

Mating behavior of a Japanese *Hotaria* firefly (Coleoptera: Lampyridae)

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(With 2 text-figures and 3 tables)

日本産 *Hotaria* 属ホタルの配偶行動

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日本産 *Hotaria* 属ホタルの一種であるヒメボタル *Hotaria parvula* の配偶行動様式を 16 mm シネフィルムにより記録、解析し、日本で初めて日本産ホタルの発光交信様式を明らかにした。

ヒメボタルの雄は日没後に飛翔発光する(発光間隔 0.92 秒前後、発光持続時間 0.06 秒前後)。雌は雄の飛翔発光行動に誘起され、草の根元から茎に這い上り、雌固有の発光パターンで発光し続ける(発光間隔 2.73 秒、発光持続時間 0.21 秒前後)。雌の光を発見した雄は 10-20 cm の範囲にまで接近し、更に発光を繰り返す。その後雄の発光に対して雌は一定時間後(約 0.32 秒後)に応答発光する。雌の発光はややキラメキを伴い、雄が発光を中止すると雌も中止する。雌雄が接近するに伴い、両者の発光間隔は次第に短くなり、近似する。交尾直前の発光間隔は雄 0.50 秒、雌 0.53 秒であり、発光持続時間は雄 0.05 秒、雌 0.16 秒である。ヒメボタルは以上の様な光の交信を行なった後に交尾に至った。この配偶行動様式は LLOYD (1978) が示した system II に相当するものと考えられる。同一条件下では発光パターン、応答するまでの遅れの時間はほぼ一定であるが、温度他の要因で若干変化する。

Introduction

Fireflies of many species use luminescent mating signals (LLOYD, 1978). The function of flashing as a mating adaptation was established largely through the studies of MCDERMOTT (e.g., 1911). BARBER (1951) through observation of male flashing patterns, recognized several species in the genus *Photuris*. SCHWALB (1961), KAUFMANN (1965), and LLOYD (1964, 1965a, 1965b, 1972, 1973) carried out studies on communicative function. The mating behavior of most Nearctic *Photinus* has been described (LLOYD, 1966). There have been few studies on the flash communication of Japanese fireflies (OHBA, 1978, 1979a, 1979b and YAJIMA, 1978). However the above studies have not enough to disclose the nature of the mating system of Japanese fireflies. The present study is intend to establish a foundation of general knowledge on the mating behavior of the Japanese firefly, *Hotaria parvula*.

The species *H. parvula* was selected because of: (1) its terrestrial rather

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than arboreal habit, and (2) the apparent simplicity of the function of flashing in adult.

Material and methods

Observations were made on *H. parvula* inhabiting the moat of Nagoya Castle, Nagoya City, central Japan, where a large population exists. In the field, the flash intervals of flying males were measured with a stopwatch. Flash interactions were recorded with a 16 mm cine-camera (Bolex, H. 16) using 16 mm cine-film (Fujichrom RT 500). Film speed was 24 frames per second. The films were carried through the normal development time (i.e. "pushed" 2×).

Observation

Observations were made from 25 to 27 May, 1979. Flashing and flying activity of males began approximately 30 minutes after sunset, and gradually reached a peak 4-5 hours later. The flying and flashing ceased 2-3 hours later. Male flight was diminished or ended by rain, strong wind, and moonlight or other illumination. Males flew about one meter above the ground. Their flashes were very rhythmical. The interval between flashes was 0.92 seconds (a flash rate of 1.09 Hz) at 18°C (Table 1), and pulse duration was about 0.06 seconds. After the males began flying and flashing, females climbed up a stem of weed or upon the surface of a rock, and began emitting rhythmic flashes with twinkling. The interval between female flashes was about 2.73 seconds (flash rate was 0.37 Hz) at 18°C. The mean duration of their flashes was 0.21 seconds at 18°C (Table 2). When males approached to within 10-20 cm of a female, their emissions appeared to become very rhythmical. Then the interval between their flashes was approxi-

Table 1. Flash pattern interval in *Hotaria parvula* recorded.

SEX	TEMP. (°C)	N	MEAN (SEC.)	RANGE (SEC.)	NOTE
M	15	1	0.90**	-----	FLYING
M	18	4	0.92**	0.84-1.02	FLYING
M	15	1	0.67*	-----	PRE-MATING
M	18	5	0.60*	0.54-0.66	PRE-MATING
F	18	7	2.73**	1.26-3.29	
F	15	2	2.32**	1.70-2.92	
F	18	11	0.87*	0.33-1.13	PRE-MATING
F	18	5	0.58*	0.50-0.71	PRE-MATING
F	18	6	0.53*	0.33-0.96	PRE-MATING

* Determined by 16 mm cine-film. ** Measured by stop-watch.

