International Journal of GEOMATE, March, 2020, Vol.18, Issue 67, pp. 142-147
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.67.9231
Special Issue on Science, Engineering and Environment

THE HABITAT CONDITION ANALYSIS OF *LUEHDORFIA JAPONICA*, THE SIMBOL OF CONSERVATION AREA

*Michiko Masuda[1], Yoriko Gido[2], Yukimaru Tashiro[3], Atsushi Tanaka[4], and Fumitake Nishimura[5]

[1,2,3,4] Department of Civil Engineering, Nagoya Institute of Technology, Japan; [5]Department of Environment Engineering, Kyoto University, Japan

*Corresponding Author, Received: 15 June 2019 , Revised: 20 Jan. 2020, Accepted: 06 Feb. 2020

ABSTRACT: It has been pointed out that the vegetation succession brings out the reduction of the *Luehdorfia japonica*. But some researcher has insisted that thinning cannot increase the population of the butterfly. Then we cut down half of the forest and reverse succession, in order to study the influence of the population of *Asarum rigescens* var. *brachypodion*, larval food plant, and the mass of reward of the butterfly by cut off the forest. It was being thought that thinning in a forest obstructed growth of forest floor plant, but the growth of *A. rigescens* that was famous of forest floor plants, was promoted. On the other hand, *A. rigescens* did not grow up in the climax forest despite of survive. In the green house experiment we can get the proof of the growth condition. The growth of open light condition was superior to that of the 40% light penetration condition. And more the number of flowering of plants was more increased than ever. It was indicated that the thinning in a forest is important for the habitat of the symbolic butterfly, *L. japonica,* and it increased other plants bloom, and to secure source of nutrition of much insect kinds.

Keywords: Thinning, Light condition, Larval food plant, The mass of flowering, Biodiversity

1. INTRODUCTION

The 2005 World Exposition, Aichi, Japan, Nature's Wisdom, was held at Aichi Prefecture. Some *Accipiter gentilis* built nests and many *Luehdorfia japonica* grew up in the main site (named Kaisho-no-mori), so that area would be conserved in order not to develop [1] [2]. The many NPO and naturalist should claim to relocate the Expo venue. After the discussion, the main site of the 2005 World Exposition moved to the next place. Aichi Prefecture Government conserved the area named Kaisho-no-mori in order to become the symbol of the Expo. The area was divided 6 sections along the objection for the natural conservation [3]. Almost sections were adopted as untouched nature conservation. In Japan, everybody think that the conservation areas should be untouched and nobody step into the area.

Almost 10 years passed from the 2005 World Exposition, Aichi, Japan, we cannot find out the feature of *L. japonica* anymore. It continued being investigated a continuous flora and fauna by Aichi Prefecture, though it was not analyzed. Obviously the untouched conservation management is not good for the butterfly. In 2012 only one *L. japonica* observed and in 2013 and 2014 there was no *L. japonica* in the area [4].

Ishii (2005) pointed out the half of the endangered species in Japan was distributed in Satoyama [5]. Satoyama has been affected by human disturbance in order to get energy, construction and food materials for some centuries. The moderate disturbance maintained high biodiversity for 500 years. It suggested the moderate disturbance is important for the *L. japonica*.

But some researchers insisted that the disturbance is not good for the forest floor plants, *Asarum* species, that is larval food plants of *L. japonica* [6]. And some conservationists argue that the conservation should be un-disturbed. The cause of the butterfly decrease should be explained for the conservation management. The insects cannot live when the decrease of larval food plant and the decrease of adult food resource occurred. Then we investigate the influence of the thinning (moderate disturbance) on both the larval food plant growth and the mass of flower resources.

We have three hypothesis, 1) the thinning doesn't increase the death rate of *Asarum rigescens* var. *brachypodion*, 2) The lighter condition promote the growth of *A. rigescens* var. *brachypodion*, 3) the thinning increase the mass of flower reward. It was paid attention to the three points and analyzed.

2. MATERIALS AND METHODS

2.1 The Study Site

The study was carried out on the Kaisho-no-mori Conservation area (600 ha) at the center of Aichi Prefecture, the middle of Japan (Fig. 1).

