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# The geographical distribution and habitat use of the Japanese serow (*Naemorhedus crispus*) in the Fuji-Tanzawa region, Japan

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**Abstract** : The Japanese serow is an endemic ungulate in Japan. Its spatial distribution and habitat use are poorly known. This study aims to identify the geographical distribution and quantify the habitat use of the Japanese serow in the Fuji-Tanzawa region. A total of 320 point records of Japanese serow occurrence (160 presence records and 160 absence records) and 11 potential predictors were prepared in a GIS environment. The MaxEnt and GLM methods were used to model the geographical distribution of the species. The size of the total serow population was estimated. A gap analysis was conducted to identify conservation gaps. The use of habitat was analyzed with boxplots and a jackknife test. Of an estimate of 2,811 serows, 2,525 serows (90 %) were located outside game reserves. The greatest proportion, 43 %, was found for habitat within private and communal forests. The most important predictor of serow occurrence was altitude, followed by the distance to paths and stone steps, and the slope. The current population size is considered sufficient to maintain a healthy level of genetic diversity, but most of the habitat is not protected by the current zoning plan and belongs to private and communal forest. Only the Tanzawa local population appears to be sufficiently well protected by a zoning plan. The Japanese serow avoids the paths used by humans for climbing, but prefers habitat close to highways. These preferences are considered to represent the effects of humans and of interactions with Sika deer.

**Key Words** : Fuji-Tanzawa region, GIS, Japanese serow, *Naemorhedus crispus*, species geographic distribution model

## INTRODUCTION

The Japanese serow (*Naemorhedus crispus*) is an endemic ungulate, found in the montane regions of Honshu, Shikoku and Kyushu. This species is designated as a Japanese 'natural monument'. It is one of only two species of mammals to receive this designation. The Japanese serow feeds on six plant groups: deciduous broad-leaved trees, evergreen broad-leaved trees, conifers, forbs, graminoids and ferns (Deguchi *et al.*, 2002). The Japanese serow is known to prefer vegetated, steeply sloping hillsides (Yamaguchi *et al.*, 1998). The Japanese serow inhabits over wide area in Tanzawa Mountains and it mainly uses the locations at 400-800 in altitude and their density was low in higher and lower altitude (Yamaguchi *et al.*, 1998). The main habitats of the Japanese serow are forests belonging to the subalpine zone or below subalpine zone, especially broad-leaved forests composed of Japanese beech (*Fagus crenata*) and Japanese oak (*Quercus crispula*) (Hidaka, 1996).

Little knowledge on the spatial distribution of Japanese serow is available. In contrast, habitat conditions (Ochiai *et al.*, 1993a; Ochiai *et al.*, 1993b), food analysis (Deguchi *et al.*, 2002), and competition and interaction with other mammals (Huygens *et al.*, 2003; Koganezawa, 1999) are topics that have received relatively thorough study.

Recently, a methodology to apply a predictive geographic distribution to conservation biology was developed (Doko *et al.*, 2011), but the previous study targets the Asiatic black bear distributions. There are a very few studies which aim to model geographic distribution of the Japanese serow.

Objectives of the study are to generate geographic distributional maps with a resolution of 50 by 50 m in the Fuji and Tanzawa region, to examine conservation gaps and population size, and to examine habitat use of the Japanese serow.

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## 1. METHODS

The overall methodological procedure of this study is presented in Fig. 1. In total, there are five processes: 1) GIS dataset, 2) Variable selection, 3) Model development, 4) Model validation, and 5) Outcome. Detailed description will be given in the following sub-sections.

### 1.1 Study area

The study was conducted in the Fuji and Tanzawa region of Japan (35°10' to 35°40' N and 138°30 to 139°20' E in Japanese Geodetic Datum 2000, Fig. 2 (C)). Because the boundary of these regions is not clear, the larger extent of a drainage basin based on 21 integrated watersheds (Fig. 2 (A) and (B)) was taken for modelling. Predicted serow distributions around the Fuji-Tanzawa region were then clipped from this larger area. The study area includes three local populations, namely, the Fuji local population, the Tanzawa local population, and the South Alps local population. The study area is mountainous and, includes Fuji National Park, as well as Tanzawa Quasi-National Park. These parks contain various landscapes and are characterized by a very high biodiversity, including the occurrence of a number of endemic species (Doko *et al.*, 2011).

