Relationship Between Human Maintenance and the Population of Endangered Grassland Butterflies

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Introduction:

Satoyama (the countryside) has long been an integral part of Japan's rural culture. It provides important resources such as wood fuel, thatch, and herbal plants for local residents. Grasslands are a defining element of the satoyama environment and provide vital habitats for many unique plants and animals that have adapted to these areas. Moreover, these grasslands can only be sustained through regular human intervention (Watanabe, 2008). Generally butterfly populations within Japanese grasslands are larger in the grasslands which are regularly maintained. Additionally, high butterfly biodiversity is a good indication of healthy habitats (Watanabe, 2008). However, due to decreasing relevance in modern Japan, many satoyama grasslands are abandoned and being encroached upon by adjacent woodlands. The shrinking habitat of these grasslands poses a threat to dependent species, including several endangered species of grassland butterflies. Sixty-two butterfly species are listed in Japan's Red Data Book, a list of threatened species created by the International Union for Conservation of Nature (IUCN). Thirty-nine of those are grassland butterflies (Hong, 2004).

We hypothesize that there are more endangered butterflies in well-maintained grasslands, those which experience intense human disturbance. For our field study, we partnered with Michihito Watanabe, a local ecologist from the Laboratory of Natural Science for the Coexistence of Humans and Nature. Watanabe acted as our guide and butterfly-identification expert during our research process. We conducted our field study together with two other research groups who studied plant biodiversity and soil composition.

Site Description:

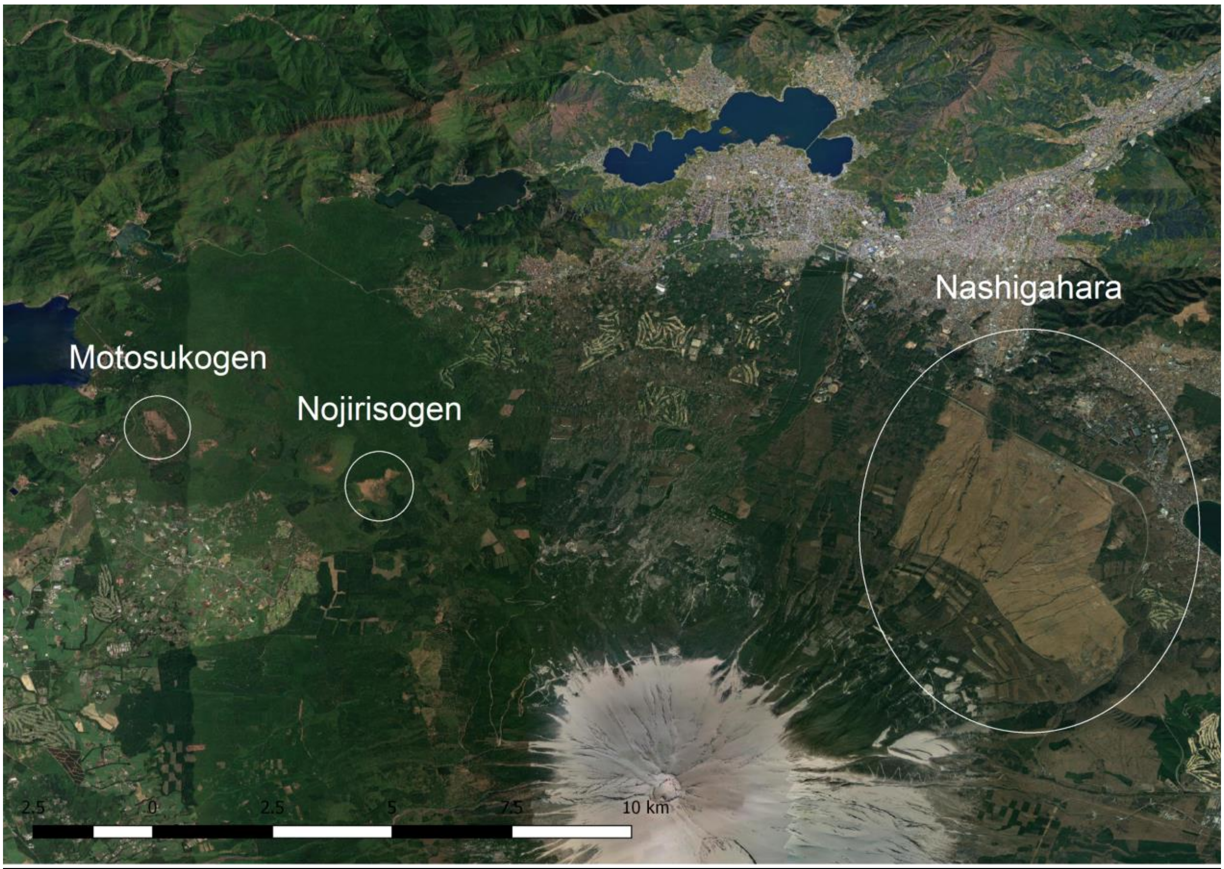

Fig.1. Location of the three grassland study sites relative to Mt. Fuji (center of bottom edge).