The area has been conserved from 2005 in order to prevent the disorder construction and over use.

Especially no one step into northeastern conservation area. The geological feature of the area assumes rich groundwater and the soil of the oligotrophy base. 16 Tokai hilly land elements [7] that are endangered species are grown up in the area.

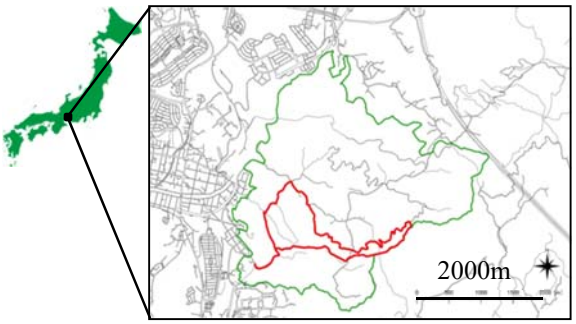

Fig.1 The area of the study site (green line) and route of the phenology census (red line)

2.2 The Study Plant

Asarum rigescens var. *brachypodion* (ARISTOLOCHIACEAE) is a perennial herb in the temperate forest distributed in Chubu Japan (Fig. 2). The habitat of the species is deciduous or evergreen forest floor. From January to March the species is flowering close to the ground 1 to 10 flowers. From April to May the seed dispersal occurred by some kinds of ants. The each of seeds has elaiosome that is nutritional source for many ants. Ants moved the seeds to their nests, and removed the elaiosome from the seeds, they throw away the seeds from the nest. The seeds emerged from the refuse dump. The seedling emergence occurred in April. Despite of the leaves of the species have aristolochic acid, the leaves of the species is larval food of *L. japonica* (Fig. 3), then the butterfly species have tolerance to the toxin.

Fig.2 Photos of *A. rigescens* var. *brachypodion*, under right photo shows the flowers of the species

Fig.3 Photos of *L. japonica* and under right photo shows the eggs of the species

2.3 The Field Census

To know the distribution of *A. rigescens* var. *brachypodion*, we walked everywhere of Kaisho-no-mori along the ridges and the valleys using GPS from January to March in 2016 and made a distribution map. When we detected the species, we took the photo for the number of the leaves.

In order to investigate the effect of thinning, we set up the quadrat (10 m x 10 m) and cut off every woods and weeds except *Asarum* in June 2016. And we set up the same size quadrat at 100 m away. At each quadrat we made a map of distribution of every *A. rigescens* var. *brachypodion*, and measured the size of the species. The individual size was estimated by five index, number of leaves (n), largest leaf length (l_{max}), largest leaf width (w_{max}), smallest leaf length (l_{min}), and smallest leaf width (w_{min}). Then size index (S_{index}) was shown by following equation (1).

$$S_{index} = \frac{n}{2} (l_{max} \text{ x } w_{max} + l_{min} \text{ x } w_{min}) \quad (1)$$

From June 2016 to Nov. 2018, we measured every individual size index in early summer and autumn in each year to detect the difference of growth rate in each quadrat.

And we took the photographs to investigate light condition at each individual location using omnidirectional camera (RICOH THETA S) and calculated the open sky degree using software (CanopOn2).

To measure the mass of flowering reward, we took every flower photographs at a week interval from March to April in 2016 and 2018 along the field census route 4m wide 20m long (Fig. 1 red line). Using the phots we grasped the number of flowers. In 2016 we measured the honey amount of each flower of Rhododendron and Viola (the flowers attract the butterfly). To compare the reward of the flowers, we counted another place (where we can observe a lot of *L. japonica*).

2.4 Comparison of Growth Rate

Two condition were prepared to measure the growth rate of the species. One condition was open light condition (where 50% open sky) and the second condition was closed by cheesecloth (where 20% open sky). We collected from the field 84 individuals of *A. rigescens* var. *brachypodion* on October 2017. After collecting, each individual was washed to remove the soils in order to measure fresh weight. After wiping water by paper towel, we measured fresh weight, we planted in 10cm diameter pot with cultivation soils. We divided two groups that has same size distribution, one group lay in open area, and the other lay in closed area. One years later, we measured fresh weight and calculated the growth rate.

