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OPTIMUM AREA OF SEMI-NATURAL GRASSLAND TO MAINTAIN MAXIMUM BUTTERFLY AND AVIAN SPECIES RICHNESS IN JAPAN

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Abstract

To evaluate the optimum area of semi-natural grassland to maintain maximum butterfly and avian species richness in Japan, digitalized grid data of butterfly and avian distribution, as well as vegetation distribution, throughout the country were used. After obtaining logistic regression models explaining the probabilities of occurrence of each species with semi-natural grassland area and latitude as variables, the optimum value was calculated. The expected maximum species richness of butterflies in the country was the highest in the case of about 40 square kilometers of semi-natural grassland per 100 square kilometers, though the value varied somewhat with latitude. The expected maximum species richness of birds was the highest in the case of about 60 square kilometers of semi-natural grassland per 100 square kilometers. This study showed that the decrease in semi-natural grassland in Japan has resulted in far from ideal conditions for many species.

Keywords: Birds, butterflies, digitalized grid data, logistic regression analysis, optimum area, semi-natural grassland, species richness

Introduction

Semi-natural grassland accounted for more than 10% of the total land area of Japan in the early part of the 20th century (Himiyama at al., 1991). However, by 1990 such land, including temporary grassland such as clear-cut and abandoned cropland, had diminished to 3.3% of the country's total land area (Environment Agency, 1994) as a result of the industrialization of agriculture and animal husbandry in rural areas.

Semi-natural grassland is very important as the habitat of many grassland-dependent species, especially in countries such as Japan that are dominated by forest communities as the climax of vegetational succession. The decrease in semi-natural grassland is one of the reasons that many grassland-dependent plant species (about 90) are included in the Red List (Environment Agency, 1997). However, for butterfly and avian species, it has not been clarified whether the decrease in semi-natural grassland is desirable or not, and the optimum area of semi-natural grassland has not yet been determined.

Using digitalized grid data provided by the Environment Agency, this study clarified (1) which butterfly and avian species decrease or increase with increasing area of semi-natural grassland, or have the optimum area of semi-natural grassland in their habitat, and (2) the optimum area of grassland to maximize species richness.

Material and Methods

Digitalized grid data on butterfly, avian, and vegetation distribution, provided by the Environment Agency and based on the National Survey on the Natural Environment, was used to calculate the optimum area of semi-natural grassland to maintain maximum butterfly and avian species richness.

For butterflies, a distribution survey of the whole country was conducted for two years from 1989, as a part of the Animal Distribution Survey (All-Species Survey) of the 4th National Survey on the Natural Environment by the Environment Agency. For birds, the same type of survey was conducted in 1978 as the nationwide breeding bird survey of the 2nd National Survey on the Natural Environment. All of the distribution data consisted of code numbers for species present in every 2nd Section (about 10 km X 10 km) of the Grid Square System, which uses lines of longitude and latitude to divide the whole country into rectangular sections (Administrative Management Agency, 1973).

The vegetation data was recorded as precisely classified community code number dominant in the center area of every 3rd Section (about 1 km X 1 km, divided section of the 2nd Area Section into 10 X 10 parts of equal length and breadth) of the Grid Square System. The vegetation data obtained after the 4th survey conducted around 1990 was used for butterfly analyses, and for avian analyses, combined vegetation data of the 2nd and the 3rd surveys, both of which were conducted around 1980, was used.

The enumerations composed of butterfly and avian species code numbers were converted into sets of presence/absence (1/0) data for each species every 2nd Section. From each set of vegetation data, the 3rd Section occupied by semi-natural grassland (*Zoysia*-type, *Miscanthus*-type and *Sasa*-type grassland) that might be maintained by means of agricultural activities were extracted, and the area of semi-natural grassland was calculated every 2nd Section. Then, the data sets composed of the area of semi-natural grassland every 2nd Section were generated.

To explain the probabilities of occurrence for each butterfly and avian species by area of semi-natural grassland and latitude, multiple logistic regression analyses were conducted. Logistic regression is a special case of the generalized linear model, and can be used even if the errors are not normally distributed and have no constant variance, instead of ordinary least-squares regression (ter Braak & Looman, 1995). The selection of significant explanatory variables from among four variables (linear and quadratic terms for grassland area and latitude, as including the quadratic terms in the regression equation enables the Gaussian curves to be obtained and the optimum values to be calculated) through the stepwise procedure and the estimation of parameters using the maximum likelihood principle were performed.

All the calculated probabilities of occurrence for each species were summed separately for butterflies and birds in order to calculate the optimum area of semi-natural grassland to maintain maximum expected butterfly and avian species richness. Because of the nondifferentiability of the cumulative formula, the optimum values were evaluated after drawing the expected species richness curves to the grassland area at each latitude.

The analyses were conducted using the statistical software *SAS* (SAS Institute Inc., 1994).