We conducted our field research on three different grasslands on the northern foot of Mt. Fuji: Motosukōgen, Nashigahara, and Nojirisōgen (Fig.1). These grasslands were all made and maintained by humans through mowing and annual burning. However, changes in the maintenance of these grasslands have occurred in response to social and economic changes following World War II. Iriai land refers to common property "with identifiable communities of co-owners" (McKean, 1985). The three grasslands we surveyed are all iriai land traditionally maintained by local communities through mowing or burning. Although the Nashigahara has been used by the Japanese military for training since before World War II, iriai groups continue to exert their rights through annual burning and mowing. In contrast, maintenance of the Motosukōgen and Nojirisōgen grasslands has diminished over the years. The Motosukōgen is mowed annually, but no longer burned. The Nojirisōgen is sporadically maintained. It was burned once three years ago; before that, the grassland had not been maintained for over 50 years. Since the Nojirisōgen has been maintained the least, encroachment of woodlands was most noticeable here. (Refer to "Land use history" post.)

All three grasslands are situated on unique volcanic materials that differ in age and geological substrate (Table 1). The Motosukōgen grassland is situated on the oldest lava flow amongst the three grasslands. The Nashigahara has the highest range in altitude while the Nojirisōgen is the flattest grassland. The Nashigahara has the biggest area while Nojirisōgen has the smallest area. However, each grassland is located in the same temperate monsoon climate zone (Mount Fuji Nature Conservation Center, 2017). They experience four distinct seasons and receive significant rainfall, up to 1876 mm per year (Climate Data, 2017). This rainfall can contribute to soil redistribution and weathering over time.

	Lava flow	Altitude (meters)	Total area (hectares)
Motosukōgen	Fujinomiya	970 - 990	50
Nashigahara	Hinokimarubi	950 - 1300	1,880
	Takamarubi		
Nojirisōgen	Subashiri-b stage	1260 - 1270	40

Table 1. Geological characteristics of the three grassland study sites.

Methods:

We recorded the butterfly population of each grassland by using a net to capture and record individual butterflies. We used Fulcrum, a geo-mapping survey app, to record our data and a GPS to record the exact location of each captured butterfly. We sampled from four plots in the Nashigahara, two plots in the Nojirisōgen, and two plots in the Motosukōgen.

Because each individual grassland contains significant land use differences, we decided to survey at least one plot from each area. Namely, for the Motosukōgen, we surveyed one plot in the middle of the grassland and one plot in the fire break zone. For the Nashigahara, we surveyed one plot on the Hinokimarubi lava flow, two on the Takamarubi lava flow (labeled Takamarubi A and B), and one on an older, unidentified lava flow in between these two younger lava flows. Lastly, for the Nojrisogen, we surveyed two plots on opposing sides of a main road cutting through the grassland. To account for the different number of plots surveyed in each grassland, we standardized our data by dividing the number of butterflies or number of species by the number of plots to obtain the respective average number of butterflies per plot.

Grassland	Plot Number	Altitude (meters)
Motosukōgen	Plot 1	950-960
	Plot 2	950-960

Nashigahara	Plot 1 (Middle)	930-970
	Plot 2 (Hinokimarubi)	1240-1280
	Plot 3 (Takamarubi A)	970-1100
	Plot 4 (Takamarubi B)	1140-1180
Nojirisōgen	Plot 1	1260-1280
	Plot 2	1260-1280

Table 2. Altitude of each survey plot in all three grasslands.

To select survey plots, Watanabe first situated the adjoining research group studying plant biodiversity. While the plant and soil study teams remained in their area, Watanabe led us through a portion of each grassland. Generally we followed deer trails. We were occasionally rerouted by high grass.

Our data collection survey on the Fulcrum app included name of the surveyed grassland, lava flow, species name, sex, endangered status, GPS coordinates, and a photo of each butterfly. We identified each captured butterfly by its Japanese name with the aid of Watanabe. We also recorded identifiable endangered butterflies that were observed but not caught. We used general guidelines such as shape of abdomen and sex-specific wing patterns to identify the sex of each butterfly. We later exported our data to Quantum Geographic Information System (QGIS) to map out the distribution of the butterflies recorded in each grassland.

