

## Recovery of an endangered butterfly species, *Shijimiaeoides divinus*, population at Azumino in Nagano Prefecture, Japan

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**Summary** : The large shijimi blue, *Shijimiaeoides divinus*, is a grassland lycaenid butterfly classified as an endangered species by the Ministry of Environment. In this study, I report on the life history of *S. divinus barine* and provide new data on the recovery of the natural population in Azumino. This butterfly is single-breeded with the adults usually appearing from late May to early June in Nagano Prefecture. Only three populations of *S. divinus barine* are maintained in Nagano Prefecture by several volunteer groups. In Azumino, efforts to introduce individuals at pupal stage in a butterfly sanctuary failed because of appearance of the egg parasite *Trichogramma chilonis*, which is an important mortality factor of the egg stage of *S. divinus barine*. On March 29, 2009, we experimentally tested the effect of bush burning on eggs parasitoids. Bush burning proved to have a negative effect on *T. chilonis*. Subsequently, bush burning was performed in a wide area during 2011 as a conservation measure. As a result, natural population of *S. divinus barine* recovered at the sanctuary area in Azumino after 15 years of absence.

**Key word** : *Shijimiaeoides divinus*, endangered butterfly, Azumino, *Trichogramma chilonis*, bush burning

### Introduction

The large shijimi blue, *Shijimiaeoides divinus* (Lepidoptera: Lycaenidae), is a grassland lycaenid butterfly, classified as an endangered species by the Ministry of Environment<sup>3)</sup> and by Nagano Prefecture<sup>13)</sup>. *S. divinus* comprises five subspecies worldwide, but only two of those subspecies have been reported from Japan, *S. divinus barine* from the eastern part of Honshu<sup>8)</sup> and *S. divinus asonis* found in the Kuju Kogen and Mt. Aso in Kyushu<sup>2,9)</sup>. The other three subspecies are found in the Korean Peninsula, Northeastern China, and the Southern Amur region<sup>1)</sup>. The type specimen of the original subspecies *S. divinus divinus* was collected at Kaesong in North Korea (Fig. 1). The other two subspecies were *S. divinus asahii*, recorded from the Great Ussuri Island, and *S. divinus shinichiroi*, recorded from Shanxi area in China<sup>1)</sup>.

In this study, I report the life history of this species in Japan and provide evidence on the recovery of the natural population of *S. divinus* in Azumino, Nagano Prefecture. From these results, I discuss how to increase the numbers of this butterfly.

### Life history

Fig. 2 shows the life cycle and photos of *S. divinus* in various developmental stages. The wing size of adult is 3–4 cm, which is relatively large for a lycaenid butterfly. The wings are light blue. While female wings have several black spots, males are spotless. This butterfly is single-breeded and the adult usually appearing from late May to early June in Nagano Prefecture. Females lay eggs on the flower buds of *Sophora flavescens*, which is the only host plant of *S. divinus*. Eggs hatch in one week after oviposition, and the larvae develops through four feeding instars in June and July. The last instar larvae pupate under withered leaves or in the soil, where they over-