### 1.2 Data management

#### 1.2.1 Extraction of species' records

First, a map containing the 160 observed point localities for the Japanese serow in the Tanzawa

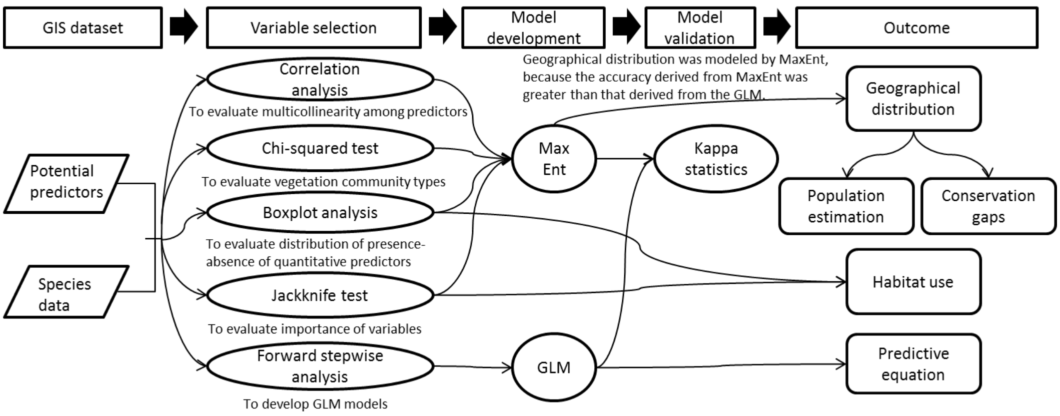


**Fig. 1 Flowchart of the methodology of this study**

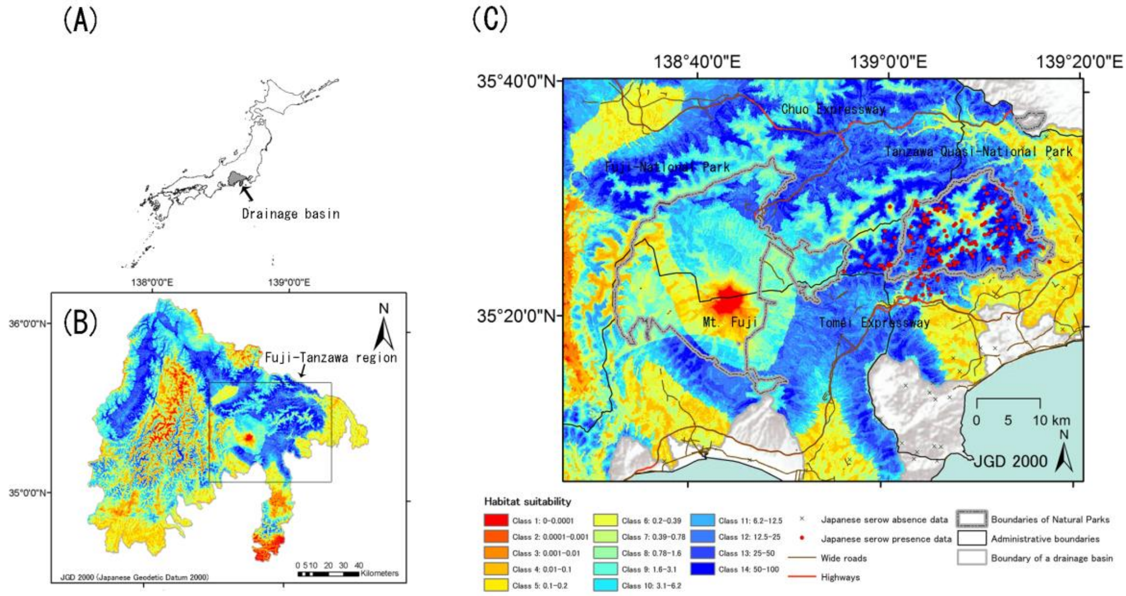


**Fig. 2 Study area and predictive geographical distribution of the Japanese serow based on MaxEnt**

Note. Numerical number of each class of Habitat suitability denotes the probability of occurrences of the Japanese serow.

Table 1 Potential spatial predictors and selected predictors for final models

| Category (Source) | | Environmental predictor | Unit | MaxEnt | GLM |
|---|---|---|---|---|---|
| Topography (DEM data from SRTM) | | Altitude | m | X | X |
| | | Slope | ° | X | X |
| Water resources (Digital Map 25000 and Global Map Japan Ver.1) | | Distance to rivers | m | X | |
| Roads (Digital Map 25000) | All | Distance to all roads | m | | |
| | Type | Distance to highways | m | X | |
| | | Distance to general roads | m | X | |
| | | Distance to paths and stone steps | m | X | |
| | Width | Distance to wide roads (more than 13 m) | m | | |
| | | Distance to narrow roads (less than 13 m) | m | | |
| Vegetation (Landsat-7 ETM+ from GLCF for NDVI and The dataset for GIS on the Natural Environment, MoE, for vegetation cover) | | NDVI (Normalized Difference Vegetation Index) | N/A | X | |
| | | Vegetation cover types (at vegetation community level) | N/A | | |