Results:

In total, we recorded 124 butterflies, 24 different species, and five endangered species across the three grasslands. The Nojirisōgen had the highest total number of butterflies recorded (50), followed by the Motosukōgen and then the Nashigahara. Despite having the lowest number of recorded butterflies, the Nashigahara had both the highest number of different species and the highest number of endangered species (Fig.2). However, when we took the average number per plot, the Nojirisōgen had the highest number of endangered species per plot, while the Nashigahara had the highest number of endangered butterflies per plot.

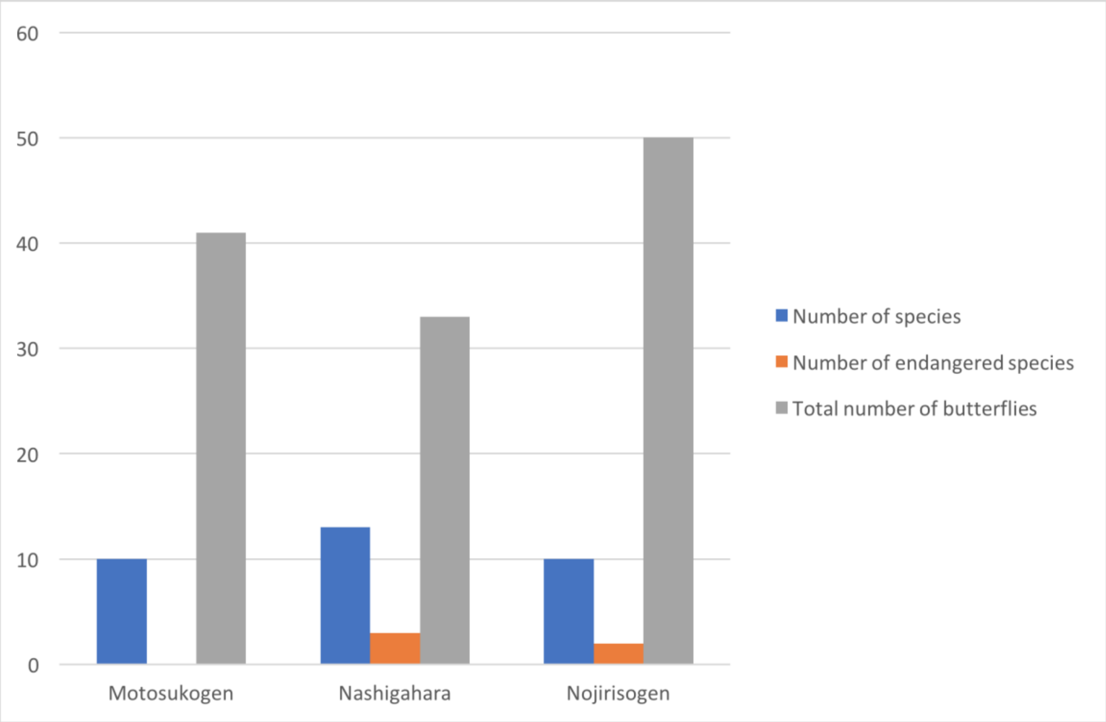

Fig.2 Total number of butterfly individuals, number of species, and number of endangered species recorded in each grassland.