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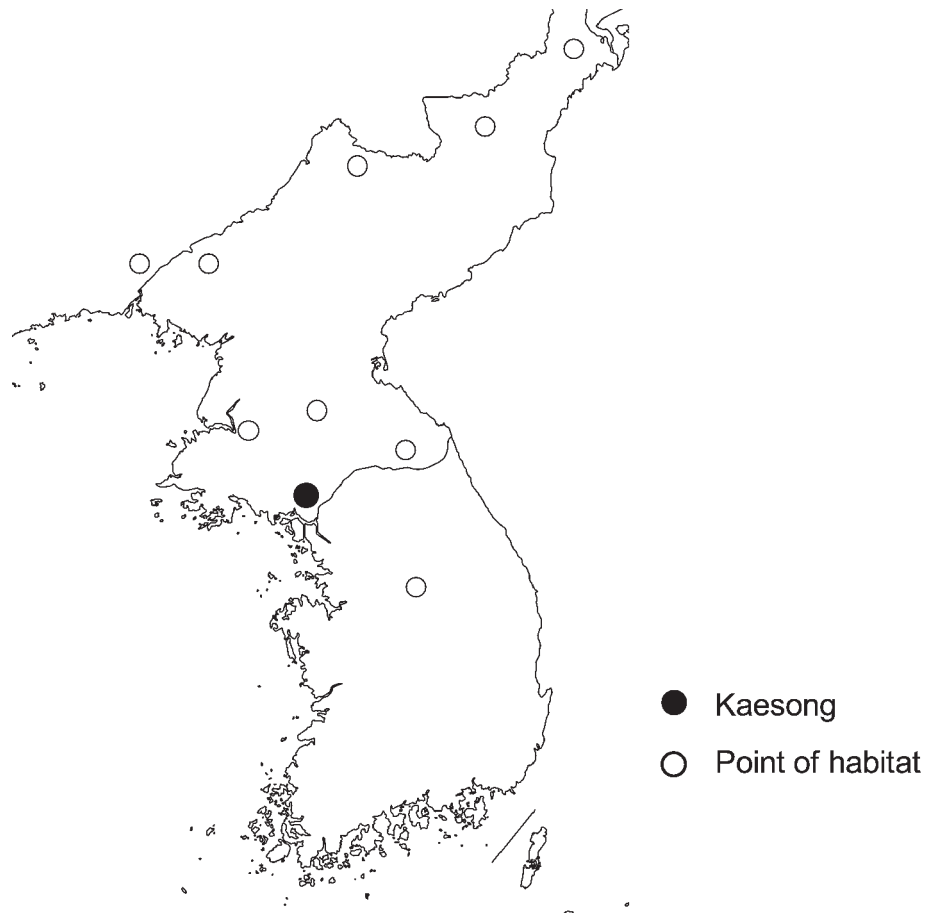


Fig. 1 Distribution map of *Shijimiaeoides divinus*. Original subspecies, *S. divinus divinus* was collected at Keasong. (revision of Koda, 2010)

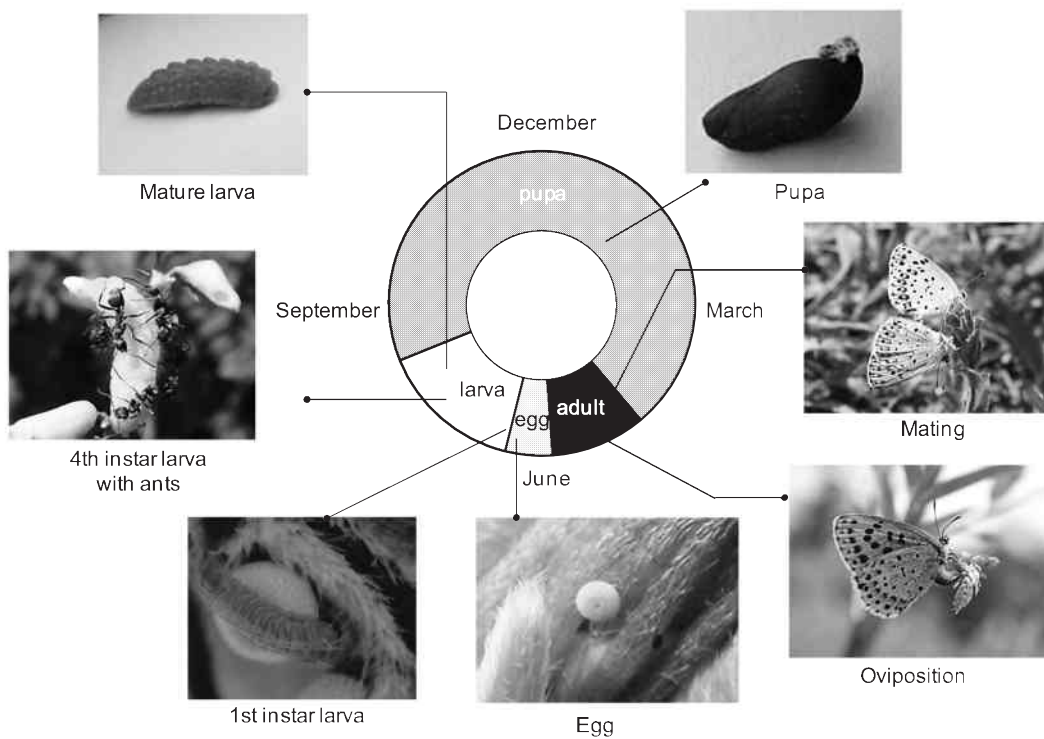


Fig. 2 Life cycle of *Shijimiaeoides divinus barine* in Nagano Prefecture.