M: male, F: female

Table 2. Flash duration in *Hotaria parvula*, recorded by 16mm cine-film.

SEX	TEMP. (°C)	N	MEAN (SEC.)	RANGE (SEC.)
M	20	10	0.06	-----
M	18	6	0.06	0.04-0.08
M	18	7	0.05	0.04-0.13
F	18	6	0.21	-----
F	18	10	0.19	0.17-0.20
F	18	7	0.16	0.13-0.21

mately 0.60 seconds and duration of their flashes about 0.06 seconds. Females responded to the flashes of male. Female response flashes with twinkling was flashed after a short delay (Fig. 1, Table 3). Females emitted flashes with at average delay time of 0.32 seconds at 18°C. If the flashes of male stopped, the female flashes ceased. As the female flashing returned to normal and the male detected the female flashes the male walked toward the female, flashing as it proceeded. Then the flash interval of male approached approximately 0.58 seconds and the duration of flashes was approximately 0.05 seconds. At such times the female flash interval became 0.53 seconds and the flash duration 0.16 seconds. After a while, the male reached and mounted the female at once, and both stopped flashing immediately.

Discussion

A diagram of the mating behavior of *H. parvula* is shown in Figure 2. Female flash intervals and durations are longer when males are absent, than when a flashing male is approaching.

When a male approaches a female, the luminescence interval and duration of the female gradually shorter but response delay time remains almost constant (Fig. 1, Table 3).

The male then flies and walk towards the female, and during this approach the pair maintain a flash dialogue. *H. parvula* displays the simple "flash-answer" (male: single flash, female: short delay, single flash) type of signal. This flash communication system is the same one as system II (LLOYD, 1978).

For Japanese fireflies, *H. parvula* is the first flash communication system to be so determined.

As the flash patterns of three Japanese fireflies, *H. parvula*, *Luciola kuroiwae*, and *L. fliformis yayeyamana* are very similarly short pulsed (OHBA, 1979b), it may be suspected that the flash communication system of these fireflies are same as in system II.

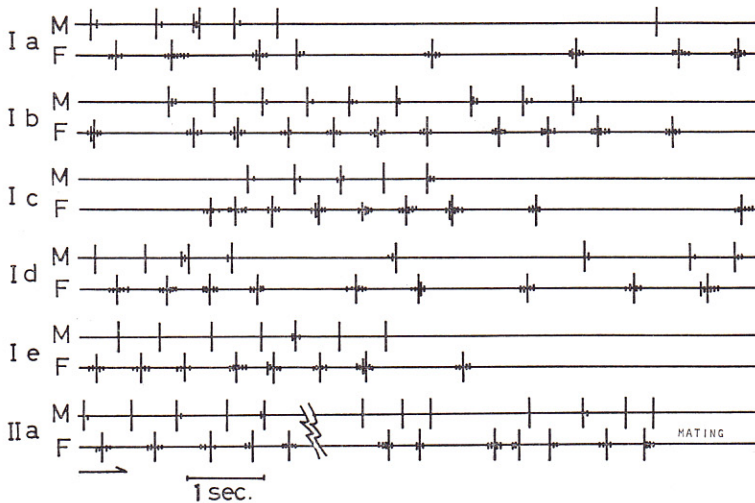


Fig. 1. Flash communication of *Hotaria parvula*.
Read left to right, from Ia to Ie. M: male, F: female, |: bright flash
|||: twinkling dimiflashes.