3. RESULTS

Fig. 4 showed the distribution of the species now and Fig. 5 showed two decades ago [4]. The distribution of the present time is very different from 20 years ago. Half of the populations disappeared, and we can find out new populations in the different area.

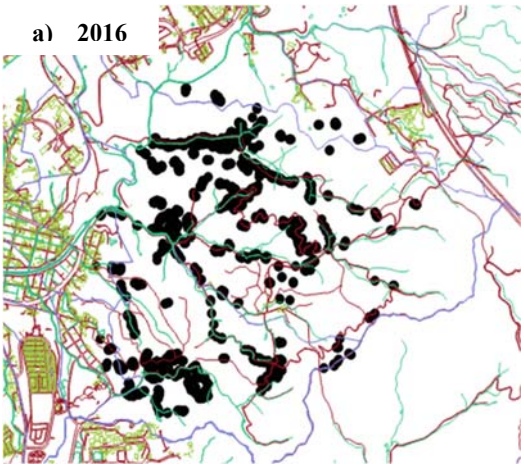

Fig. 4 The distribution of *A. rigescens* var. *brachypodion* in 2016

Fig. 6 showed the density distribution of the species. Two decades years ago, the census was only distribution, but the most crowded distribution areas was very different from the condition of now. The highest density exists (■: over 500 leaves in the quadrat) in the empty area in 1998 and 1999.

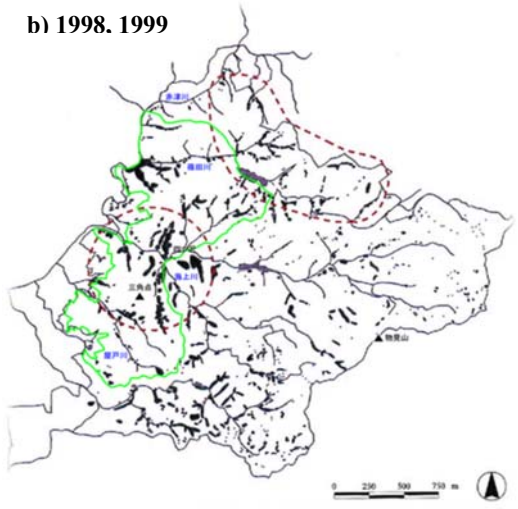

Fig. 5 The distribution of *A. rigescens* var. *brachypodion* in 1998, 1999

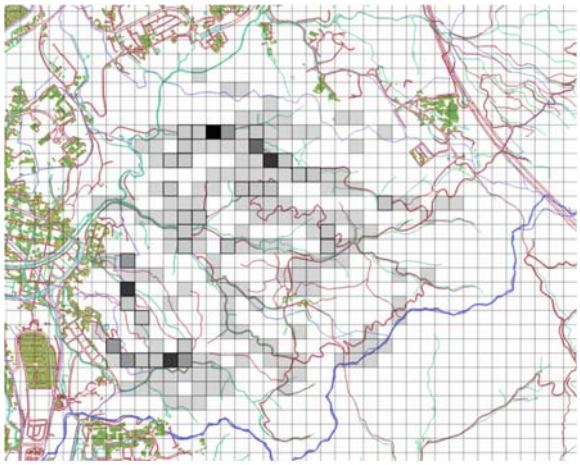

Fig. 6 The density distribution of *A. rigescens* var. *brachypodion* in 2016 (■: over 500, ■: 400-500, ■: 300-400, ■: 200-300, ■: 100-200, ■: 0-100, □: 0)

Fig. 7 showed the size distribution between thinning area and controlled area from 2016 to 2018. In the thinning area, we can find out the increase of $S_{index,}$ especially from autumn to summer. There was a difference between the growth of shining area and that of the control area. From the Steel Dwass test of each season distribution 15 pairwise within each area, there were 8 significant differences ($p<0.05$) observed in thinning area, but in control area there were 3 significant difference observed. The growth rate of thinning area was superior to that of control area. We also found out the difference between the variance. The variance of the tinning area was larger than that of the control area.