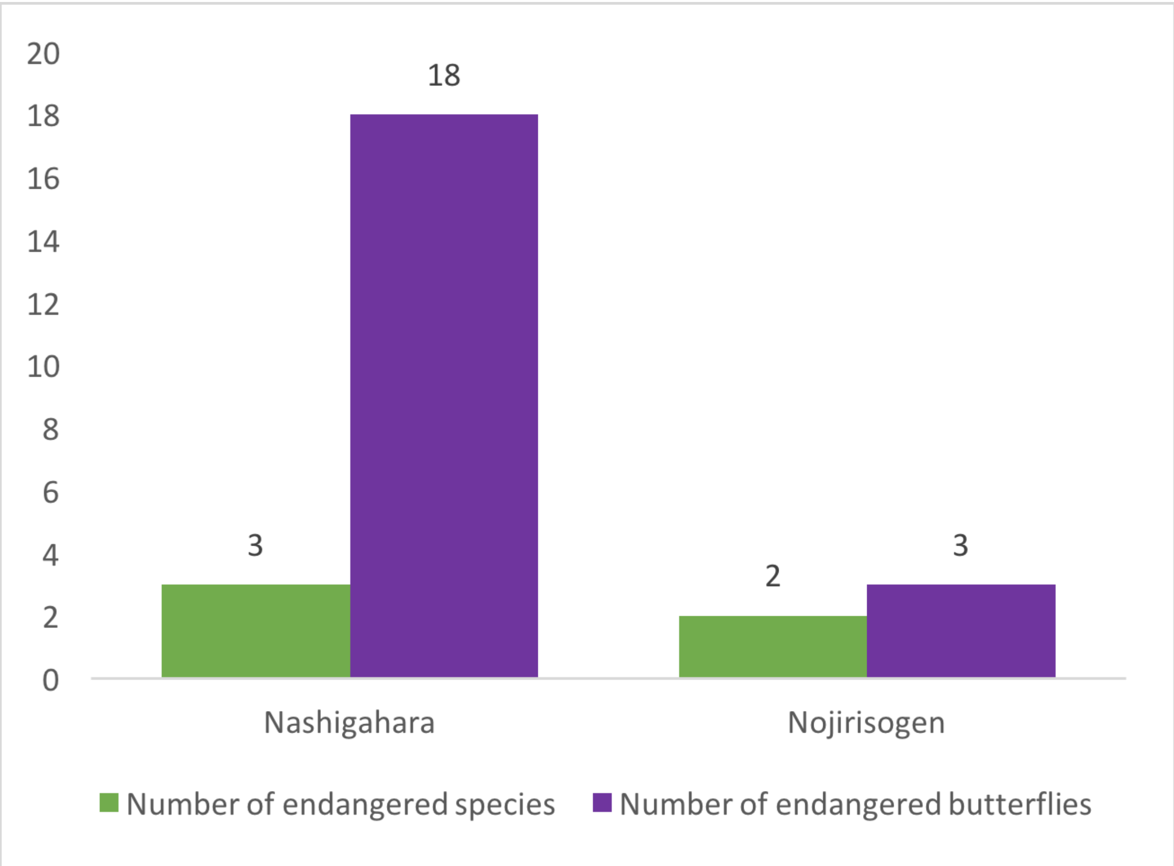

Fig.3 Total number of endangered species and endangered butterflies recorded in Nashigahara and Nojirisōgen.

