An Occasional Journal of the Nodai Ent. Lab.
NODAI ENTOMOLOGY
ISSN 2435-3965 (Online)

Nodai Entomology (3): 1-7 (2022)
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https://www.nodai.ac.jp/agri/original/konken/shigen/publication/publication.html

Butterfly diversity in a vineyard developed from abandoned orchards

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Abstract A vineyard was developed from abandoned orchards in Koshu-shi, Yamanashi Prefecture, Central Japan, in 2017. To investigate the effect of development of abandoned farmland on biodiversity and evaluate the biodiversity in Japanese vineyards, we surveyed butterflies in this vineyard from 2016 to 2022. The species richness and diversity index of butterflies were low in 2016, before the vineyard was developed. After 2018, the butterfly diversity increased as vineyard vegetation became richer and more abundant. *Argyronome laodice japonica*, a vulnerable species, was observed in 2021 and 2022. This study was the first to evaluate the biodiversity in a Japanese vineyard; it revealed that the development of vineyards from abandoned orchards is effective for the conservation of butterflies.

Biodiversity loss continues despite substantial ongoing efforts for biodiversity conservation and sustainable use (Secretariat of the Convention on Biological Diversity, 2020) and an average of approximately 25% of species in assessed animal and plant groups are threatened (IPBES, 2019). In Japan, biodiversity loss has recently been remarkable in agroecosystems (Hidaka, 1998; Katoh *et al*., 2009). The traditional agroecosystem "satoyama", commonly known as SEPLS (socio-ecological production landscapes and seascapes), conserves biodiversity while providing various resources including food, fuel, and building materials (The International Partnership for the Statoyama Initiative, 2022). However, abandonment of farmland has threatened to cause biodiversity loss of various taxa in agroecosystems in Japan as well as worldwide (Koshida & Katayama, 2018), and as a result, a number of species inhabiting satoyama are now endangered (Hidaka, 1998; Katoh *et al*., 2009; Ministry of Environment, 2020). Restoration of abandoned farmlands is expected to recover biodiversity.

Many studies have evaluated the biodiversity of plants and arthropods in vineyards in Europe, the United States of America, and the Republic of South Africa (*e.g*., Nicholls *et al*., 2001; Kehinde & Samways, 2014; Cohen *et al*., 2015; Burgio *et al*., 2016). In contrast, no study has investigated vineyard biodiversity in Japan.

Yamanashi Prefecture ranks first in grape production in Japan (Ministry of Agriculture, Forestry and Fisheries, 2022). In particular, Koshu-shi is well known for producing wine-brewing and table grapes.

Mercian Corporation (a wine maker), Kirin Holdings, developed a vineyard from abandoned orchards in Koshu-shi, in 2017. An investigation of changes in biodiversity caused by vineyard development could elucidate the effect of abandoned farmland development on biodiversity and evaluate the biodiversity status in Japanese vineyards. To address these objectives, we started survey of plants and insects in this field in 2016, just before the vineyard was developed. We chose butterflies as an indicator insect taxon for the following reasons. Butterflies depend on plants; the larvae of most butterfly species feed on specific species or groups of plants and the adult butterflies suck flower nectar or tree sap. Thus, butterflies are suitable indicators of vegetation types and quality. In addition, it is easy to identify butterfly species. This paper shows and discusses the changes in butterfly diversity after the vineyard development.

Accepted 22 November 2022; published 9 December 2022

Materials and Methods

Study area

The vineyard, named "Tenguzawa vineyard", was developed from abandoned orchards at an elevation of 820–860 m in Kamiodawara, Koshu-shi, Yamanashi Prefecture, Central Japan, in 2017. These orchards mainly included peach and plum trees and were abandoned sometime around 1990. In 2016 before the vineyard development, grasses dominated in this area, and trees including chestnut (*Castanea crenata* Siebold et Zucc.), oak (*Quercus acutissima* Carruth.), and pine (*Pinus densiflora* Siebold et Zucc.) grew sparsely (Fig. 1). In a wide region of Yamanashi Prefecture including the study area, the sika deer *Cervus nippon* Temminck, 1838 has caused serious damage to vegetation (Iijima *et al*., 2013; Iijima & Nagaike, 2015). Consequently, dominant weeds were unpalatable plants for sika deer, *i.e*., *Pennisetum alopecuroides* (L.) Spreng., *Miscanthus sinensis* Andersson (Hashimoto & Fujiki, 2014), and *Cirsium vulgare* (Savi) Ten. (Tazaki *et al*., 2014). In addition, heavy grazing and stamping of sika deer resulted in patches of bare ground where *Oxalis corniculata* L. and *O. dillenii* Jacq. invaded.

