, M., Yoshida, Y., & Chijiiwa, A. (2006). Not only annual food abundance but also fallback food quality determines the Japanese macaque density: evidence from seasonal variations in home range size. *Primates*, *47*(3), 275-278.

Hanya, G., Yoshihiro, S., Zamma, K., Matsubara, H., Ohtake, M., Kubo, R., ... & Takahata, Y. (2004). Environmental determinants of the altitudinal variations in relative group densities of Japanese macaques on Yakushima. *Ecological Research*, *19*(5), 485-493.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Andrew Royle, J., & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, *83*(8), 2248-2255.

Ministry of the Environment, Forest Agency and Agency for Cultural Affairs 2012. Yakushima World Heritage Area Management Plan (in Japanese) Available from : <http://kyushu.env.go.jp/pre_2012/data/1001aa.pdf>.

MIYATA, A., YOSHIHIRO, S., TAKAHATA, Y., MANDA, M., FURUICHI, T., KURIHARA, Y., … HANYA, G. (2017). Changes of abundance of Japanese macaques in Yakushima over the past 20 years. *Primate Res*, 33-001.

Okano, T., & Matsuda, H. (2013). Biocultural diversity of Yakushima Island: mountains, beaches, and sea. *Journal of Marine and Island Cultures*, *2*(2), 69-77.

de Solla, S. R., Shirose, L. J., Fernie, K. J., Barrett, G. C., Brousseau, C. S., & Bishop, C. A. (2005). Effect of sampling effort and species detectability on volunteer based anuran monitoring programs. *Biological Conservation*, *121*(4), 585-594.

Yamagiwa, J. (2010). Research history of Japanese macaques in Japan. In: (N. Nakagawa, M. Nakamichi and H. Sugiura, eds.) *The Japanese macaques*. Springer, Tokyo. pp.3–25.

Yamagiwa, J. (2008). History and present scope of field studies on *Macaca fuscata yakui* at Yakushima Island, Japan. *International Journal of Primatology*, *29*(1), 49-64.

Yoshihiro, S., Ohtake, M., Matsubara, H., Zamma, K., Han'ya, G., Tanimura, Y., ... & Furukawa, M. (1999). Vertical distribution of wild Yakushima macaques (*Macaca fuscata yakui*) in the western area of Yakushima Island, Japan: preliminary report. *Primates*, *40*(2), 409-415.

YOSHIHIRO, S., FURUICHI, T., MANDA, M., OHKUBO, N., KINOSHITA, M., AGETSUMA, N., ... & KIDO, E. (1998). The distribution of wild Yakushima macaque (*Macaca fuscata yakui*) troops around the coast of Yakushima Island, Japan. *Primate Research*, *14*(3), 179-187.