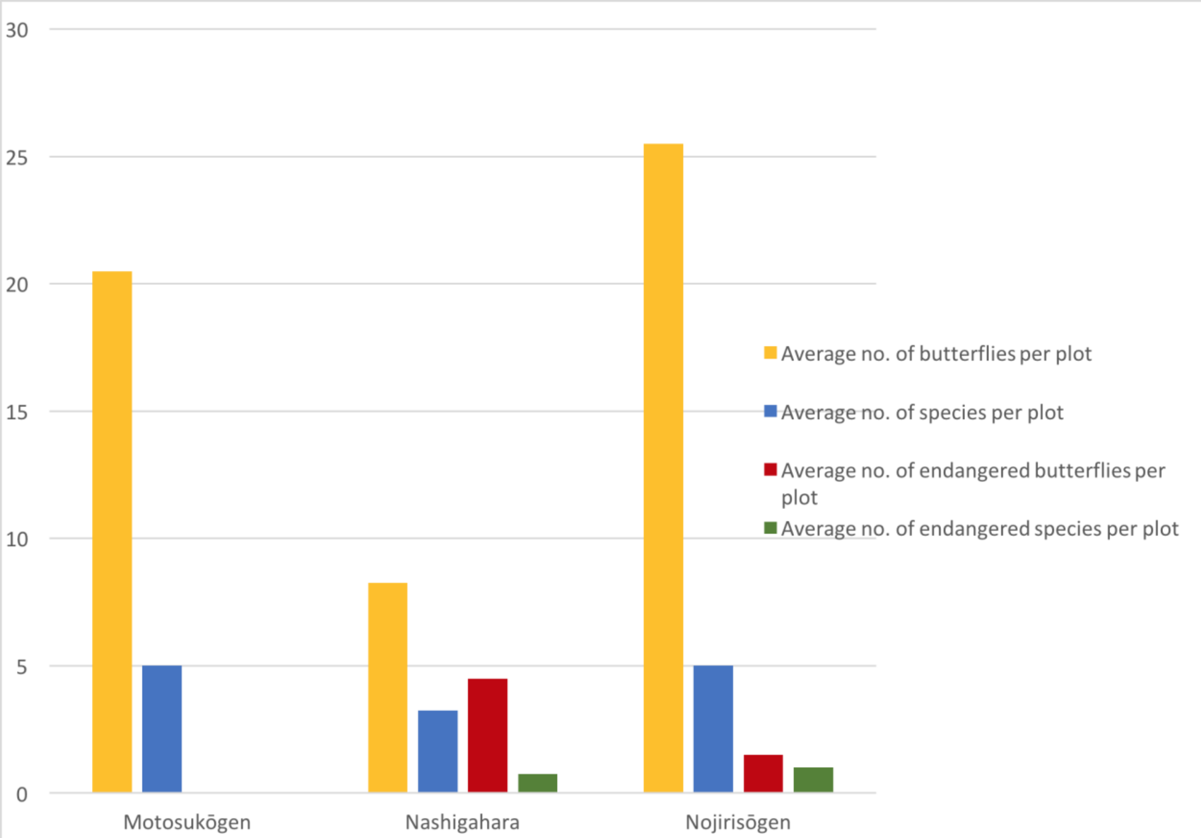

Fig.4 The average number of endangered and non endangered butterfly species and individuals in all three grasslands.

We only found twenty-one individual endangered butterflies across all three grasslands, with eighteen found in the Nashigahara and three in the Nojirisōgen (Fig.3). The endangered species found in these two grasslands are distinct from each other (Table 3).

Name of endangered species	Total number	Number caught in Nashigahara	Number caught in Nojirisōgen
Aka seseri	6	6	-
Hime shirochou	11	11	-
Kuro shijimi	1	1	-
Uraginsujihyoumon	2	-	2
Yamaki chou	1	-	1

Table 3. Number of individuals of each endangered species recorded in Nashigahara and Nojirisōgen.