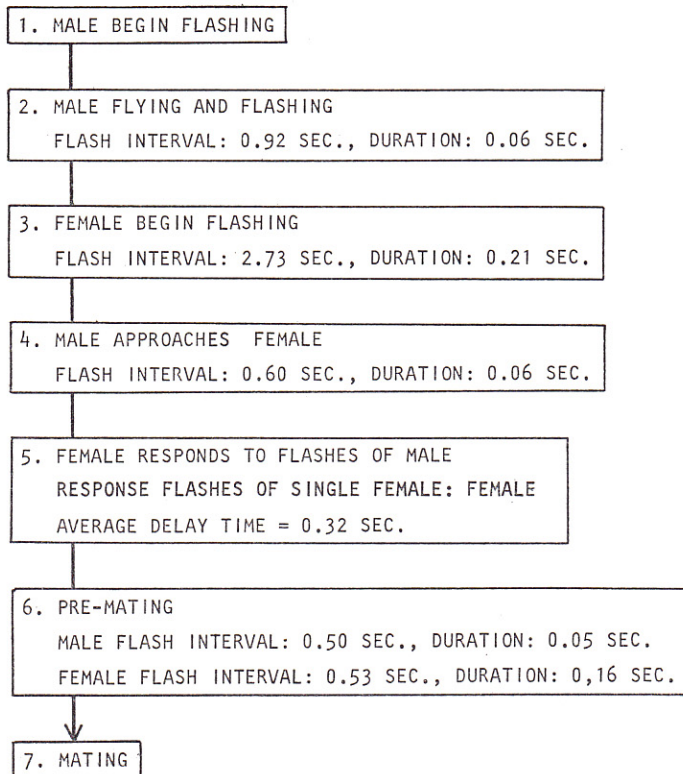


Fig. 2. Diagram of the *Hotaria parvula* flash communication system.

Table 3. Female *Hotaria parvula* response delay time at 18°C, recorded by 16mm cine-film.

FEMALE NO.	MEAN(SEC.)	S	RECORDED VALUE(SEC.)
1	0.29	0.04	0.33, 0.25, 0.33, 0.25, 0.29
2	0.35	0.04	0.33, 0.33, 0.33, 0.38, 0.42 0.38, 0.33, 0.33
3	0.31	0.02	0.33, 0.33, 0.29, 0.29, 0.33
4	0.30	0.03	0.33, 0.29, 0.29, 0.33, 0.29, 0.25
5	0.32	0.02	0.29, 0.33, 0.33, 0.33, 0.33

S: Standard deviation in seconds

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References cited

- BARBER, H. S. 1951. North American fireflies of the genus *Photuris*. *Smithsonian Inst. Collection*, 117: 58 pp.
- KAUFMANN, T. 1965. Ecological and biological studies on the west African firefly *Luciola discollis* (Coleoptera: Lampyridae). *Ann. Ent. Soc. America*, 58: 414-426.
- LLOYD, J. E. 1964. Note on the flash communication in the firefly *Pyroactomena dispersa* (Coleoptera: Lampyridae). *Ibid.*, 57: 260-261.
- 1965a. Observations on the biology of three luminescent beetles (Coleoptera: Lampyridae, Elateridae). *Ibid.*, 58: 588-591.
- 1965b. Aggressive mimicry in *Photuris*: Firefly femmes fatales. *Science*, 149 (3684): 653-654.
- 1966. Studies on the flash communication system in *Photinus* fireflies. *Univ. Michigan, Mus. Zool., Misc. Pub.*, (130): 96 pp.
- 1972. Mating behavior of a New Guinea firefly: a new communicative protocol. *Coleop. Bull.*, 26(4): 155-163.
- 1973. Model for the mating protocol of synchronously flashing fireflies. *Nature*, 245: 268-270.
- 1978. Insect bioluminescence. In HERRING, R. J. ed. *Bioluminescence in Action*: 241-272. Academic Press.
- McDERMOTT, F. A. 1911. Some further observations on the light emissions of American Lampyridae: The photogenic function as a mating adaptation in the Photinini. *Canadian Ent.*, 43: 399-406.
- OHBA, N. 1978. Life of a firefly, *Hotaria parvula* (in Japanese). *Insectarium*, 15(6): 32-36. Tokyo Zool. Park Soc.
- 1979a. Luminescent patterns and behavior of fireflies (preliminary report) (in

- Japanese). *Kanagawa-ken Museum Gazett*, (41): 1-9. Kanagawa-Ken Mus. Soc.
- 1979b. Flash patterns and behavior of some Japanese fireflies (Coleoptera: Lampyridae) (in Japanese with English abstract). *Sci. Rept. Yokosuka City Mus.*, (26): 21-30, pl. 6-7.
- SCHWALB, H. H. 1961. Beiträge zur Biologie der einheimischen *Lampyris noctilca* GEOFFR und *Phausis splendula* LEC. und experimentable Analyse Beutefang und Sexualverhaltens. *Zool. Jb. Syst.*, 88: 399-550.
- YAJIMA, M. 1978. Durnal activities and luminous signals of firefly—The case of *Luciola cruciata* (in Japanese). *Insectarium*, 15(6): 12-19.