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Seasonal Variation in the Adult Body Size of the Genji-firefly *Luciola cruciata* (Coleoptera: Lampyridae)

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Abstract Field research on adult *Luciola cruciata* revealed that both males and females showed noticeable seasonal variation in body size. As the season advanced, male body size decreased at an almost constant rate, whereas females showed a more complicated pattern of seasonal variation in body size. The reason for the different patterns of seasonal variation in adult body size may have been due to a difference in the duration of the larval stage between males and females. The present results suggest that the data on adult body size reported so far may have included seasonal variation as well as geographic variation.

Introduction

Morphological studies hitherto handled *Luciola cruciata* MOTSCHULSKY showed noticeable geographic variation in adult body size (reviewed by OHBA, 1988 and MITSUISHI, 1991). However, there were no studies on seasonal variation in body size in this firefly except for Yuma (1981), who showed that larger larvae climbed up to the river bank to pupate earlier in the season. If seasonal variation in body size exists, it must be included in the data of the geographical variation in the previous reports. Therefore, it is important to know whether or not body size varies in the season. In the present study, I will describe patterns of seasonal variation in male and female body sizes in a field population.

Materials and Methods

The study route was located along a stream called “Denbei-segi” in Matsuo-kyo, Tatsuno-machi, Kamiina-gun, Nagano Prefecture, Japan (Fig. 1). My past

research in 1994–1997 showed that more than 100 adult fireflies emerged along the route, outside which the number abruptly decreased. Therefore the route was suitable for the field observation of seasonal variation in adult body size and number.

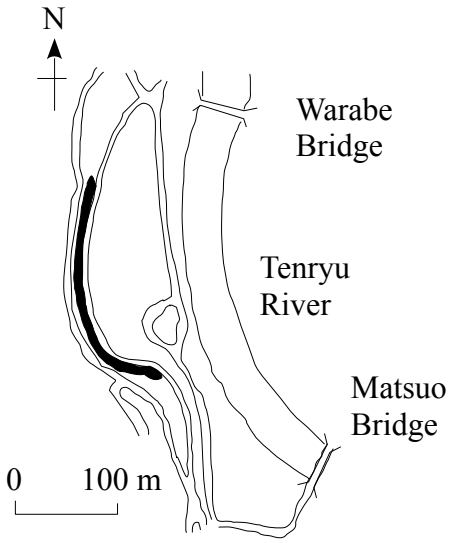

Fig. 1. Map showing the study route (thick line) in Matsuo-kyo, Tatsuno-machi, Kamiina-gun, Nagano Prefecture.

Field investigations were carried out when fireflies were inactive between 23:00 and 3:00 on 4, 11, 18, 20, 25 June and 2 July 1998. On each night, all adults emitting light were counted first. Then, 30–100 adult, which corresponded to ≧ 20 % of the number of adults counted, were randomly captured with an insect net. The sex ratio of the adults captured was used to estimate the numbers of male and female adults present. This method may not indicate the exact number of each sex (HORI, et al., 1978). In the present study, however, this method is sufficient to describe the pattern of seasonal trend in the number of each sex. For each adult captured, sex and body size were recorded. The body size was measured as the length of the body excluding the head, because the body length including the head length tended to produce a considerable measurement error due to its flexible position. The measurement was taken to 0.1 mm with a slide caliper.

The pattern of seasonal variation in body size was analyzed as follows. First, the data were tested for the following quadratic equation:

$y = ax^2 + bx + c$

where y denoted body length on a day x in June, and a, b and c were regression coefficients. Then, if a did not differ significantly from zero, the data were tested to the following regression line:

$$y = px + q$$

where x and y was defined above, and p and q were regression coefficients.

Results

As Fig. 2 shows, the observed seasonal variation in male body size was expressed as a straight line, $y = -0.036x + 12.87$. This line had a negative slope, which differed significantly from 0 (t =3.90, df =224, $P < 0.001$). In contrast, the female variation was expressed as a parabola having a peak in the mid season, $y = -0.004lx^2 + 0.13x + 13.75$.

The analysis of variance showed significant difference in the body size of both males and females among the 6 observation days (males: $F = 4.33$, df = 5, 220, $P < 0.001$; females $F = 2.52$, df =5, 72, $P < 0.05$). The mean body size of males varied from 12.0 to 12.7 mm and the range in variation corresponded to ca. 6 % of the mean body size of all the males (12.4 mm). On the other hand, the mean body size of females varied from 13.5 to 15.1 mm and the range in variation corresponded to ca. 11 % of the mean body size of all the females (14.6 mm). The variance of body size for all the females was significantly larger than that for all the males ($F = 1.55$, df = 177, 225, $P < 0.01$).