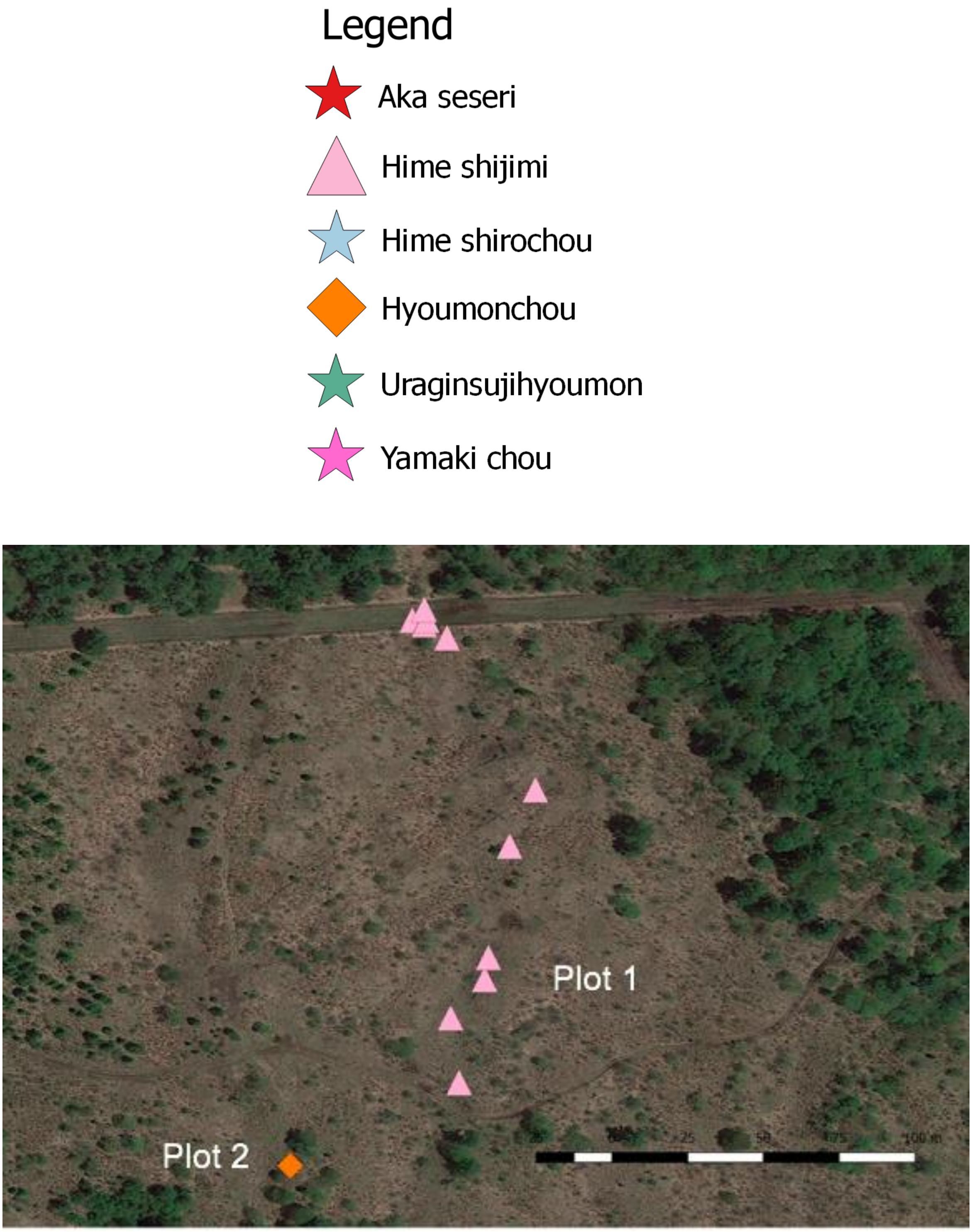

Fig.5 Distribution of recorded butterflies in Motosukōgen. Color distinguishes each species of butterfly. Different symbols represent the endangered status of each butterfly species: a triangle signifies nearly threatened (NT), a square signifies vulnerable (VU), and a star signifies endangered (EN).

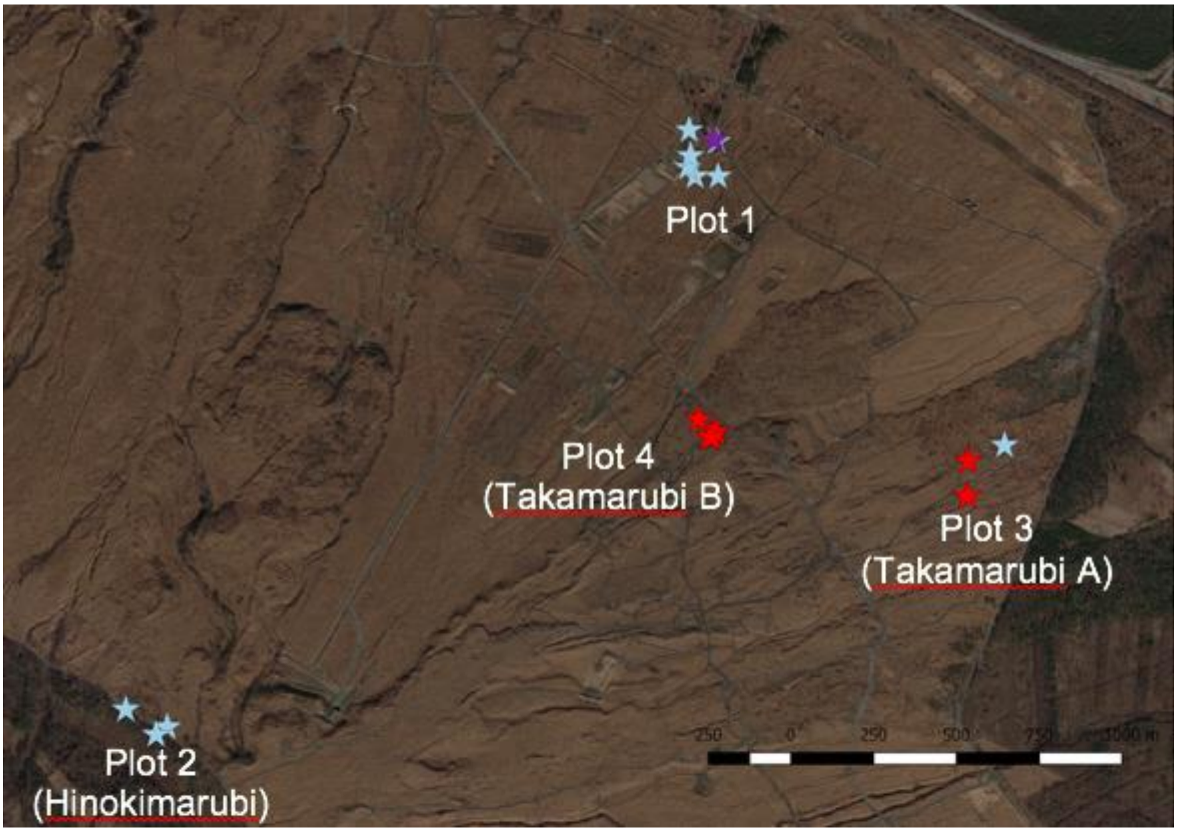

Fig.6 Distribution of recorded butterflies in Nashigahara. Symbols and colors are the same as in Figure 4.