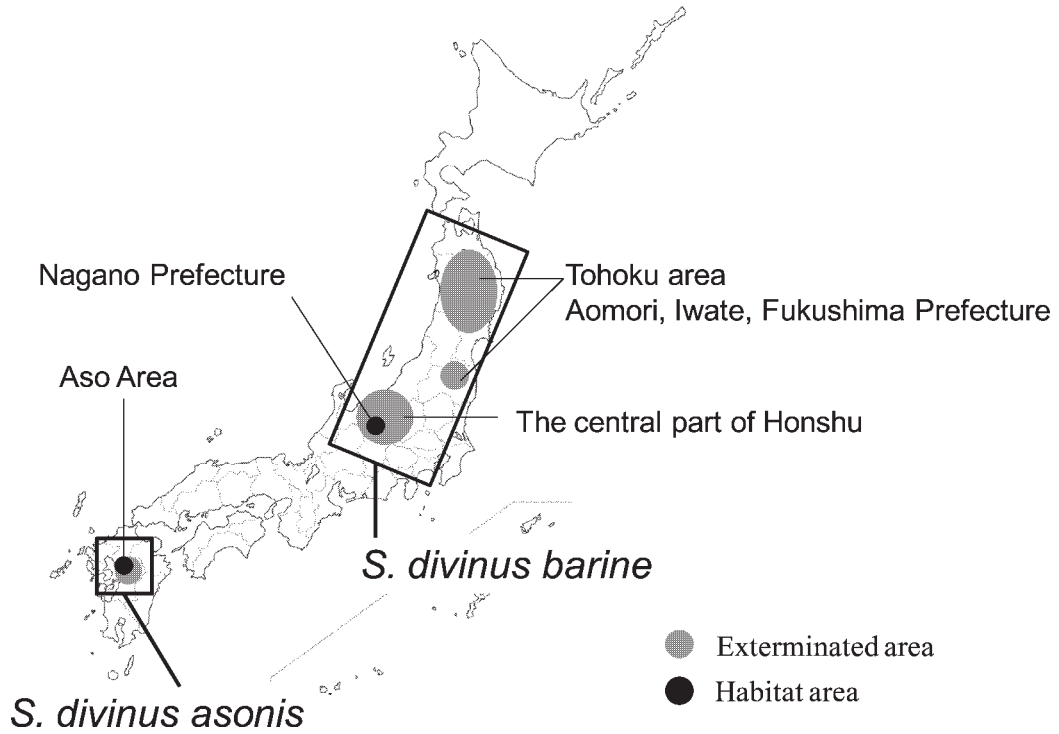


Fig. 3 Distribution map of *Shijimiaeoides divinus* in Japan.

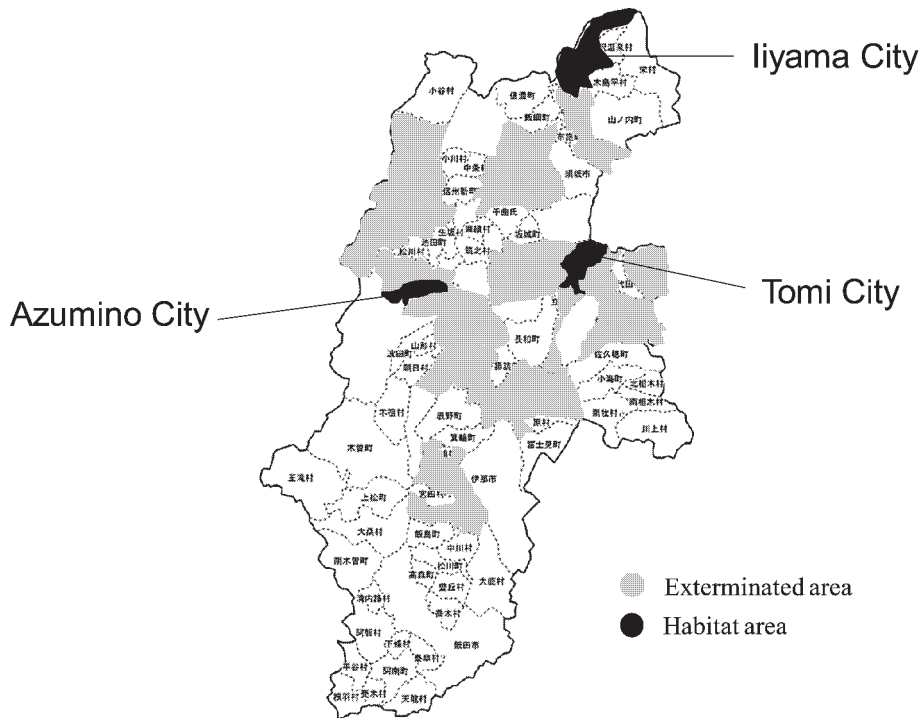


Fig. 4 Decrease in the distribution area of *Shijimiaeoides divinus barine* in Nagano Prefecture.

winter until next year<sup>3)</sup>.

