Risk Evaluation on the Impact of Deer Overabundance Consisting with Global Warming and Natural Park Management Policy, A Case Study on the Tanzawa Mountains, Central Honshu, Japan.

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Abstract: We analyzed spatial model on sika deer (Cervus nippon) habitat selection and their distribution as well as the future risks for the forest ecosystem aiming to evaluate the influence of global warming and park management system in Pacific climate zone in Japan. We chose a local deer population on the Tanzawa Mountains, Central Japan where is less snow and employs typical natural park management system. The area has thereby suffered serious forest degradation due to deer overabundance earlier than other areas. In first part, we summarized the causes of deer overabundance with the ecological viewpoints. Second part consists of a GIS macro-scale analysis on the limiting factor of current deer distribution and the habitat selection of recent deer populations with special reference to terrain future and park management system. Regression analysis showed urban area was limiting factors of current deer distribution and such factors as slope angle, intensity of solar radiation and the presence of hunting area among well-explained deer density. These findings showed good agreements with the current spatial distribution of deer impact on the mountains. Final parts provided discussions on the future risk of deer overabundance consisting with warmer future and sustaining current natural park management policy. Thus we concluded that the risk of deer overabundance will be worsening and expanding without the bold reforms of natural park management policy and hunting system.

Keywords: Risk Evaluation, Deer Overabundance, Global Warming, Natural Park Management Policy, GIS Analysis
1. Introduction

Last two decades serious forest ecosystem degradation in many mountainous natural parks of Japan have occurred due to sika deer overabundance [8,9]. Deer ecologists indicate that the underlying causes of such phenomena is global warming and park management system especially prohibiting deer hunting in sanctuary in addition to drastic land use change [8,9]. Thus we can evaluate the future risks of deer overabundance using some key spatial information such as topographic future, sanctuary arrangement and land use if appropriate parameters for limiting factors of local deer population’s distribution and regulating factors of their densities are obtained through proper statistical analysis.

As a study area, we choose the Tanzawa Mountains where has enough spatial information regarding this issues. This article is organized into three major parts. In first part, we summarized causes of deer overabundance with the ecological view points. Part two consists of a GIS macro-scale analysis on the limiting factor of current deer distribution and the habitat selection of recent deer populations with special reference to terrain future and park management system. Final part provided discussions on the future risk of deer overabundance consisting with warmer future and sustaining current natural park management policy.

This study was a part of results from Kanagawa prefectures sika deer management projects and All Round Research Project of the Tanzawa Mnts.

2. Study Area

The Tanzawa Mountains is our study site, which is located in the north northwestern part of Kanagawa prefecture, central Honshu, Japan. The area has less snow accumulation and has employed typical natural park management system in Japan. The area also has suffered serious forest degradation due to deer overabundance [3, 4, and 5]. These conditions are fit to developed sika deer habitat selection model for Pacific climate zone in Japan.

The elevation of the study site ranges from approximately 100 m to 1,671 m above the sea level. The area belongs to Pacific climate zone. The annual mean temperatures at 1,100 and 1,450 m elevation are 9°C and 7°C respectively, and the annual mean precipitation is about 2,300 mm falling as snow sometimes from January to March. In general, snow lies more deeply on north or northeast slopes above 1,300 m and less deeply at lower elevations. The natural forest below 800 m is temperate zone forest, but with many plantations of Japanese ceder (Cryptomeria japonica) and Japanese cypress (Camaecyparis obtuse). The natural forest above 800 m belongs to the cool temperate zone consisting with beech (Fagus crenata) and maple (Acer palmatum) are dominant.

In the southern part of the Kanto plane, central Honshu of Japan, sika deer was widely inhabited on piedmont flat or plane field, but due to rural development in particular during the Meiji Period 1868-1912 deer population became to inhabit in high mountainous areas. The local population in Kanagawa prefecture was obliged to inhabit in the Tanzawa Mountains. In the 1970s and 1980s, high deer density was observed on young plantations. Additionally, the excessive browsing by sika deer has been observed to cause large-scale degradation of plant communities below 1300 meters in the eastern part of the Mountains since the middle of 1980s [4,5]. This impact was the most visible on suzutake (Pseudosasa purpurascens), a species of dwarf bamboo, particularly since the early 1980s [3]. Since the middle of 1990s, a high density, and extremely concentrated deer (around 50/km²) have been observed above 1300 m and strong deer impact on ground floor vegetation has been occurred [13].