Discussion

In the present study, males and females showed different patterns of seasonal variation in body size. As the season advanced, male body size decreased at an almost constant rate. In contrast, female body size was more variable and showed a parabolic pattern of seasonal variation. YUMA (1981) examined the body sizes of male and female larvae climbing up the bank, and revealed that as the season advanced, the body size of male larvae decreased more clearly than that of female larvae. The present results were consistent with his observation. In this firefly, males usually pupate after the 6th instar, whereas females pupate after the 7th instar as well as the 6th instar (YUMA, 1986). The reason that females showed a more complicated pattern of seasonal variation in body size may have been due to the presence of females that pupated in two different larval stages.

Past studies on adult body size in *L. cruciata* (e.g. OHBA, 1988 and MITSUISHI, 1991) showed noticeable geographic variation, but not seasonal variation. However, the present study showed the noticeable seasonal variation in adult body size in this firefly. Therefore, the data on adult body size reported

so far must include seasonal variation as well as geographic variation. As the results obtained by the present study, the body sizes of *L. cruciata* must be examined from the geographical and seasonal points of view for comparison in the future.

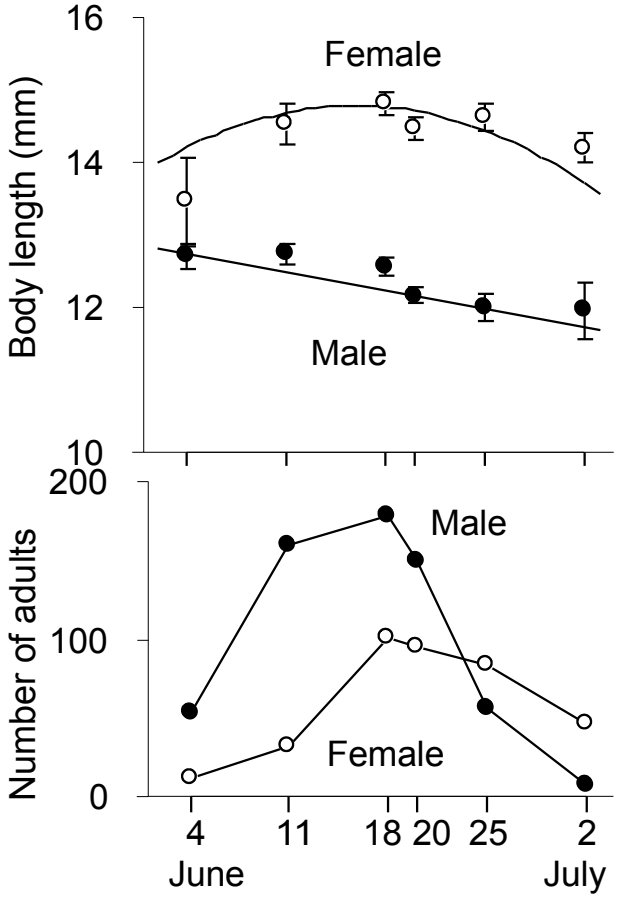

Fig. 2. Seasonal changes in the number and body length of male and female adults in *L cruciata*. For each sample, the mean ± standard error is indicated. Body length was measured as the length of the body excluding the head. The numbers of males and females were estimated from two parameters, the total number of adults counted and the sex ratio of adults captured.

要　　約

井口豊：ゲンジボタルの体長の季節変化．――― 野外採集したゲンジボタル成虫の体長の季節的変異を調べた．その結果，雄の体長は季節が進むにつれてほぼ直線的に減少したのに対し，雌の体長は放物線的に変化した．過去の研究から，ほとんどの雄が 6 令幼虫で蛹化するのに対し，雌は 6 令幼虫でも 7 令幼虫でも蛹化することがわかっている．この幼虫期間の違いが，雌の体長の複雑な季節的変異を生んでいると推察できる．本研究において，雄と雌の体長は顕著な季節的変異を示した．これまで報告されたゲンジボタル成虫の体長に関するデータには，地理的変異だけではなく，季節的変異も含まれている可能性がある．

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