Note. X denotes the selection of predictors.

region (Yamaguchi *et al.*, 1998) was scanned. This map was created based on the questionnaires and interviews to surveyors of the Research Group of the Tanzawa Mountains whose research was conducted from 1993 to 1996 (57 persons), nature guides of prefectural parks (100 persons), members of nature conservation groups (32 persons), and the mountaineers' associations (72 groups) and so on, by Yamaguchi *et al.* (1998). Those selected respondents were considered to represent the people who may have knowledge and information of the Japanese serow in field of Tanzawa Mountains. The purpose of this activity was to collect observation information regarding the Japanese serow inhabiting the Tanzawa Mountains, because the distribution and habitat of this species in Tanzawa was completely unknown (Yamaguchi *et al.*, 1998). The extent of this map includes entire area of the Tanzawa region (See Japanese serow presence data in Fig 2 (C)).

The scanned map was then geo-referenced. The map was suitable for georeferencing, as there were localities of rivers in the map so that authors could find GCPs (Ground Control Points) easily. A 1st-order polynomial affine transformation was applied to rectify the scanned image. The associated RMS error was 251 m. Based on the rectified image, 160 points were digitized manually. Geographic coordinates were calculated by ArcMap®.

Due to lack of accurate absence data of the Japanese serow, absence data were obtained from the national distributional map of Japanese mammals (Biodiversity Center of Japan, 2004) with the method of Doko *et al.* (2011). A total of 160 absence points were generated. The national distributional map of Japanese mammals is composed of the grid cells measuring 5 km by 5 km across Japan. However, instead of using grid cells directly, this method plots random points inside of the polygons where no observation of the serows between 1978 and 2003. Hence, the spatial resolution of the absence points can be considered to be comparable to the presence data.

### 1.2.2 Geo-database for predictors

Based on knowledge of the ecology of the Japanese serow (Deguchi *et al.*, 2002; Matsumoto *et al.*, 1984; Nowicki *et al.*, 2001; Yamaguchi *et al.*, 1998), the following predictors, which can potentially influence the serow's distribution, were selected: altitude, slope, distance to rivers, distance to all roads, distance to highways, distance to general roads, distance to paths and stone steps, distance to wide roads (> 13 m), distance to narrow roads (≦13 m), the NDVI (Normalized Difference Vegetation Index), and the vegetation cover types at the vegetation community level. The threshold value of 13 m of road width was used for this study for the following reason. Width of 13 m contains 2 lanes or more, and crossing such a road for animals is assumed to have a big negative impact. The NDVI is derived from the red:near-infrared reflectance ratio as follows. NDVI=(NIR - RED)/(NIR+RED), where NIR and RED are the amounts of near-infrared and red light, respectively, reflected by the vegetation and captured by the sensor of the satellites. NDVI values range from −1 to +1, where negative values correspond to an absence of vegetation. All variables were obtained digitally from various sources (Table 1) and stored in a GIS environment. Considering the relatively small size of important landscape elements in the Japanese landscape and the high precision of the species' records, all predictor variables were compiled at a resolution of 50 by 50 m. Erdas Imagine® 8.7 was used to calculate NDVI value. ArcGIS® 9.3 was used for other variables. The image processing procedures specified in Doko *et al.* (2011) were applied.

### 1.2.3 Preparation for test and training data

Pixel values were extracted from all layers of environmental predictor variables by ArcMap 9.3® to obtain the geographic coordinates of the records of species presence and absence.

Subsequently, the dataset, which contained the species' presence-absence records, geographic coordinates, and the values of each environmental predictor, was prepared. Because no independent dataset for the Japanese serow was available, a split-sample approach (Guisan *et al.*, 2000) was adopted: the data records were randomly partitioned into two subsamples. One subsample (80 presence records and 80 absence records) was used as the training dataset, and the second subsample (the remaining 80 presence records and 80 absence records) was used to test the models.

## 1.3 Modeling and validation

The MaxEnt (Phillips *et al.*, 2006) and GLM techniques and algorithms were used in this research to predict the probability of species occurrences by the environmental variables. These methods have disadvantage and advantage. Hence, we adopted two methods for this study in order to complement their disadvantages each other. For instance, MaxEnt is specialized to make predictive maps for the area of interest, whereas GLM is not. On the other hand, GLM can produce a predictive equation, which makes extrapolation of the model to other regions easier.

