Ecology and Yearly Cycle of the Firefly *Photuris pennsylvanica* (Coleoptera: Lampyridae)

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Abstract: Several preliminary experiments were conducted to examine factors influencing the daily feeding rhythm and the yearly developmental sequence of the larval stage of the firefly *Photuris pennsylvanica*. Loose, loamy, well-drained soil allowed normal circadian behavior while sand, sawdust, and clay-like mud prevented larval migration. The yearly developmental sequence could be duplicated in the laboratory by simulating environmental conditions, and acceleration of this sequence was achieved by manipulating the length of exposure to simulated winter temperature.

Photuris pennsylvanica is the common late summer species of Lampyridae found in the northeastern United States, where both the larval and adult forms are quite common from June until early September. Lampyridae larvae resemble the female glowworm (Darwin, 1859) with each segment possessing a horny brown plate dorsally, soft, rose-colored sides with white spiracles on brown patches, and a cream colored ventral surface with one pair of short legs (Boving and Craighead, 1931). The larvae of *Photuris pennsylvanica* are nocturnal (Arnett, 1960), remaining in subterranean burrows during the day and feeding on soft-bodied insects, earthworms, and snails on the surface at night. Lampyridae larvae have long, hollow, and slender mandibles with which they inject a digestive enzyme into their prey (Winkler, 1964). This enzyme causes the body of the prey to liquify, and this aqueous flesh is then consumed. Perhaps the most interesting aspect of the anatomy of these larvae is the two singular light organs located on the ventral surface of the next-to-the-last segment of the abdomen. The larvae possess similar luminous characteristics to that of the female *Photuris*, and in fact are often mistaken for a female at night when observed among the foliage. On the last segment of the abdomen there is a ventral prop-leg that aids in surface locomotion and also serves as a brush for grooming.

Although the literature concerning the anatomy, physiology, and behavior of the adult firefly is fairly extensive, few observations have been made on the larval stage, and those that do exist have been gathered primarily through limited field observations. For example, Darwin (1859) made some observations on lighting, feeding, and grooming behavior, while Riley determined that a two-year period was required for larval maturity (Arnett, 1960). Due to the general scarcity of information regarding the ecology of this larval stage, the following preliminary studies were undertaken to determine:

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1. whether the normal developmental sequence of larval feeding, inactivity, pupation, and eventual adult emergence could be maintained in the laboratory under simulated environmental conditions.
2. whether this sequence could be altered by experimentally manipulating the length of exposure to different temperatures.
3. whether the texture of the soil is an important factor in determining the circadian feeding behavior of the larvae.

METHODS

While an overall attempt was made to maintain the larvae within terraria in the laboratory under conditions similar to those existing in the normal environment, three major variables were examined: Effect of Soil Texture on Larval Migration; Simulation of Winter Temperature, and Length of Exposure to the Simulated Winter Temperature.

The experimental terraria were large wide-mouthed, one gallon pickle jars approximately 6 inches in diameter and 14 inches in height. Approximately ⅙ of the bottom of the terrarium was filled with stones, to ensure drainage, then soil was placed on top of the stones until approximately ⅔ of the terrarium was filled. Next, the surface of the soil was partially covered with grass and foliage. The mouth of the terrarium was covered with fine mesh cheesecloth to prevent the escape of the garden slugs (used as food for the larvae) and the adult fireflies after they emerge. Finally, 50 *Photuris pennsylvanica* larvae, each at least ½ inch in length, were caught and placed in each terrarium.

The initial experiment consisted of storing terrarium 1 in a cold storage area with an approximate temperature of 9° C. to simulate fall external temperature for a period of 30 days. This terrarium was then stored in a refrigerator with an average temperature of 6° C. for 120 days and 3° C. for 73 days. The terrarium was then placed on a windowsill having an average ground temperature of 24° C. for a period of 40 days when emergence of adult flies occurred. This experiment was designed to demonstrate that normal daily migratory patterns and proper life cycle sequences can be maintained in the laboratory.

The second experiment dealt with the effects of different types of soil upon the migratory habits and life cycle of *Photuris* larvae. One terrarium was filled with loose loamy soil (the control terrarium), a second was filled with sand, while a third was filled with decomposing sawdust, and the fourth was filled with a heavy clay-like moisture-retaining soil. Each of these terraria was filled with 50 larvae, and exposed to the sequence of simulated temperature described above.

The third experiment was designed to determine if the basic yearly sequence could be accelerated by exposing the larvae to the same temperature pattern as in the control situation, but for a shorter interval. Thus, terrarium 2 was maintained at 9° C. for 30 days, 6° C. for 100 days, and 3° C. for 20 days.

After exposure to temperatures of 24° C. emergence of adults took place in 35 days. The cycle had thus been reduced from 263 total days, and emergence in June, to only 185 days and emergence during April.