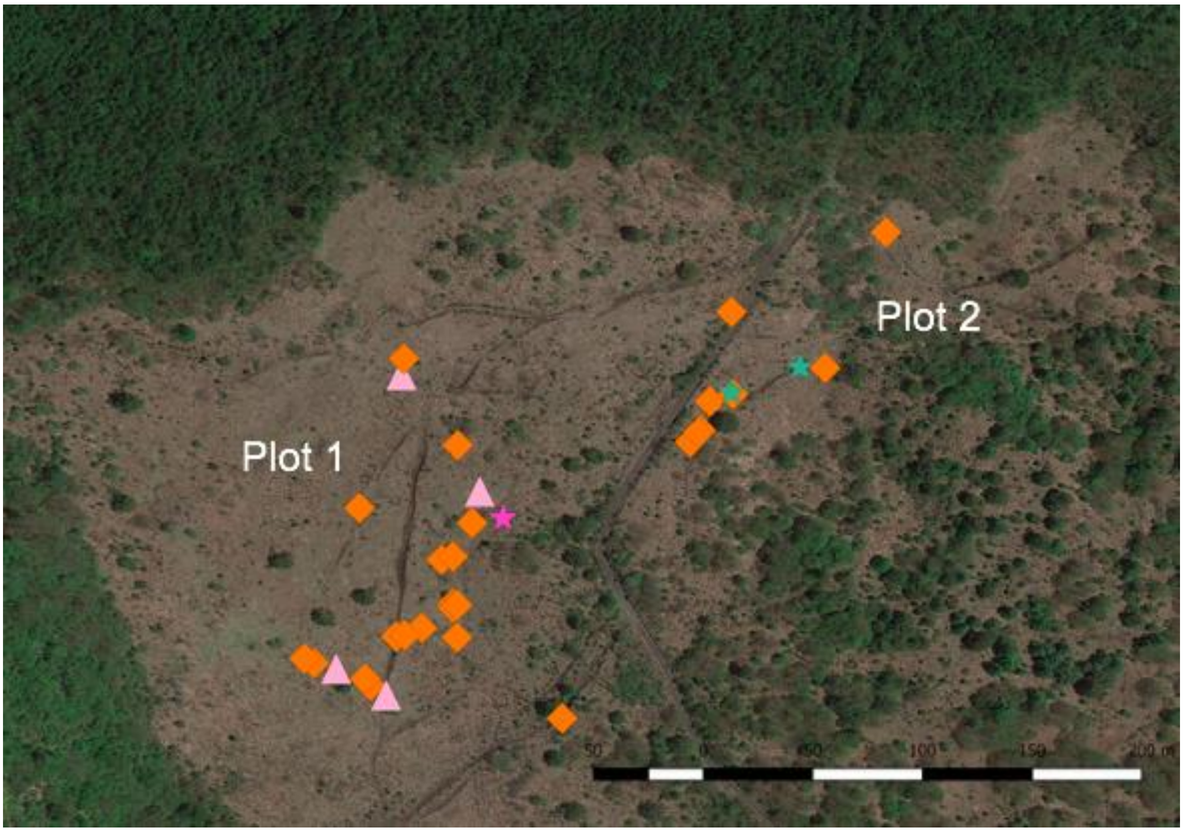

Fig. 7 Distribution of recorded butterflies in Nojirisōgen. Symbols and colors are the same as in Figure 4.

While we did not find any endangered butterflies In the Motosukōgen, we did observe a concentration of hime shijimi, a nearly threatened species (NT), in the fire break zone (Fig. 5). In the Nashigahara, aka seseri, an endangered species (EN), was only found in Plots 3 and 4, which were located on top of the Takamarubi lava flow (Fig. 6). In the Nojirisōgen, the two endangered species recorded were observed in different plots: Yamaki chou in Plot 1 and Uraginsujihyoumon in Plot 2 (Fig. 7).