The choice of predictors is a primary concern. Therefore, a set of chosen predictors was screened prior to the creation of the predictive model using statistical analysis based on correlation analyses, chi-squared tests, boxplot analysis, and jackknife tests. The purposes of these analyses were illustrated in Fig. 1. The boxplot analysis and the jackknife test were applied in order to examine habitat use of the Japanese serow in addition to screening procedures. These analyses were performed with R software, version 2.14.0. The method presented in Doko *et al.* (2011) was applied. The screened variables included altitude, slope, the distance to rivers, the distance to highways, the distance to general roads, the distance to paths and stone steps, and the NDVI (Table 1). These variables were used to build the MaxEnt model.

A forward stepwise analysis was conducted to construct the GLM models. In this analysis, the models were compared based on values of AIC, Adjusted $D^2$, AUC, sensitivity, specificity, and statistical significance of the coefficients to determine the optimal model.

The accuracy of the predictive models was measured with Kappa statistics. The pixel values for the predictive maps generated by the modeling algorithm were extracted for the data points of both the training and the test datasets with ArcMap 9.3®. A database including presence-absence data (values of either 0 or 1) as its ground truth information and the predicted values from each modeling algorithm was prepared as the test dataset. The MaxEnt and GLM results were compared, and the model with greater accuracy was used for further habitat analysis.

## 1.4 Geographic distribution

### 1.4.1 Population size

The predictive map was used to estimate the population size. First, the predictive raster maps were reclassified into predicted presence and predicted absence using the optimum probability as cutoff values. The optimum probability was calculated based on ROC Plotting and AUC Calculation Transferability Test Version 1.3-7 (Bonn *et al.*, 2001). The predicted present location was considered to represent the core habitats. The reclassified raster maps were then converted to the ESRI®'s shape files to calculate the area of the core area in $km^2$ using ArcMap® 9.3. Finally, the population of the Japanese serow was estimated based on the known population density and area in $km^2$.

The population density value of 1.0 / $km^2$ found in Nikko National Park (Nowicki *et al.*, 2001) was adopted in this study for the following reasons. The Japanese serow is known as a solitary ungulate (Ochiai *et al.*, 2002). The typical mating unit consists of a monogamous pair (1 male with 1 female), but polygamous units (1 male with 2 or 3 females) also exist (Ochiai *et al.*, 2002). The territory size is larger for males (10.4 ha to 22.8 ha) than for females (6.9 ha to 14.1 ha) (Ochiai *et al.*, 2002). Based on this minimum territory size, patches smaller than approximately 6.9 ha were eliminated from the core area, and the other patches were grouped into potential suitable habitat patches. Ochiai *et al.* (1993a) found that a serow population maintained a stable density in a stable environment in which food supply remained fairly constant. In contrast, the serow density fluctuated in an unstable environment in which the food supply fluctuated significantly (Ochiai *et al.*, 1993b). For example, the population density was stable from 11.7 to 16.7 / $km^2$ in a stable environment in Aomori Prefecture (Ochiai *et al.*, 2002), whereas it did not exceed 1.0 / $km^2$ in a competitive environment with Sika deer in Nikko National Park (Nowicki *et al.*, 2001). In this study, it is assumed that the Japanese serow competes with Sika deer in the study area. This assumption is based on the known national distributional maps of Japanese serow and Sika deer (Biodiversity Center of Japan, 2004). From the maps of Aomori Prefecture, it appears that no competition occurred between Japanese serow and Sika deer in this region. In contrast, in Nikko National Park and in the study area, the habitat appears to be shared with Sika deer. Among regions where the Japanese serows were surveyed by previous studies, the habitat situation of the Nikko National Park appeared similar to the one of the Tanzawa region.

The minimum viable population (MVP) (Gilpin *et al.*, 1986) concept was applied to assess the risk of extinction of Japanese serow. Because of the lack of accurate MVP information for the Japanese serow, the 50/500 rule (Franklin, 1980; Gilpin *et al.*, 1986) was applied to establish an assessment criterion. In this study, habitat patches with a population under 50 were considered to involve a *serious danger of extinction*, the patches with a population size of 50 to 500 were considered *endangered* patches, and those with a population size over 500 were considered *healthy* patches.

#### 1.4.2 Multi-layered overlay analysis and gap analysis

A multi-layered overlay analysis was conducted. The national parks, including Fuji National Park (part of Fuji-Izu-Hakone National Park, and Tanzawa Quasi-National Park) and the major mountains in this region, were overlaid with the predicted geographic distribution. Three highways: Road 707, Chuo Expressway, and Tomei Expressway, were mapped, as well as wide roads.