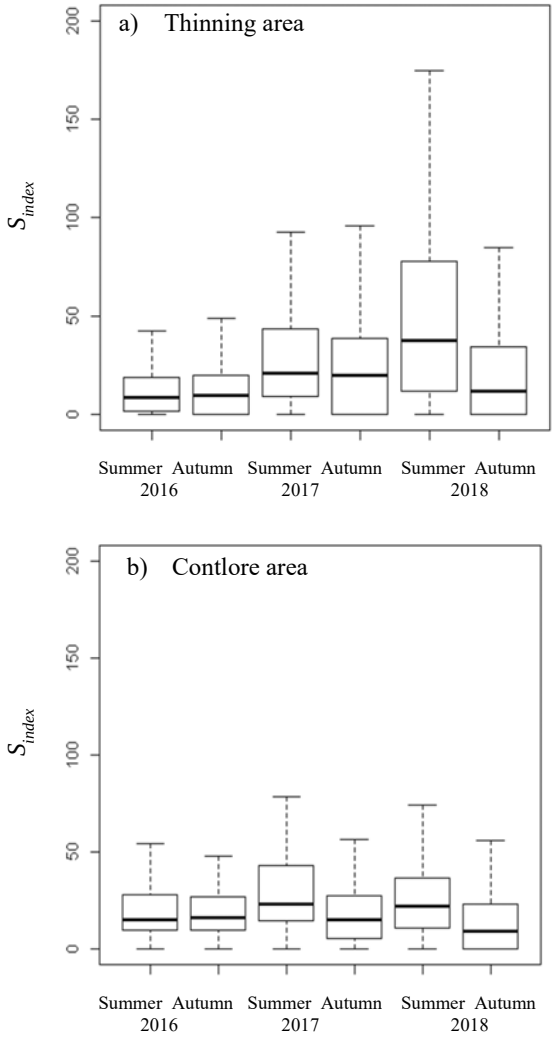

Fig. 7 The S_{index} distribution of *A. rigescens* var. *brachypodion*, from summer in 2016 to autumn in 2018. a) thinning area, b) controle area

Fig. 8 showed the relationship between light condition (open sky percentage) and the growth rate (increase percentage of S_{index}) from summer in 2016 to summer in 2018. Remarkably growth rate was observed in 40% to 50% open sky percentage condition.

The amount of flower from 2016 and 2018 in spring showed in Fig.9. Amount of the nectar was increasing after thinning. The histogram skewed to right. The number of the increased nectar quadrats was larger than that of decreased quadrats.

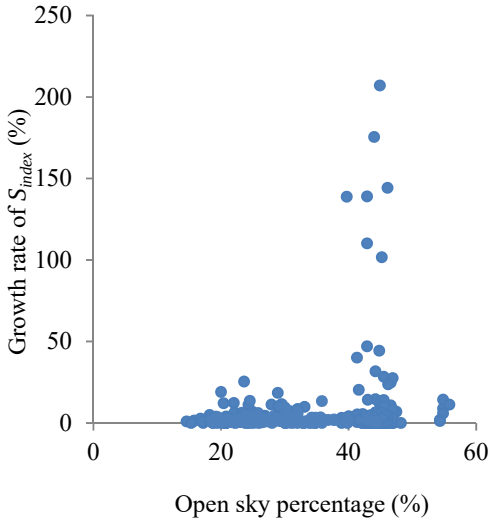

Fig. 8 The relationship between light condition and growth rate of S_{index} of each individual

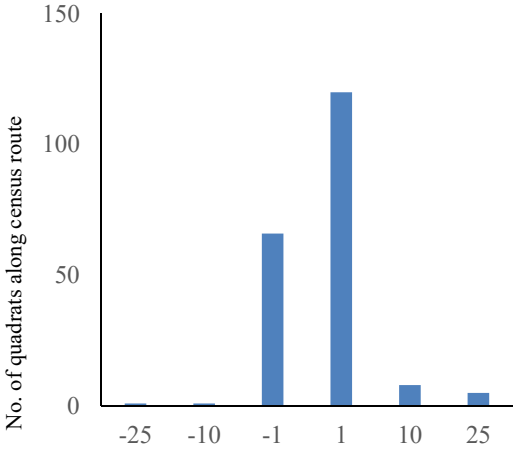

Fig. 9 The difference of nectar at each quadrat along the route of phenology census from 2016 to 2018

The growth amount at open environmental condition and closed condition showed in Fig. 10. From the Wilcoxon test, the growth rate of open condition was superior to that of closed condition ($p<0.05$). And we could observe the variance difference between the two condition.