Fig. 1. Study area of abandoned orchards in 2016 before the Tenguzawa vineyard was developed.

The Tenguzawa vineyard covers an area of approximately 50,000 m^2, consisting of several terraced fields because it is located on a slope. To protect grapevines from sika deer, the vineyard was enclosed with 2.3 m-high wire-mesh fencing. The grapevines were cultivated using a training system of vertical shoot positioning on a vertical trellis. In each terraced field, a margin of 4–8 m surrounded the vine rows to allow farm machinery to pass. The white clover (*Trifolium repens* L.) and pasture grasses (*Festuca arundinacea* Schreb., *Poa pratensis* L., and *Lolium perenne* L.) were planted on the field margins and between the vine rows as ground cover plants, whereas herbs and grasses were planted on the slopes between fields. These plants were sparse in 2018 and grew denser annually (Fig. 2).

Fig. 2. Study area of the Tenguzawa vineyard in 2018 and 2022.

Survey methods

Butterflies were censused in July 2016 (before the vineyard development) and May, June, July, and September as a rule from 2018 to 2022 (after the vineyard development). However, in 2020, no surveys were carried out in May and June because the national government declared a state of emergency for the Kanto district including Kanagawa Prefecture owing to pandemic of the COVID-19 (coronavirus disease 2019). The survey dates were July 25, 2016; May 19, June 23, and July 29, 2018; May 11, June 16, and September 20, 2019; July 22 and September 24, 2020; May 14, June 21, July 12, and September 14, 2021; and May 12, June 27, July 18, and September 21, 2022. The censuses were conducted between 9:00 to 16:00 on fine days by Tanaka alone. It took 2.5–3.0 h to census the entire vineyard. Butterflies were identified and counted by direct observation, observation through field glasses, or by capture with an insect net on the field margins and the slopes between the fields. To evaluate the butterfly diversity, species richness and the Shannon-Wiener diversity index (*H*') were calculated.

Results

A total of 35 species of butterflies were observed for six years (Table 1). In 2021 and 2022, *Argyronome laodice japonica* (tribe Argynnini), a vulnerable species in the Japanese Red List 2020 (Ministry of the Environment, 2020) was identified. The species richness (number of species) and number of individuals of butterflies observed by each census are shown in Table 2 and 3, respectively.

Table 1. Butterfly species observed in the Tenguzawa vineyard in 2016–2022

Family Species	Japanese name	2016	2018	2019	2020	2021	2022
Hesperiidae							
Erynnis montana montana (Bremer, 1861)	ミヤマセセリ		●			●	●
Isoteinon lamprospilus lamprospilus C. Felder et R. Felder, 1862	ホソバセセリ					●	
Ochlodes venatus venatus (Bremer et Grey, 1852)	コキマダラセセリ	●			●		●
Pelopidas mathias (Fabricius, 1798)	チャバネセセリ				●		●
Parnara guttata guttata (Bremer et Grey, 1852)	イチモンジセセリ				●	●	●
Papilionidae							
Papilio xuthus Linnaeus, 1767	アゲハ					●	●
Papilio dehaanii dehaanii C. Felder et R. Felder, 1864	カラスアゲハ	●			●	●	●
Pieridae							
Eurema mandarina mandarina (de l'Orza, 1869)	キタキチョウ	●	●	●	●	●	●
Colias erate poliographa Motschulsky, [1861]	モンキチョウ	●	●	●	●	●	●
Pieris rapae crucivora Boisduval, 1836	モンシロチョウ	●		●	●	●	●
Pieris melete Ménétriès, 1857	スジグロシロチョウ		●	●	●	●	●
Pieris nesis japonica Shirôzu, 1952	ヤマトスジグロシロチョウ						●
Lycaenidae							
Curetis acuta paracuta de Niceville, 1902	ウラギンシジミ					●	●
Arhopala japonica (Murray, 1875)	ムラサキシジミ						●
Japonica saepestriata saepestriata (Hewitson, [1865])	ウラナミアカシジミ	●		●			●
Antigius attilia attilia (Bremer, 1861)	ミズイロオナガシジミ	●					
Lycaena phlaeas chinensis (C. Felder, 1862)	ベニシジミ		●	●	●	●	●
Lampides boeticus (Linnaeus, 1767)	ウラナミシジミ			●	●	●	●
Zizeeria maha argia (Menetries, 1857)	ヤマトシジミ	●	●	●	●	●	●
Everes argiades argiades (Pallas, 1771)	ツバメシジミ		●	●	●	●	●
Celastrina argiolus ladonides (de l'Orza, 1869)	ルリシジミ					●	●
Nymphalidae							
Libythea lepita celtoides Fruhstorfer, [1909]	テングチョウ			●		●	●
Argyronome laodice japonica (Ménétriès, 1857)	ウラギンスジヒョウモン					●	●
Argynnis paphia tsushimana Fruhstorfer, 1906	ミドリヒョウモン				●	●	●
Nephargynnis anadyomene ella (Bremer, [1865])	クモガタヒョウモン					●	●
Fabriciana adippe pallescens (Butler, 1873)	ウラギンヒョウモン	●	●	●		●	●
Argyreus hyperbius hyperbius (Linnaeus, 1763)	ツマグロヒョウモン	●	●	●	●	●	●
Limenitis camilla japonica Menetries, 1857	イチモンジチョウ					●	
Neptis sappho intermedia W. B. Pryer, 1877	コミスジ			●	●	●	●
Polygonia c-aureum c-aureum (Linnaeus, 1758)	キタテハ			●	●	●	●
Kaniska canace nojaponicum (von Siebold, 1824)	ルリタテハ	●					
Inachis io geisha (Stichel, 1908)	クジャクチョウ		●	●		●	
Vanessa cardui (Linnaeus, 1758)	ヒメアカタテハ		●	●	●	●	●
Ypthima argus argus Butler, 1866	ヒメウラナミジャノメ	●	●	●	●	●	●
Minois dryas bipunctata (Motschulsky, [1861])	ジャノメチョウ	●	●	●	●	●	●
No. of species	35	13	13	18	19	28	30