The concept of gap analysis (Burley, 1988) was applied to identify "conservation gaps." The analysis was applied to four types of existing systems that function as protected areas in Japan, namely, 1) Game reserves (*Choju-hogo-ku*), 2) Nature Conservation Areas (*Shizen-hozen-chiki*), 3) Natural Parks (*Shizen-koen*), and 4) Forest areas.

### 1.5 Habitat use

Habitat use by the Japanese serow was analyzed with two techniques. First, boxplots of the predictors were plotted by splitting two samples of presence and absence data to evaluate the distribution of the predictors. Second, a jackknife test was applied to examine the relative importance of the predictors. R version 2.14.0 software and MaxEnt were used for the boxplots and the jackknife test, respectively.

## 2. RESULTS

### 2.1 Modeling and validation

The optimal GLM model was $\log(p/(1-p)) = -$

5.91 + $x_1$ * 0.04 + $\sqrt{x_2}$ * 0.26, where $p$ is the probability of occurrence of Japanese serow, $x_1$ is the slope and $x_2$ is the altitude. The coefficients of the optimal model are summarized in Table 2. All coefficients were statistically significant ($p<0.01$).

Table 3 shows the results of accuracy assessment. The accuracy derived from MaxEnt was greater than that derived from the GLM. For MaxEnt, the test data very rarely outperformed the training data, although the difference in accuracy is slight (Kappa=0.88 for test data, Kappa=0.87 for training data).

### 2.2 Geographical distribution

Fig. 2 (B) shows the Japanese serow's predicted geographic distributional map by MaxEnt for the larger extent of a drainage basin. Fig. 2 (C) shows the same distributional map for the area of the Fuji-Tanzawa region overlaid with the multi-layers. The natural parks included only a portion of the predicted habitat patch locations. Of the natural parks, only Tanzawa Quasi-National Park completely included the habitat patches. The Chuo Expressway was centrally located within the Japanese serow's predicted habitat. In addition, Tomei Expressway passed through the predicted serow habitat near the boundary between Kanagawa Prefecture and Shizuoka Prefecture. Suitable habitat patches did not exist around the top of Mt. Fuji. Three highways run through the area, and most of them were covered by habitat suitable for the Japanese serow. However, most of the wide roads were not included within the habitats.

The results of the gap analyses are shown in Table 4 and Fig. 3. In all, 2,811 Japanese serows were estimated to inhabit 2,811 km$^2$. Fig. 3-1 shows the gap analysis for the Game reserves (*Choju-hogo-ku*). Most of the serow habitat (2,525 km$^2$, 90 %) was located outside of the Game reserves. Within the Game reserves, an area of 282 km$^2$ corresponded to 10 % of the total predicted serow habitat. The northern and southern parts of the Fuji region were included in the Game reserves. The estimated population sizes were 282 and 2,525 within the Game reserves, and outside of the Game reserves, respectively. The populations of both areas were assessed as "healthy." Almost all habitat patches (2,701 km$^2$, 96%) were located outside Nature Conservation Areas (*Shizen hozen chiki*, Fig. 3-2). The Natural Parks (*Shizen-koen*, Fig. 3-3) included a large habitat area, but the edge of the area was patchy. The patch showed a complete overlap with Tanzawa Quasi-National Park and a partial overlap with the northern and southern parts of Fuji National Park. In Tanzawa, the habitat was located within Special Protection Zones in Tanzawa Quasi-National Park and in other prefectural natural parks. The greatest area was located outside Natural Parks, a total of 81 % (2,266 km$^2$), followed by Special Zones (402 km$^2$, 14 %), Ordinary Zones (130 km$^2$, 5%), and Special Protection Zones (11 km$^2$, 0%). The estimated population sizes for each category were 11, 402, 130, and 2,266 for Special Protection Zones, Special Zones, Ordinary Zones, and outside Natural Parks, respectively. The types of forest areas were examined (Fig. 3-4). The habitat within private and communal forest showed the greatest area, 43 % (1,201 km$^2$). The second largest area was located outside forest areas, a total of 798 km$^2$ (28 %), followed by conservation forest (779 km$^2$, 28 %), and national forest (30 km$^2$, 1%).