Discussion:

Although we surveyed four different areas in the Nashigahara, our results show the smallest total number of butterflies were found there (Fig.2). This was an unexpected result because the Nashigahara was the largest grassland in our survey. Furthermore, according to previous studies from Watanabe, the Nashigahara usually has a large population of butterflies. We first noticed the lack of butterflies when surveying Plot 2 in the Nashigahara. As Plot 2 is located on the Hinokimarbui lava flow, it is at a higher altitude (Table 2) than the plots we had previously studied (Plot 1 in Motosukōgen and Plot 1 in Nashigahara). At high elevation, butterfly emergence generally occurs later due to relatively cooler temperatures. We first hypothesized that elevation was to blame for the small butterfly population in Plot 2. However, when we surveyed Plot 3 and Plot 4 on the Takamarubi lava flow, which is located at a lower elevation, we still observed a small butterfly population. Furthermore, the largest number of butterflies was recorded in Nojirisōgen despite it being at the highest altitude. Thus, we reject our initial assumption about the effects of elevation in this case. Our observations, along with Watanabe's previous records of the Nashigahara, suggest that the small butterfly population we experienced might be due to random annual fluctuation of the butterfly emergence cycle.

Nevertheless, when we looked at the total number of endangered individuals (Fig.3) and average number of endangered butterflies per plot (Fig.4), Nashigahara had the highest number of the three grasslands. This suggests that heavily maintained grasslands support a larger number of endangered butterflies than neglected grasslands. Regular burning at the Nashigahara may have reset the plant succession cycle, allowing growth of diverse plant species (Bond et al., 2010). The increase in plant biodiversity might also result in an increase of larva-stage food source plant species or habitats for endangered butterflies.

Further analysis of individual plots supports the hypothesis that human maintenance is correlated with endangered butterfly population. In the Motosukōgen, a higher concentration of red listed and common butterflies was observed along the firebreak, which is an area well maintained by mowing (Fig.5). Our colleagues who studied plant biodiversity also found the highest concentration of endangered plant individuals in the Motosukōgen firebreak zone. Watanabe said that even though butterflies (including endangered species) feed on common plants, he has observed a higher concentration and biodiversity of butterflies in areas with a larger number of endangered plants and greater plant diversity. The correlation between our data and that of our colleagues parallels Watanabe's findings. This might suggest the importance of grassland maintenance to the population of endangered plants and subsequently the biodiversity of butterflies.

However, this suggestion should be taken with skepticism. Our study had several methodological inconsistencies. First, the Nashigahara is thirty-seven times larger than the Motosukōgen and the Nojirisōgen (Table 1). Second, we surveyed a larger total area in the Nashigahara than in the Motosukōgen and the Nojirisōgen. Additionally, the plots we surveyed were arbitrarily chosen by Watanabe and not uniform in size. Although we had tried to minimize this error by taking the average number of butterflies or species per plot, the unstandardized plot area still affected the accuracy of our data.

As the survey progressed our method of recording butterflies changed as well. In the beginning, we only recorded butterflies that were identified after we caught them. Later, in the Nashigahara, we recorded butterflies that were not caught but were identified in flight by Watanabe. This inconsistency might have altered our results considerably. Moreover, our study took place over the span of five days. This gave us limited time for field research. We also experienced a variation in day to day weather. Butterflies are sensitive to minor temperature changes. They will remain hidden in undergrowth if the temperature is too hot. In addition, they do not tend to fly in the rain. During our first day in the Motosukōgen our survey was cut short due to a minor rain storm. In the Nashigahara, temperatures were sweltering -- a factor that may have affected the number of butterflies we surveyed that day. Unfortunately, we did not include weather data in our survey. If we were to do this research again we would take data on the weather to better understand how it can affect the population of butterflies on a day to day basis. Finally, other random fluctuations in butterfly emergence cycles might have also affected the accuracy of our data.

We will refrain from articulating a conclusive statement about the relationship between endangered butterfly species and human maintenance in grasslands, even though our data does mirror certain butterfly population trends found by Watanabe's ten years of research (personal communication, July 12, 2017). In addition, further studies of other variables, such as the effects of plant and animal biodiversity on the biodiversity of grasslands butterflies, should be conducted. There are also other interesting findings in our data that require further research. For example, aka seseri (EN) was only found in Nashigahara and more specifically only upon the Takamarubi lava flow (Fig.6). This suggests that geological differences might be an important determining factor for endangered butterfly populations. Externally sourced soils, particularly those brought by floods, facilitate plant growth due to age, weathering, and soil fertilization, are a source of nutrients which may not be found in the lava flow (Deligne et al., 2012). Perhaps such variations in soil source at different lava flows may explain the trends we witnessed, especially since slush flows are so common in the area.

Although our results are inconclusive, our data can contribute to long term population studies. As Watanabe suggested, studying the biodiversity of grassland butterflies is important because they are good indicators of healthy habitats. By studying the biodiversity of grassland butterflies and focusing on endangered species, we can assess the quality of habitats in each grassland. Subsequently, we could potentially devise appropriate conservation plans for Japan’s satoyama environments.

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