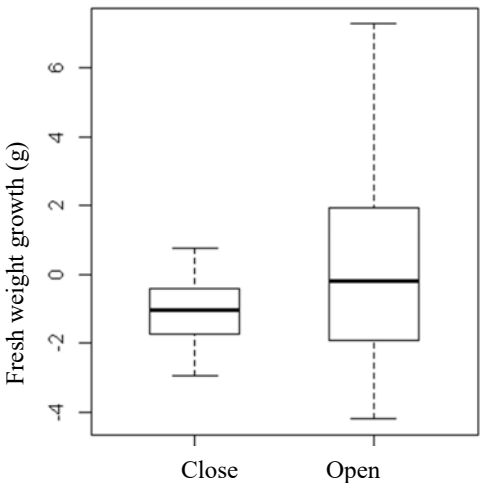

Fig. 10 he growth amount in closed by cheese cloth and open for one year

4. DISCUSSION

IUCN (International Union for Conservation of Nature) has developed a system of classifying protected areas that ranges from minimal (nature reserves, national parks, etc.) to intensive use of the habitat by humans, with six categories [8]. There strict nature reserves and wildness areas have the high quality of biodiversity. So almost people believe that the untouchable nature is very precious. Nature should be leave as they are. That is a true because the development destroys the biodiversity. But recently the role of moderate disturbance is regard as important.

Jacobson et al. (1991) reported the human moderate disturbance reversed the vegetation succession and formed the valuable biodiversity [9]. The mechanism of disturbances was reported by many other researchers [10][11]. These researches were about wetlands and grasslands where vegetation succession is affected seriously. Stop the succession is very important for the special vegetation. In the forest, people think that biodiversity of forest will be increasing along succession. Because there were many kinds of species that likes closed, humidity and nourishment condition under the condition, so the disturbances destroy such a condition and shade species. In Japan the moderate disturbance has been continued over 500 years in near the village.

The data of the biodiversity was investigated because of the 2005 World Exposition, Aichi, Japan, Nature's Wisdom. After 18 years passed some nature conservation association reported the decrease of biodiversity, especially *L. japonica*. The cause of butterfly decrease was undetected. Every conservationist insisted the conservation area closed and no one affect the biodiversity.

In order to realize the cause of butterfly decrease, the resource condition of both larva and adult were investigated. The distribution of larva food plant, *A. rigescens* var. *brachypodion* was changed from 18 years ago. The center of distribution moved to the area of Japanese oak die. It was suggested that the light condition is darker and darker, the growth condition is worse and worse. *A. rigescens* var. *bracypodion* is a famous of forest floor plant, but almost individuals have a few leaves only. It is not sufficient to serve larva, because it is needed at least 3 leaves to nurse the butterfly. The difference about the condition of the forest is disturbance. 20 years ago, the forest supplied as fuel, building materials, materials for fungi agriculture and food to near agricultural village people. Utilization by people can make the oligotrophic and intolerant tree forest.

In fact, the growth rate of the species accelerates by shining, and growth experiment showed the light condition is very important for the species. Each light condition in the field, the 40-50% open sky conditions are very good condition for the growth. By the experiment the light condition is very important of the forest floor plant. But there is large variance observed in shining, it is showed the open light condition is very strict condition, some individuals can grow up, but the other cannot grow up. The severe natural selection occurred in open condition, especially more than 50% open sky. Perhaps drying and strong light inhibition prevent the growth.

The thinning brought another effect of the amount of reward to the adult butterfly. The increase amount of reward is not so much, but the light condition brought a good condition for photosynthesis and rhododendron (short tree) and viola (herb) can produce many flowers than before. The condition will be good for the butterfly and other insects.