**Table 2 Coefficients of the optimal GLM model of Japanese serow**

| | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | −5.91785 | 0.76429 | −7.743 | 9.71e-15 *** |
| Slope | 0.04024 | 0.01282 | 3.138 | 0.0017 ** |
| Square root of altitude | 0.26479 | 0.03459 | 7.655 | 1.93e-14 *** |

*** means $p<0.001$; ** means $p<0.01$

**Table 3 Accuracy assessment of predictive models**

| | model | $p$ as a cutoff | $K$ | $PA$ | $BI$ | $PI$ | sensitivity | specificity |
|---|---|---|---|---|---|---|---|---|
| Test data | MaxEnt | optimized $p$=0.04 | 0.88 | 0.94 | 0 | 0 | 0.93 | 0.93 |
| | GLM | optimized $p$=0.63 | 0.75 | 0.88 | 0 | 0 | 0.87 | 0.87 |
| Training data | MaxEnt | optimized $p$=0.03 | 0.87 | 0.93 | 0 | −0.01 | 0.93 | 0.93 |
| | GLM | optimized $p$=0.52 | 0.81 | 0.91 | 0.02 | 0.02 | 0.93 | 0.88 |

$P$ as a cutoff: probability, $K$: Kappa, $PA$: proportion agreement, $BI$: bias index, $PI$: prevalence index

**Table 4 Metrics of Gap Analysis between protected areas and Japanese serow habitat**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. Game reserve (*Choju-hogo-ku*) | | Inside Game reserve | | | Outside | Total ($km^2$) |
| Habitat | Size ($km^2$) | 282 | | | 2525 | 2807 |
| | Population (head) | 282 | | | 2525 | |
| | Proportion (%) | 10 | | | 90 | |
| 2. Nature Conservation Area (*Shizen-hozen-chiki*) | | Inside Nature Conservation Area | | | Outside | Total ($km^2$) |
| | | Special Area | Wilderness conservation area wilderness reserve | Nature conservation area | | |
| Habitat | Size ($km^2$) | 4 | 0 | 106 | 2701 | 2811 |
| | Population (head) | 4 | 0 | 106 | 2701 | |
| | Proportion (%) | 0 | 0 | 4 | 96 | |
| 3. Natural Parks (*Shizen-koen*) | | Inside Natural Parks | | | Outside | Total ($km^2$) |
| | | Special Protection Zones | Special Zones | Ordinary Zones | | |
| Habitat | Size ($km^2$) | 11 | 402 | 130 | 2266 | 2809 |
| | Population (head) | 11 | 402 | 130 | 2266 | |
| | Proportion (%) | 0 | 14 | 5 | 81 | |
| 4. Forest area (*Shinrin-chiki*) | | Inside forest area | | | Outside | Total ($km^2$) |
| | | Conservation forest | National forest | Private and communal forest | | |
| Habitat | Size ($km^2$) | 779 | 30 | 1201 | 798 | 2808 |
| | Population (head) | 779 | 30 | 1201 | 798 | |
| | Proportion (%) | 28 | 1 | 43 | 28 | |