The most portions of the Mountains are designated as prefecture Natural Park and Quasi-National Park. In the area wildlife sanctuaries are mostly allocated above 800 m elevation and hunting area were arranged at the periphery of these sanctuaries.
3. Methods

We employed the following three steps approach to attain our goals. These are 1) literature review, 2) GIS macro-scale habitat analysis, and 3) risk evaluation.

1) Literature Review

We summarized the causes of deer overabundance based on the ecological viewpoints from key reports and articles. Focus was set on factors related to limiting factors of sika deer habitat and regulating factors of deer density.

2) GIS Macro-Scale Habitat Analysis

We analyzed the limiting factor of current distribution and the recent local deer habitat selection with special reference to terrain future, vegetation type, and park management system. Regarding the limiting factors of current distribution, we use auto-logistic regression model [1] to construct a habitat model. In the model we used direct observation records in 1 km square grid for the independent variable, and land categories and elevation of observation spots were dependent variables (Tab. 1). As for the habitat selection of recent local deer populations, we constructed a habitat selection model by means of a linear model (GLM, Poisson error distribution, log link function). Fecal mass (/ha/day) based on winter survey in 2003-2004 were employed as the independent variable. Ten variables shown including terrain factors, vegetation type, average annual solar radiation and factors regarding the effect of wildlife sanctuary were used for dependent variables.

3) Risk Assessment of Deer Overabundance

Under the assumption of no change in deer management system and climate condition, we applied the model for the habitat selection of sika deer on the Tanzawa Mountains to seek potential landscape where sika deer will be overabundant in the near future. The result was examined with the recent reliable surveys for deer density distribution [10] and their impact on vegetation [4]. Then we assessed the risk of deer overabundant with the viewpoint on the impact on vegetation if the easy winter due to global warming, especially less snow, will be accelerated.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>its explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average elevation AE</td>
<td>Averaged elevation (m) in a counting unit.</td>
</tr>
<tr>
<td>Average slope angle ASA</td>
<td>Averaged slope angle (degree) in a counting unit.</td>
</tr>
<tr>
<td>Maximum slope angle MSA</td>
<td>Maximum slope angle (degree) in a counting unit.</td>
</tr>
<tr>
<td>Annual average of solar radiation (AASR)</td>
<td>Averaged annual solar radiation (MJ/cm²/year) * in a counting unit.</td>
</tr>
<tr>
<td>Vegetation type (VT)</td>
<td>Dominant vegetation category in a counting unit</td>
</tr>
<tr>
<td>Share of cool temperature natural forests(%CTF)</td>
<td>Percentage in size the forests in a counting unit</td>
</tr>
<tr>
<td>Share of secondary forests (%SFT)</td>
<td>Percentage in size of the forests in a counting unit</td>
</tr>
<tr>
<td>Share of plantations (%PLT)</td>
<td>Percentage in size of the forests in a counting unit</td>
</tr>
<tr>
<td>Size of wildlife sanctuary size (SWS)</td>
<td>percentage in size of sanctuary</td>
</tr>
<tr>
<td>Accessibility to wildlife sanctuary</td>
<td>cost distance ** in meters from a counting unit to the nearest neighbor sanctuary</td>
</tr>
</tbody>
</table>

* [7]. **: Calculated by Euclidean distance and slope angle
4. Results

1) Causes of Deer Overabundance

Sika deer prefers to inhabit less snow cover at relatively lower elevation s[12] but due to rural development and / or another reasons they have been obliged to inhabit on higher mountain zones [8]. Overabundance of local deer populations is said to cause proximately by the increase of deer number in a given habitat. Net increase of deer number is a result of such changes as less mortality especially in fawns [8, 9], high reproduction [6, 8], and more seasonal immigration and colonization [2]. Underlying causes of these change are discussed or examined with the connection of easy winter [8], good forage condition [4, 14], declining hunting activities [8, 9], and safeguard combining with prohibition of shooting [8, 14]. As for the phenomena of heavy deer concentration, emerging favorable forage spot [13] or space limitation [2] due to deep snow cover, which should bring migration, are also recognized to be underlying causes of overabundance. When the carrying capacity of a given habitat drops significantly with same number of deer, overabundance occurs as a corollary of relative deer density increased drastically.

2) The Factors Determined Sika Deer Distribution on Tanzawa Mountains

The map of recent deer observation (Fig. 2) shows that sika deer in Kanagawa prefecture basically are ranging in the Tanzawa Mountains, and the distribution of local population seems to be restricted by urban area. The distribution, however, shows a tendency to be expanded toward suburban green area on outer Tanzawa. The result of auto-logistic regression model (Tab. 2) suggested that the key limiting factor of current deer distribution of the prefecture is urban landuse and thus their expansion has been observed only at significant secondary forests on low-land next to the Tanzawa Mountains.