**Habitat loss**

*Shijimiaeoides divinus barine* inhabits the central part of Honshu, including Niigata, Nagano,

and Gunma Prefectures. In the 1990s, most of its populations were exterminated (Fig. 3). Currently, this species is only found in Nagano Prefecture. In Kyushu, a large population of *S. divinus asonis* is still found around Mt Aso, but habitat change has caused a decline in the butterfly population<sup>10,11)</sup>.

Before 1964, this butterfly inhabited 19 villages and towns in Nagano Prefecture<sup>12)</sup>. Thereafter, areas of suitable habitat have gradually decreased, and this butterfly disappeared rapidly after 1980 (Fig. 4)<sup>14)</sup>. Only three populations of *S. divinus barine* are maintained, thanks to the efforts of several volunteer groups, who perform conservation and management activities aimed at preserving this butterfly.

### Conservation activities in Azumino

*Shijimiaeoides divinus barine* population in Azumino has faced an extremely high risk of extinction. A voluntary group has been performing conservation activities, patrolling, artificially rearing the eggs, and releasing the pupae in the sanctuary of *S. divinus barine* since 1994. Individuals introduced at pupal stage failed to establish in the sanctuary despite the abundance of the host plant, *S. flavescens*<sup>3)</sup>.

I investigated mortality factors affecting the eggs and the larval stages to the fourth instar in Azumino to clarify the reason why *S. divinus barine* population introduced at the pupal stage did not establish. Main mortality factors of the egg stage were parasitism, dropping, physiological death, and unfertilized egg. The dominant egg parasitoid was *Trichogramma chilonis* (Hymenoptera; Trichogrammatidae; Fig. 5). Predation by spiders such as *Misumenops tricuspoidatus* and stinkbugs such as *Eocanthecona japonicola* was also observed at the larval stage. Larvae of the third and fourth instar were often accompanied by ants such as *Lasius japonicus* or *Formica japonica*<sup>3)</sup>.

### Evaluation of egg parasitism

It has been shown that the egg parasitoid, *T. chilonis* is an important mortality factor of the egg stage of *S. divinus barine*. To examine impact of parasitism in Azumino, *S. divinus barine* eggs were sampled at the sanctuary area where artificial breeding pupae are released every year. Approximately 30% of individuals were parasit-

ized by early June 2006 when adult butterflies began to emerge, and it exceeded 60% after mid-June. From this investigation, it was clarified that most of the eggs were killed by this egg parasitoid<sup>5)</sup>.

In 2008, I compared the incidence of parasitism in the sanctuary with a natural population area where *S. divinus barine* is rarely found. The result clearly indicated that parasitism incidence was higher in the sanctuary (58.8%) than in the natural population area (12.1%; Fig. 6). *T. chilonis* adults were also collected by a sticky trap, and the number of *T. chilonis* captured at the natural population area in June and July was lower than that in the sanctuary<sup>5)</sup>.

### Bush burning experiment

Why *T. chilonis* incidence at the natural population area was lower than that in the sanctuary? While the natural population area was burnt in

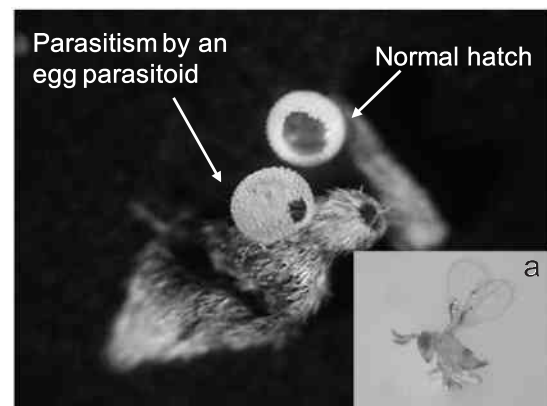


Fig. 5 Parasitized and normal hatched eggs. a: *Trichogramma chilonis* (revision of Koda, 2011).