The species richness in July was low in 2018, a year after the vineyard establishment; however, it subsequently increased and was higher in 2020–2022 than it was before the vineyard was established. In May, June, and September, the species richness of butterflies tended to increase annually. On the other hand, the number of butterfly individuals did not consistently increase nor decrease although it fluctuated annually (Table 3).

Table 2. Butterfly species richness (number of species) in the Tenguzawa vineyard

Year	May	June	July	Sep.	Total
2016	—	—	13	—	13
2018	6	6	7	—	13
2019	3	10	—	12	18
2020	—	—	16	13	19
2021	10	14	15	16	28
2022	9	13	18	18	30

—: Surveys were not carried out.

The Shannon-Wiener diversity indices (*H*') of butterflies are shown in Table 4. Because the species richness was low in May (Table 2), the index was not calculated for this month. The lowest *H*' was observed in July 2016 and the *H*' became higher annually as well as the species richness. The *H*' in July 2016 was lower than that in June and July 2018 although the species richness in July 2016 was higher than that in June and July 2018. In July 2016, two dominant species, *i.e.*, *Zizeeria maha argia* (109 individuals) and *Minois dryas bipunctata* (85 individuals) accounted for 89% of a total of 218 butterfly individuals observed (Table 3). After 2018, in addition to these two species, two pierid species, *i.e.*, *Colias erate poliographa* and *Eurema mandarina mandarina*, became dominant (Table 3).

Table 3. Number of butterfly individuals observed in the Tenguzawa vineyard

Year	May	June	July	Sep.
2016	—	—	218 (109, 85, 1, 9)[1)]	—
2018	19	50	95 (35, 7, 3, 25)	—
2019	23	98	—	136
2020	—	—	194 (27, 44, 31, 33)	245
2021	58	64	89 (30, 9, 18, 5)	249
2022	59	129	122 (15, 13, 31, 17)	210

—: Surveys were not carried out.

1) The figures in the parenthesis (Z, M, C, E) indicate the numbers of individuals of *Zizeeria maha argia* (Z), *Minois dryas bipunctata* (M), *Colias erate poliographa* (C), and *Eurema mandarina mandarina* (E).

Table 4. Butterfly diversity index (Shannon-Wiener *H'*) in the Tenguzawa vineyard

Year	June	July	Sep.
2016	—	1.182	—
2018	1.469	1.488	—
2019	1.822	—	1.851
2020	—	1.979	1.702
2021	1.958	2.115	1.944
2022	1.874	2.315	2.120

—: Surveys were not carried out.

Discussion

This study was the first to evaluate the biodiversity of the Japanese vineyard by surveying butterflies. In the abandoned orchards surveyed in 2016, prior to vineyard development, the species richness of butterflies was low, and especially the diversity index (the Shannon-Wiener *H*') was low. The observed low diversity index was due to dominance of two species, *Z. maha argia* and *M. dryas bipunctata*. Heavy grazing by sika deer caused poor vegetation in the abandoned orchards where unpalatable plants for sika deer (*i.e.*, *P. alopecuroides*, *M. sinensis*, and *C. vulgare*) were dominant, and *Oxalis* plants were abundant in patches of bare ground. *Oxalis* and *M. sinensis* are the host plants of *Z. maha argia* and *M. dryas bipunctata*, respectively. Thus, the dominance of a few plant species due to the sika deer grazing resulted in the dominance of two butterfly species and low butterfly diversity.