Results and Discussion

Significant equations accounting for the probabilities of occurrence of 225 species of butterflies and 212 species of birds were obtained. The probabilities of occurrence of 18 butterfly species increased with increasing area of semi-natural grassland, 69 species had the optimum area of grassland, the probabilities of occurrence of 42 species decreased with increase in the grassland area, and 96 species were not significantly regressed with the grassland area but only with latitude, or had a constant probability of occurrence.

For birds, the probabilities of occurrence of 23 species increased with increasing area of semi-natural grassland, 39 species had the optimum area of grassland, the probabilities of occurrence of 20 species decreased with increase in the grassland area, and 130 species were not significantly regressed with the grassland area but only with latitude, or had a constant probability of occurrence.

The cumulative value of all the probabilities of occurrence of butterflies, which means the expected species richness of butterflies, was largest in the 2nd Sections containing about 40 square kilometers of semi-natural grassland, although slight latitudinal differences were recognized and the value was largest in the 2nd Sections having no semi-natural grassland at high latitude (Fig. 1). The reason appeared to be that the *Sasa*-type grassland which is dominant in Hokkaido, the most northerly main island, has little floristic diversity.

The expected avian species richness was largest in the 2nd Sections containing about 60 square kilometers of semi-natural grassland, although slight latitudinal differences were recognized (Fig. 2).

In most areas of Japan, agricultural activities are indispensable for maintenance of semi-natural grassland to prevent vegetational succession. However, after the period of rapid economic growth in the latter half of the 1950s, the industrialization of agriculture and animal husbandry in rural areas caused the conversion of some semi-natural grassland into highly productive artificial grassland composed of introduced species, and dependence on imported forage resulted in disuse or forestation of a large area of semi-natural grassland.

This study showed that maximum expected values of species richness of butterflies and birds could be maintained if semi-natural grassland occupied an area much larger than it does at present. Decrease in semi-natural grassland implies far from ideal conditions for many species. Reuse of semi-natural grassland might be the only way to improve the national food self-sufficiency ratio while increasing the nation's biodiversity.

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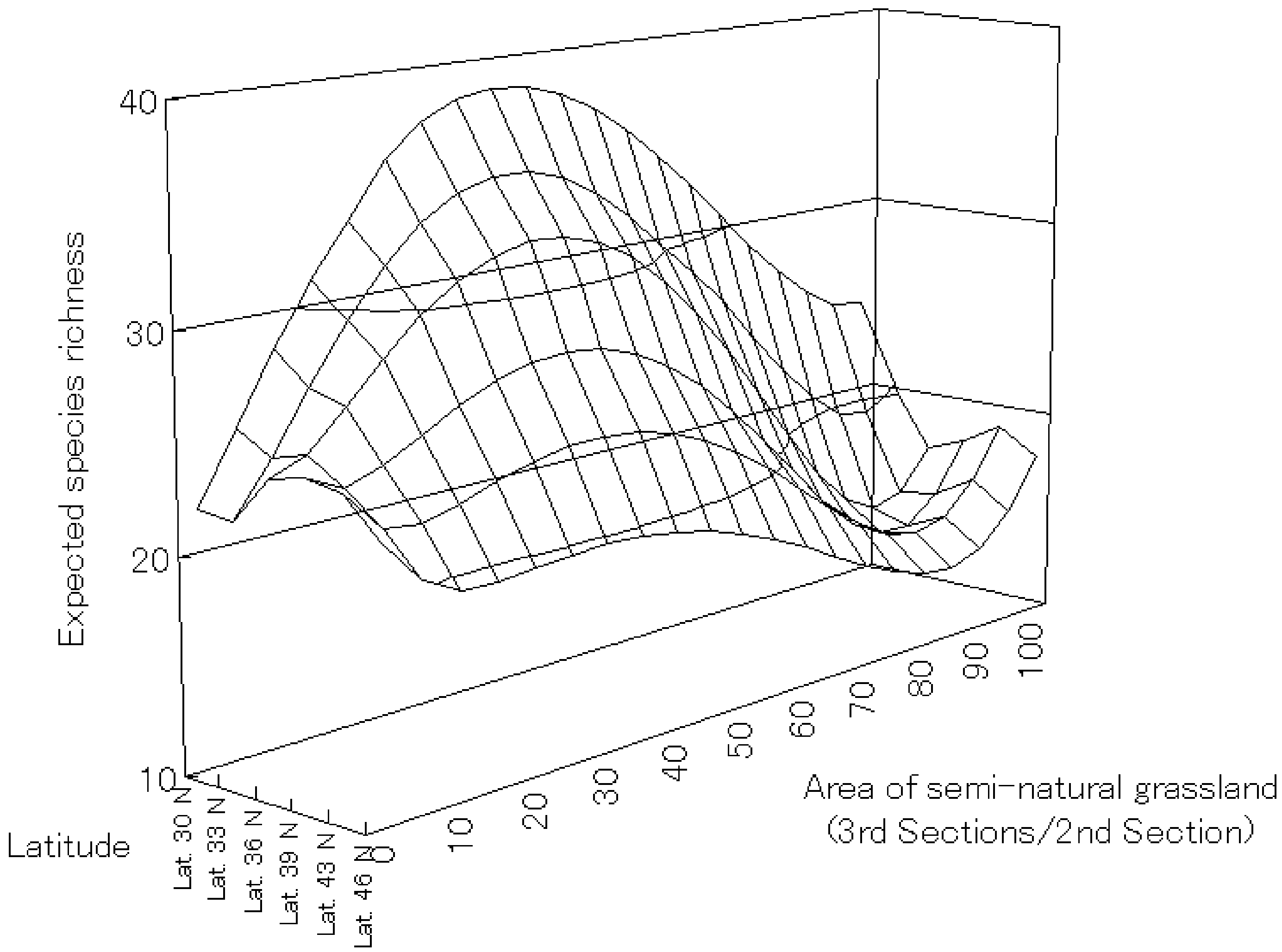