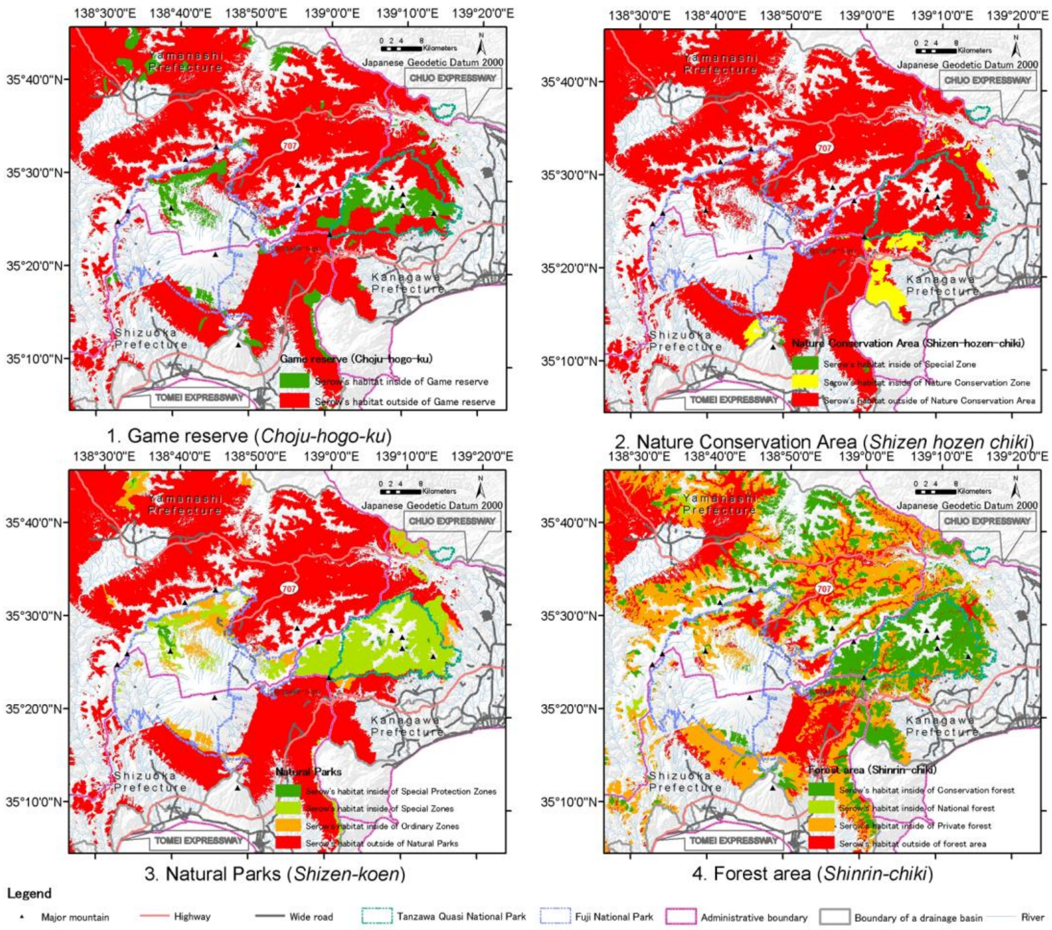


**Fig. 3 Gap Analysis between habitat of Japanese serow and zoning of protected area in Fuji and Tanzawa regions**

The populations within all forest types except national forest were assessed as "healthy".

### 2.3 Habitat use

A boxplot analysis (Fig. 4) showed good separation between presence and absence data for altitude, slope, distance to paths and stone steps, and distance to narrow roads. However, the serow's absence and presence records were not well separated for distance to wide roads, distance to rivers, and NDVI.

Fig. 5 shows the results of the jackknife test of the importance of variables. The environmental variable with the highest gain was altitude. The second most important factor was the distance to paths and stone steps, followed by the slope.

## 3. DISCUSSION

### 3.1 Geographical distribution

The overall population size of Japanese serow in the Fuji-Tanzawa region was estimated to be 2,811 (Table 4). The size was considered sufficient to maintain a healthy local population. Compared with the Tanzawa region, the Fuji region does not have highly suitable habitat for Japanese serow. In particular, there is no suitable habitat around the top of Mt. Fuji. In general, the predicted suitable habitat is located along highways and distant from paths and stone steps. According to Nowicki *et al.* (2001), the Japanese serow selects steep slopes and areas close to roads, apparently to avoid Sika deer. The selection of habitats in geographic proximity to highways and at lower altitudes found by this study may reflect the results of competition with Sika deer.

The gap analysis showed that large areas of Japanese serow habitat exist (Fig. 3). However, the current zoning for the protection of animals does not protect this species. Most serow's habitat is located outside protected areas such as Game reserves, Natural Conservation Areas, and Natural Parks. The habitat area in the Tanzawa region appears to be protected only by Tanzawa Quasi-National Park, and by Prefectural Natural Parks. The private and communal forest is the largest forest area that overlaps the Japanese serow's habitat. Note, however, that the Japanese serow is recognized as a special animal, and that its hunting is forbidden. Overhunted for meat and fur in the past, it became so rare that the government of Japan declared it a national treasure (Hidaka, 1996). Hence, although its habitats are not protected by proper zoning, population may be

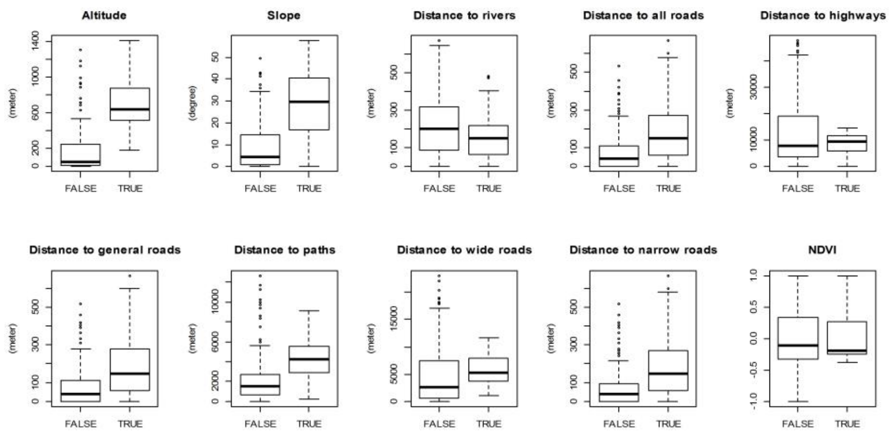


**Fig. 4 Boxplot analysis for distribution of predictors**

FALSE and TRUE denote absence and presence of Japanese serow, respectively.