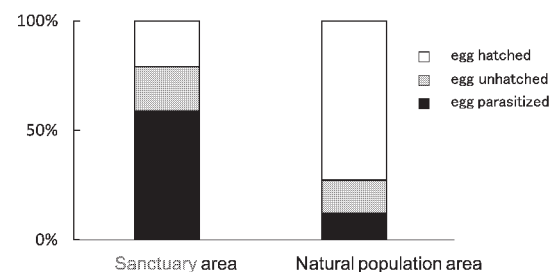


Fig. 6 Parasitism incidence by *Trichogramma chilonis* on eggs of *Shijimiaeoides divinus barine* in Azumino (revision of Koda, 2011).

spring every year, the sanctuary was not, suggesting that bush burning may be playing an essential role controlling the population of *T. chilonis*. *T. chilonis* overwinters in Lepidopteran eggs, and the larvae of *S. divinus barine* pupate underground. If the habitat is burnt, *T. chilonis* may be killed by fire, but pupae of *S. divinus barine* may survive under the ground.

An experiment of bush burning was performed at the sanctuary area in Azumino on March 29, 2009 to verify its effect on parasitism of egg parasitoid (Fig. 7). Immediately after bush burning, cages were set up in the burned and control areas. *S. divinus barine* eggs were then collected for observation, and *T. chilonis* adults were collected by sticky trap both inside and outside the cages. The parasitism incidence inside the cage on June 9 was 2.3% in the burned area and 30.3% in the control area, reaching similar values outside the cage (Fig. 8). A total of 21 individuals of *T. chilonis* were captured by sticky trap inside the cage from May 5 to June 9 in the control area, but no individuals were captured in the bush burning area, suggesting that bush burning had a negative effect on *T. chilonis*. Bush burning was thus proven to be efficient to control the levels of parasitism on *S. divinus barine* eggs.

### Recovery of the natural population in Azumino

Bush burning in a small area in the sanctuary was performed in 2010 following the same method, but parasitism incidence was not reduced outside the cage. However, bush burning was successfully performed in a larger area in 2011, and as a result, the natural population of *S. divinus barine* (Fig. 9) recovered at the sanctuary in Azumino after 15 years of absence<sup>4)</sup>. Many butterflies were found in 2012 and 2013 without releasing the pupae.

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Fig. 7 Photo of bush burning experiment at the sanctuary in Azumino (March 29, 2009).

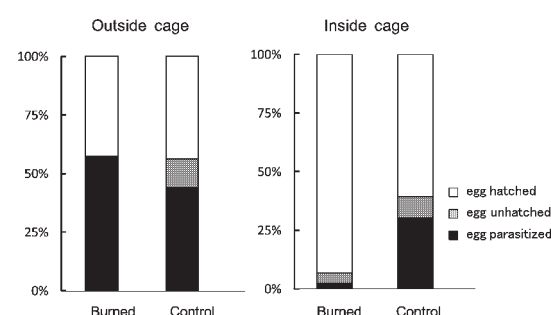


Fig. 8 Percentage of parasitism incidence by *Trichogramma chilonis* on eggs of *Shijimiaeoides divinus barine* after bush burning.



Fig. 9 *Shijimiaeoides divinus barine* female from the natural population recovered at the sanctuary in Azumino.

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## 長野県安曇野における絶滅危惧種オオルリシジミ个体群の回復

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### 要 約

オオルリシジミは草原性のシジミチョウで、環境省の絶滅危惧種に指定されている。ここではオオルリシジミの生活史と、長野県安曇野における自然个体群回復のための研究を報告する。このチョウは年1化性で、長野県では5月下旬から6月上旬に成虫が出現する。オオルリシジミ本州亜種は、保護グループによって長野県の3个体群のみが維持されているに過ぎない。安曇野では保護区に蛹を人為的に導入しているが定着していない。卵寄生蜂のメアカタマゴバチが、オオルリシジミ卵期の重要な死亡要因であることがわかった。野焼きが卵期寄生率に効果があるかを確かめるために、2009年3月29日に安曇野の保護区で野焼き実験がおこなわれた。野焼きはメアカタマゴバチの寄生を減らす効果があるという結論が得られた。そこで広範囲の野焼きが2011年におこなわれ、その結果、オオルリシジミの自然个体群が15年ぶりに安曇野の保護区において回復した。

キーワード：オオルリシジミ，絶滅危惧種，安曇野，メアカタマゴバチ，野焼き