In 2018, a year after the vineyard development, vegetation was poor in the vineyard, and thereafter became richer annually. As vegetation became richer, the species richness and diversity index of butterflies increased. In addition, a vulnerable species, *Argyronome laodice japonica*, was identified in

2021 and 2022. The tribe Argynnini, which includes this species, is representative taxon of grasslands, and its host plants are members of a genus *Viola*, such as *V. grypoceras* A. Gray and *V. verecunda* A. Gray. Although five Argynnini species (*Argyronome laodice japonica*, *Argynnis paphia tsushimana*, *Nephargynnis anadyomene ella*, *Fabriciana adippe pallescens*, and *Argyreus hyperbius hyperbius*) were observed in the vineyard, they were not abundant. Surveys in the area surrounding the vineyard showed that the *Viola* plants were not abundant there. This low abundance of *Viola* plants was certainly ascribed to grazing by sika deer, which may have caused low populations of the Arginnini butterflies. In the vineyard, *Viola* plants were not seen until 2020 but were observed in 2021 and increased in 2022. In addition, a final instar larva of *Argyreus hyperbius hyperbius* was found within the vineyard on September 21, 2022. *Argyreus hyperbius hyperbius* has rather different biology from other Arginnini species; its habitat includes residential areas and the larvae feed on decorated *Viola* cultivars (pansies) as well as wild *Viola* species unlike other Arginnini species depending on wild *Viola* species. However, the finding of the Arginnini larva which has grown in the vineyard suggests that Arginnini butterflies including *A. laodica japonica* will inhabit the vineyard when *Viola* plants become more abundant. Arginnini butterflies visited the flowers of *Taraxacum officinale* Weber et F. H. Wigg., *Erigeron annuus* (L.) Pers., and *Erigeron philadelphicus* L. in the vineyard. These plants were scarce outside the vineyard, while their abundance in the vineyard increased during the study period. This observation indicates that the vineyard provides nectar resources for butterflies. In addition, many bees, such as *Apis mellifera* Linnaeus, 1758, visited flowers of *T. repens*. Kratschmer *et al*. (2019) demonstrated that increasing floral resources and reducing vegetation management promoted wild bee diversity and abundance in the European vineyards. These observations suggest that the vineyard also had an important function of providing nectar and pollen resources for pollinators.

This study revealed that the Tenguzawa vineyard provides habitats for insects, as observed in plants and arthropods in vineyards of Europe, the United States of America, and the Republic of South Africa (*e.g*., Nicholls *et al*., 2001; Kehinde & Samways, 2014; Cohen *et al*., 2015; Burgio *et al*., 2016). This result indicates that developing vineyards from abandoned orchards is effective for conservation butterflies, particularly grassland butterflies. Grasslands, especially semi-natural grasslands, have drastically decreased in Japan (Ogura, 2010); consequently, many species of plants and animals inhabiting grasslands are endangered (Nakamura, 2011; Ministry of Environment, 2020). Thus, farmlands such as the vineyards developed from abandoned orchards are certainly important to conserve the grassland-dwelling species. However, research evaluating the vineyard biodiversity in Japan is lacking. Therefore, further studies are needed to investigate vineyard biodiversity in other regions and taxa.

要　約

田中幸一・楠本良延：耕作放棄果樹園から造成したワイン用ブドウ園におけるチョウ類の多様性．———— 2017 年に山梨県甲州市において，耕作放棄された果樹園からワイン用ブドウ園が造成された．耕作放棄地を農地に造成することが生物多様性に及ぼす影響を調査すること，また日本のブドウ園における生物多様性を評価することを目的として，造成されたブドウ園において，2016 年から 2022 年までチョウ類の調査を行った．造成前の 2016 年には，チョウ類の種数および多様度指数は低かった．2018 年以降は，ブドウ園の植生が豊かになるにつれて，チョウ類の多様性が増加した．2021，2022 年には，絶滅危惧種であるウラギンスジヒョウモンが確認された．本研究は，日本のブドウ園における生物多様性を評価した最初のものであり，耕作放棄果樹園をブドウ園に造成することが，チョウ類の保全に有効であることを示した．

Acknowledgments

We thank T. Tamura, Y. Yoshida, and Y. Sonoda of Château Mercian; K. Fujiwara, Y. Okamoto, Y. Okonogi and C. Okimura of Kirin Holdings for allowing us to conduct field surveys and providing information of vine culture. This study was financially supported by Kirin Holdings.

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