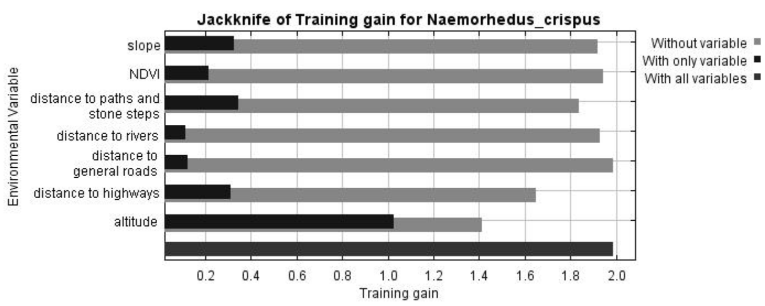


**Fig. 5 Jackknife test of the importance of variables for the Japanese serow training dataset**

sustainable as long as the government maintains the current hunting regulations.

### 3.2 Habitat use

In the boxplot analysis (Fig. 4), the altitude, slope, distance to paths and stone steps, and distance to narrow roads showed good separation. Low altitudes were included in the range of elevation where the Japanese serow inhabits. Generally, the Japanese serow is believed to occur in montane regions (Hidaka, 1996). Our findings offer new insights into the possible vertical distribution of serow. These results indicate that habitat selection differs among local populations; The presence records were derived from Yamaguchi *et al.* (1998) for only the Tanzawa local population of serow. Previous studies have related habitat selection in serow to altitude (Matsumoto *et al.*, 1984) and slope (Nowicki *et al.*, 2001). A discussion of roads has also been presented (Nowicki *et al.*, 2001). However, to the authors' knowledge, this study represents the first investigation including a statistical analysis of serow occurrence relative to the distance to roads. Our results suggest that serows prefer steep slopes. These results agree with the findings of Matsumoto *et al.* (1984). In general, the boxplots showed that the presence records were distributed in locations more distant from roads than were the absence records. Our results indicate that the serow prefers areas that are geographically distant from roads. In general the serow appears to avoid the presence of roads. However, our results showed that the serow's behavior is influenced by the type of road. For example, the presence localities for the serow were closer to highways than the absence localities. This result indicates that the serow prefers habitat near highways. This finding partly supports Nowicki *et al.* (2001)'s observation that serow selected steep slopes and areas near roads. However, Nowicki *et al.* (2001) did not specify the type of road or the numerical range of distances to the roads. The localities near highways may be suitable habitat because certain highways are built through the mountains, where the species' favorite habitat, steep slope, occurs. We also attribute the selection of localities near highways to competition with Sika deer. This suggestion is in agreement with Nowicki *et al.* (2001). Our boxplot analysis also revealed that the absence and presence records for the serow are not separated well for the following variables: the distance to wide roads, the distance to rivers, and the NDVI.

Our jackknife test (Fig. 5) of the final MaxEnt model ranked altitude as the most important variable, distance to paths and stone steps as the second most important, slope as the third, distance to highways as the fourth, the NDVI as fifth, distance to general roads as sixth, and distance to rivers as seventh. From the existing literature, we expected the important variables to include the altitude (Matsumoto *et al.*, 1984; Yamaguchi *et al.*, 1998), slope (Nowicki *et al.*, 2001) and vegetation cover type (Deguchi *et al.*, 2002; Matsumoto *et al.*, 1984; Yamaguchi *et al.*, 1998). For this reason, we consider that the selection of altitude and slope by jackknife test is reasonable. However, the vegetation cover type was not selected for inclusion in any final model. A jackknife analysis of the experimental MaxEnt model revealed that the NDVI is relatively important compared to the vegetation cover types at vegetation community level. However, compared to other environmental variables such as altitude or the slope, the degree of importance was not high. The distance to paths and stone steps was an important predictor for the Japanese serow. The results of the jackknife tests and boxplot analyses indicate that the habitat suitability for Japanese serow is greater if location is far from the route of the climb. This suggests that climbing routes are associated with negative human effects on habitat selection by the Japanese serow and that the species selectively avoids these routes. The same type of behavior occurs in Asiatic black bears (Doko *et al.*, 2009).

## CONCLUSIONS

The size of the Japanese serow population in Fuji and Tanzawa is considered sufficient to avoid inbreeding and a loss of genetic diversity, but most of the serow habitat is not protected by the current zoning plan. The Tanzawa local population appears to be sufficiently large and sufficiently protected by a zoning plan. The Japanese serow appears to select habitat along highways and on steep slopes. This pattern of selection is most likely due to competition with Sika deer. Altitude and slope were found to be important predictors for the Japanese serow, and these results agree with the findings of previous studies.


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