Figure 1 – Effects of semi-natural grassland on expected butterflies species richness

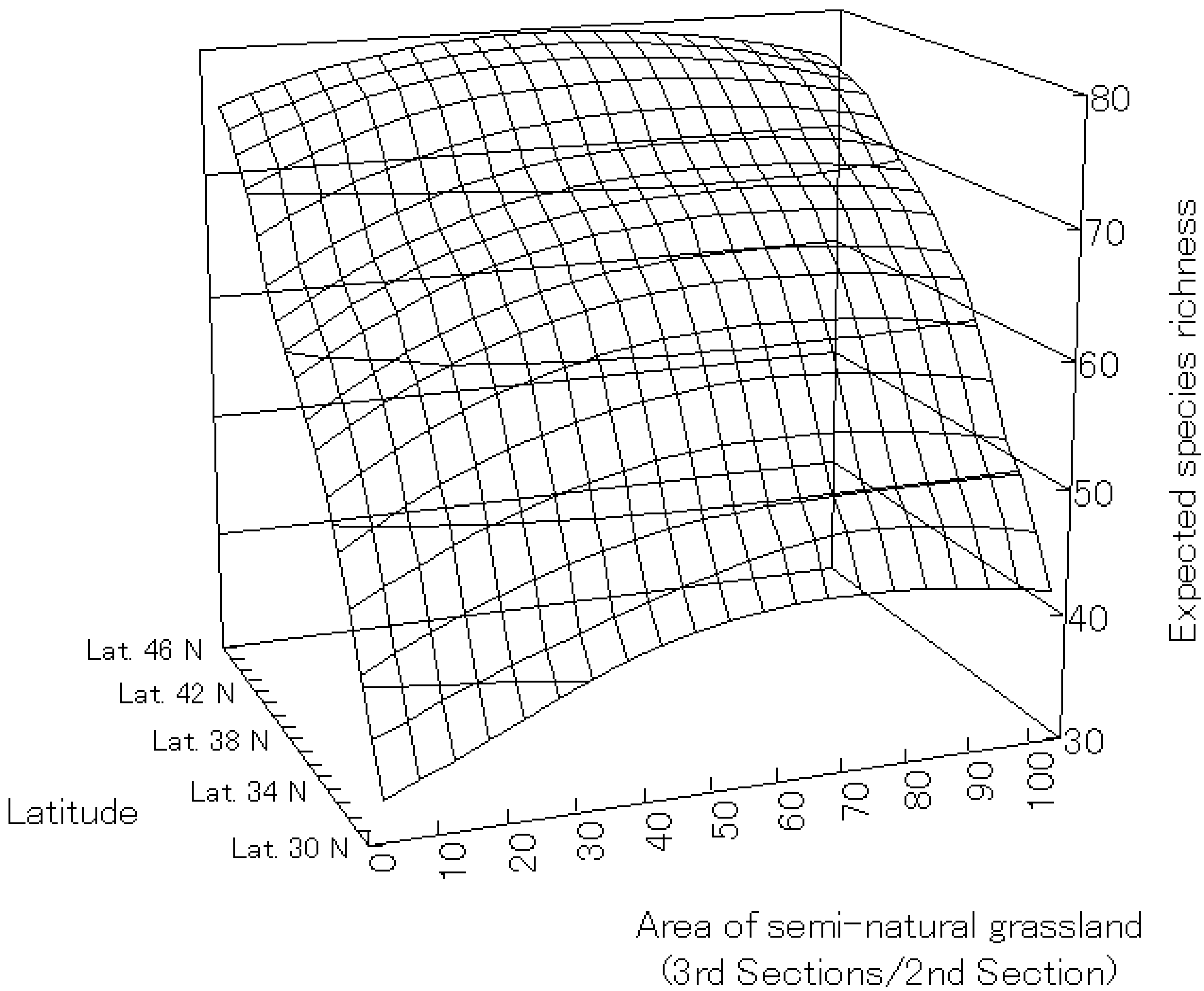

Figure 2 – Effects of semi-natural grassland on expected birds species richness.