From the experiment, the cause of the butterfly decrease is succession of the forest. Thinning is very important of the management for biodiversity. But there is problems in the management. How much may we cut down in order to maintain biodiversity? The best condition for *A. rigescens* var. *brachypodion* is 40 to 50% open sky. But it is very difficult to cut down for such a condition, and it is very difficult to maintain the condition because of vegetation succession.

The management plans are needed to maintain the biodiversity. Succession is always progress, the zoning is needed to thinning. Every 10 years interval each zone should be cut off. The first year 1/10 forest part cut, and the second year the next section of forest cut of, the third year and so on. The moderate disturbance management is very difficult, but the succession will repair the over thinning condition.

5. CONCLUSION

We get four main conclusions.

1) The forest thinning is important for the iconic butterfly (*L. japonica*) habitat, increasing the flowering of other plants and securing nutrients for many insect species.
2) The distribution of *A. rigescens* var. *brachypodion* greatly changed for 18 years.
3) The growth rate of *A. rigescens* var. *brachypodion* that is forest floor plant, is larger in thinning area than that in closed area.
4) In light control experiment, growth of *A. rigescens* var. *brachypodion* in open area was accelerate than in closed area.
5) The thinning increased the flower nectar amount in spring.

From these conclusions, it is suggested that the cause of the decline of *L. japonica* is the decline of larval food plant and adult food plant.

Based on the conclusions, two proposals about the conservation activities

1) Human disturbance is very important to maintain the biodiversity at the mountain named 'Satoyama' near the agriculture field because of the light condition maintenance.
2) The conservation activities should be done by thinning or felling instead of untouchable nature conservation.

We should remake the zoning of Kaisho no mori for maintain the biodiversity return to the 20 years ago.

6. ACKNOWLEDGMENTS

We wish to thank the members of Kaisho no mori Conservation Association for research support and section of environment at Aichi Prefecture Government for permission to work in the conserved area. We also thank Mr. Kamio, Kaisho-no-mori association and the members of our laboratory for their assistance in the field works.

7. REFERENCES

[1] Tsuboi T., The 2005 World Exposition, Aichi, Japan. The Journal of the Institute of Electrical Installation Engineers of Japan, Vol. 25, Issue 3, 2005, pp. 173-174.

[2] Hatta K., and Hiroki S., The conservation of *Luehdorfia japonica* which becomes an index of the Satoyama ecosystem. Lepidoptera Science, Vol 58, Issue 2, 2007, pp. 145-156.

[3] Aichi Prefecture, Conservation management plan of Kaisho-no-mori 2025, Aichi Prefecture, 2016, pp. 17-29.

[4] Aichi Prefecture, Conservation Plan of *Leuhdorfia japonica* in Kaisho-no-mori, Aichi Prefecture, 2016, pp. 1-36.

[5] Ishii M., Conservation of Satoyama in Ecological Aspect. Kodansha Publisher, Tokyo, 2005, pp. 1-20.

[6] Koizumi T., Phytogeographical study on the distribution of 3 species of Asarum in Tama region of Tokyo district from the development of landform. Gakugei Geography, Vol. 73, Issue 1, 2017, pp. 3-15.

[7] Ueda K., Phytogeography of Tokai Hilly Land Element: I. Definition. Acta Phytotaxonomica et Geobotanica, Vol. 40, Issue 5-6, 1989, pp. 190-202.

[8] Primack R.B., Essentials of Conservation Biology 4th ed. Sinauer Associate, Inc. Sunderland, 2010, pp. 341-366.

[9] Jacobson G.L.Jr., Almquist-Jacobson H. and Winne J.C., Conservation of rate plant habitat: Insights from the recent history of vegetation and fire at Crystal Fen, northern Marine USA. Biology Conservation, Vol. 57, Issue 3, 1991, pp. 287-314.

[10] Yuan S.Y., Jiao F., Li Y.H. and Kallenbach R.L., Anthropogenic disturbance are key to maintaining the biodiversity of grassland. Scientific Reports, Vol. 6, Article number: 22132, 2016.

[11] Hughes A.R., Byrnes J.E., Kimbro D.L. and Stachowicz J.J., Reciprocal relationships and potential feedback between biodiversity and disturbance. Ecology Letters, Vol. 10, Issue 9, 2007, pp. 849-862.