Our analysis result, shown in Tab.3, indicates that the deer on the Tanzawa prefer to inhabit such location as cool temperature zone, wildlife sanctuary and more solar radiation.

![Figure 2. Current sika deer distribution based on direct observation records in Kanagawa prefecture and estimated probability for distribution.](image)

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Estimated parameter</th>
<th>P-value</th>
<th>Change of AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>0.258</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Urban Area</td>
<td>-2.534</td>
<td>0.00</td>
<td>15.3</td>
</tr>
<tr>
<td>Others</td>
<td>-0.318</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td>-0.000</td>
<td>0.09</td>
<td>0.7</td>
</tr>
<tr>
<td>Auto-covariate</td>
<td>7.886</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Sensitivity 0.90, Specificity 0.89, Kappa 0.80.

3) Risk of Deer Overabundance in Tanzawa Mountains

Based on the previously obtained parameters, we estimated deer density distribution in the mountains under current condition. As shown in Fig. 3, deer populations are to be expected low density on outer area and high density on south facing slope on mountaintops where is designated as wildlife sanctuary. In general, this estimation can lead to good correlation with the current spatial distribution of eastern Tanzawa. On the contrary there is a distinct discrepancy in eastern Tanzawa where the density is still relatively low.

With the viewpoints on association between deer density and the impact on floor vegetation, it showed the same profile in eastern Tanzawa (i.e. high deer density connects with high degradation as shown in Fig. 4). In western Tanzawa, the degradation occurs in only at the limited site. The site on middle elevation in eastern Tanzawa Mountains was estimated that deer densities are generally low, but the degradation was observed in no small part. The fact suggests that these parts experienced high deer density in the past, or the areas are probably facing the increase of relative deer density.
Table 3. Estimated parameters and statistical indexes to explain sika deer habitat selection in Tanzawa Mnts. by GLM. Abbreviations in variable are the same as table 1.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimated parameter</th>
<th>P-value</th>
<th>Change of AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.1930</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>AE</td>
<td>0.0004</td>
<td>&lt;0.0001</td>
<td>45</td>
</tr>
<tr>
<td>MSA</td>
<td>-0.0138</td>
<td>&lt;0.0001</td>
<td>798</td>
</tr>
<tr>
<td>AASR</td>
<td>1.3950</td>
<td>&lt;0.0001</td>
<td>1593</td>
</tr>
<tr>
<td>%CTF</td>
<td>0.8260</td>
<td>&lt;0.0001</td>
<td>588</td>
</tr>
<tr>
<td>%SF</td>
<td>0.2276</td>
<td>&lt;0.0001</td>
<td>301</td>
</tr>
<tr>
<td>%PLT</td>
<td>-0.0568</td>
<td>&lt;0.0001</td>
<td>18</td>
</tr>
<tr>
<td>SWS</td>
<td>0.0000</td>
<td>&lt;0.0001</td>
<td>27329</td>
</tr>
</tbody>
</table>

5. Discussions

In eastern Tanzawa deer overabundance is an upper limit at top mountain, mostly at wildlife sanctuary, have been observed since the middle of 1990’s. The phenomenon were considered as consequence of multiple causes such as warm winter, uneven distribution of winter forage, and deer management system [14]. Our analysis results in this study indicate this conclusion was appropriate. In other words, our results suggest that deer in the Tanzawa tend to select low-mortality risk habitat, even in higher altitudes. We consequently conclude that the risk of deer overabundance will be worsening and expanding without the bold reforms of natural park management system on the basis of global warming trend.
Concerning the future risks on overabundance in the area, we can discuss possible changes both on the highland and the lowland from the macro perspective of deer habitat selection. On the lowland there are risks that the deer distribution will expand for outer area and to attain the overabundant in some years if deer start to inhabit unless appropriate measures against increased deer density will not be employed. On the highland the eastern part will remain and deepen the risk of overabundance because the frequency of deep snowing will decline as consequence of global warming. The western part has strong possibility that deer overabundance and its impact are going to worsen in proceeding with years since wildlife sanctuaries have been designated. Thus current deer management policy should be revised to avoid these risks, and multiple monitoring on deer density distribution and impact on vegetation are also required to build in appropriate deer management project in the mountains.

References