Allometric approach to the two ecological morphs in the Japanese firefly *Luciola parvula*

Yutaka Iguchi

*Affiliation not available

May 31, 2023

**Yutaka Iguchi***
Laboratory of Biology, Yamashita-cho 1-10-6, Okaya City, Nagano Prefecture, 394-0005, Japan

* Correspondence:
Corresponding Author
bio-igu@f8.dion.ne.jp

**Abstract**

*Luciola parvula* (Coleoptera, Lampyridae) is a terrestrial firefly species widely distributed in Japan. Previous studies reported that there were two ecological morphs of adults of this species: large and small morphs. However, the procedure used to identify the two morphs has remained ambiguous and confused. The present article provides a brief review of the two morphs in this species and then proposes an allometric approach to detect the existence of the two morphs.

**Keywords**

body size, variation, discontinuity, phenotypic plasticity, dimorphism

**Introduction**

*Luciola parvula* (Coleoptera, Lampyridae) is a terrestrial firefly species widely distributed in Japan and shows large geographical variation in adult body size especially in mountainous areas. Previous studies reported that there were two ecological morphs of adults of this species: large and small morphs. However, the procedure used to identify the two morphs has remained ambiguous and confused. Therefore, the present article begins with a brief review of the two morphs in this species and then proposes an allometric approach to detect the existence of the two morphs.

As far as the present author knows, Ohba (1) was the first to describe the criteria for the classification of the two morphs in this species. He collected male adults at Mt. Hakone, central Japan and then identified the large morph above 700 m altitude and the small morph below this altitude. He also reported that the approximate body length was 10 mm for the large morph and 6 mm for the small morph.

Ohba (2) further examined male adults of this species throughout Japan and then found the large morph with body length 7 to 9 mm and pronotum width larger than 2.1 mm and the small morph with body length 5 to 7 mm and pronotum width smaller than 2.1 mm.

Mitsuishi (3-6) collected male adults of this species at 41 sites in Nagano Prefecture, central Japan and classified them into the large morph (body length larger than 8 mm) and the small morph (body length...
approximately 7 mm). As a result, he found that this species in this prefecture tends to be segregated into a northeastern and a southwestern group corresponding to the large and the small morph, respectively, but that both morphs exist above 1000 m altitude. However, these findings were not consistent with Ohba’s findings (1). This may be partly due to the arbitrariness of the criteria for the two morphs.

Ohba (7) reviewed his studies on the two morphs of this species and summarized his criteria for the classification of them: the large morph with body length 7 to 8 mm below 1600 m altitude and the small morph with body length 5 to 6 mm below 800 m altitude.

Kusaoke et al. (8) investigated the distribution of this species in Toyama Prefecture, adjacent to Nagano Prefecture mentioned above and found the small morph (body length approximately 6 mm) at three sites at altitudes of 400 to 700 m and the large morph (body length approximately 8 mm) at an altitudes of 1100 m. As they mentioned, these findings almost fell into Ohba’s criteria (7). Therefore, they considered that Mitsuishi (3–6) had found only the large morph above 1000 m altitude in Nagano Prefecture.

However, Kusaoke et al. (8) also found at Mt. Daisen, Tottori Prefecture, that the large morph (mean body length 8.12 mm) exited at 1709 m altitude and small morph (mean body length 7.14 mm) at 800 m altitude. These mean values of body length were not consistent with Ohba’s criteria (7).

In these studies, this species was more or less arbitrarily classified into the large and small morphs. No statistical analysis was performed to examine whether or not body size varies continuously.

Molecular phylogenetic studies suggested that the small morph originated from an ancestor similar to the large morph (9, 10). However, no genetic difference was found between the two morphs at Mt. Daisen, Tottori Prefecture (8).

Ohba (7) also showed that the flash interval (0.5 to 0.6 s) of the small morphs is smaller than that (0.7 to 0.8 s) of the large morph. However, he did not take into consideration the effect of temperature on flash intervals. In fact, such temperature effects were found and statistically analyzed in *Nipponoluciola cruciate* (11–13). Therefore, it remains unclear whether the two morphs of this species show different flash intervals under controlled temperature.

Regarding morphological measurements of *L. parvula*, the previous studies focused on simple descriptive statistics such as mean values of body length. However, multivariate analyses are considered necessary for detecting size dimorphism in this species. Therefore, the existence of inconsistent criteria for the two morphs of this species leads the present author to reexamine published data on measurements of this species.

Fortunately, Mitsuishi (3–6) showed his measurement data on body length, body width and pronotum width at 41 sites in Nagano Prefecture. Using these data, the present article attempts to detect differences in scaling relationships between the two morphs by allometric analysis. The results will help to provide direction for future studies on the size dimorphism of this species.

**Materials, methods, and analysis**

The data analyzed here were obtained from Mitsuishi’s data (3–6) published in *Zenkoku Hotaru Kenkyukai-shi* (Proceedings of the Japan Association for Fireflies Research). These articles are freely available on the website of the Japan Association for Fireflies Research (http://zenhoken-std.sakura.ne.jp/). Mitsuishi (3–6) recorded his measurement data as the mean values of body length (length from anterior margin of pronotum to posterior margin of elytra), body width (width across both elytra covering mesonotum) and pronotum width at 41 sites in Nagano Prefecture.

In the present study, cluster analysis was first performed to classify the measurement data into two groups using Ward’s method with Euclidean distance. Then, allometric equations were applied to the two groups using standardized major axis regression with the smatr package in R version 4.2.2 (14). The data were log10 transformed and thereby the log-log relationship between pronotum width (*x*) and body length (*y*),
the log10-transformed allometric equation was expressed as:

\[ y = a + b \times x \]

where \( a \) and \( b \) are constants. The constant \( b \) is the slope of the line, also known as the allometric coefficient.

This allometric equation was fitted to each of the two groups identified by the cluster analysis. As shown in Figure 1, the two allometric lines representing the two groups did not differ significantly in slope (\( \chi^2 = 0.077, \text{df} = 1, p = 0.78 \)), but did differ significantly in elevation (\( \chi^2 = 229.6, \text{df} = 1, p < 0.001 \)). The two allometric lines were found to be parallel and share a common slope of 0.34.

Discussion

Kusaoke et al. (8) followed Ohba’s criteria (small morph, body length 5 to 6 mm, below 800 m altitude) (7) and suggested the possibility that almost all the specimens collected by Mitsuishi (3–6) may belong to the large morph. However, the present article confirmed the existence of the two morphs showing discontinuous allometric scaling relationship.

Kusaoke et al. (8) found no genetic difference between the two morphs at Mt. Daisen, Tottori Prefecture. Moreover, Suzuki (9) and Hiyori et al. (10) reported no genetic difference between them in Nagano Prefecture where Mitsuishi (3–6) collected the specimens. Therefore, in \( L. \ parvula \), the difference in allometry between the two morphs with genetic similarity may be connected with the morphological plasticity of this species.

There are few studies on intrasexual dimorphism in lampyrid species except for Wu et al. (15), who documented two distinct male morphs with different mating strategies in \( A. \ cerata \) (previously named \( L. \ cerata \)) in Taiwan. Further detailed molecular phylogenetic and morphological studies will be necessary to confirm the male dimorphism of \( L. \ parvula \) throughout Japan.

In conclusion, the present article strongly recommends that allometric analysis should be used to identify the two morphs in this species in future studies.

Acknowledgements

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

References


Figure 1
Allometric relationship between pronotum width and body length in the groups A and B in L. parvula fireflies. The groups were identified by the cluster analysis of Mitsuishi’s published data (3–6). The standardized major axis regression lines were separately fitted to each group.