Finally, an attempt was made to see if the yearly sequence could be accelerated by eliminating the 3° C. temperature from the simulated temperature pattern. Larvae in this terrarium were exposed to 9° C. for 30 days, 6° C. for 120 days, then 24° C. for 45 days until emergence of adults took place.

OBSERVATIONS AND RESULTS

In an attempt to determine if the normal behavior and development of *Photuris pennsylvanica* larvae could be maintained in the laboratory through simulation of natural temperature variations, an original population of 50 larvae was exposed to a series of temperatures beginning on September 22, 1970 and continuing to June 12, 1971, a total of 263 days. By this date, only 6 adult fireflies had emerged, or 12% of the original population. While this percentage is low, it nevertheless suggests that the proper life pattern is maintained when exposed to laboratory conditions and suggests that larvae of this species might be a useful laboratory animal for future studies.

In the second experiment, designed to determine the effects of different soil types upon larval migration and life span, the control terrarium (the one used in the previous experiment), filled with loose, loamy soil, was compared to three other types of substrate. In the terraria filled with sawdust and sand respectively, no adult flies emerged. On the surface, the sawdust did not retain any water, while the sawdust beneath the surface was saturated. The larvae did not practice daily migration, perhaps due to the hard surface crust and/or the saturated lower soil, and remained on the surface. When this terrarium was refrigerated, the unprotected larvae perished, as evidenced by the 14 dead larvae found on the surface. The sand maintained acceptable moisture, compared to the control terrarium, except for the immediate surface which became a hard-packed crust due to drying. This crust was broken twice during the course of the experiment, but quickly reformed. Once again this crust prevented daily larval migration to and from the surface, and caused the larvae to remain on the surface. At the conclusion of the experiment, 17 dead larvae were found on the surface, where they apparently perished from the cold. In the last terrarium, a heavy, clay-like, moisture-retaining soil was used. Once again, evaporation produced a crust on the surface, but the soil from about 1 inch below the surface to the bottom of the jar remained quite soft. This soil allowed larval movement up to about 1 inch of the surface. Eventually, 2 adults emerged, but the remaining larvae apparently perished, either from the cold temperatures or from suffocation due to a water-saturated lower soil. From these rather poor results, it appears that larvae of *Photuris pennsylvanica* thrive best in loose,

well-drained, loamy soil. This view is substantiated from field observations, for the greatest number of larvae are found in this type of soil.

In the third experiment, the yearly sequence was accelerated by exposing larvae to temperatures of 6° C. for only 100 days (rather than 120) and 3° C. for only 20 days (rather than 73 days). By late March, adults began to emerge, and eventually 18%, or 9 of 50 possible adults emerged. Thus it appears that the yearly cycle can indeed be accelerated, although further study is needed to determine the exact time requirements for each temperature.

Finally, an attempt was made to determine if the 3° C. temperature could be eliminated without altering the sequence. Instead of exposure to this low temperature, larvae were submitted to 120 days at 6° C. Of the original 50 larvae present, only 10%, or 5 of the 50 possible adults emerged. Once again, the percentage of emergence is low, but the results suggest that the low temperature is not needed for completion of the developmental cycle.

Several interesting observations were also made in the course of this study relating to the behavior of the larvae. The larvae migrate to the surface each night, using the same tunnels, and are most plentiful on the surface between 9:00 P.M. and 3:00 A.M.

Larvae of *Photuris pennsylvanica* seems to prefer the gray garden slug (*Deroceras reticulatum*) as a food source because the larvae could be collected in good numbers among garden litter where the slugs were prevalent. Also, garden slugs were preferred to many other types of food presented during the course of their captivity. When feeding on the slugs, the larvae apparently injected a flesh destroying enzyme that liquified the slugs flesh, allowing the liquid to then be consumed. It appeared that the slugs seemed unaware that they were literally being eaten alive. In addition to these slugs, captive larvae also consumed blue grapes, generally by drinking the juice of a broken grape. In the wild, larvae have also been observed feeding in this manner.

Photuris pennsylvanica larvae, like the adults, possess primitive light organs on the eighth segment of their body. By subjecting them to repeated flashings from an amber pen-light, imitating the normal one second lighting interval of *P. pennsylvanica* males, they have been stimulated to repeat erratic flashing responses. It is interesting to note that these responses can also be elicited by stimulating the larvae with repeated flashings of the amber light at six second intervals, the normal lighting response of males of the species *Photuris pyralis*. Such results suggest that these larvae may possess a crude understanding of the sexual communication practiced by adult Lampyridae and demand further study.

The pupae of *P. pennsylvanica* are of the exarate form where the appendages develop free of the body of the organism. The pupae resemble an enlarged, stiff image of a mature larva and remains luminous while it develops an earthen cell around itself below the surface of the soil. After between 20 and 24 days of

pupation, emergence occurs as adult fireflies escape the earthen cell and move to the surface of the soil.

Thus, while the experimental results obtained were not dramatic as far as numbers were concerned, they suggest that the yearly cycle can be manipulated experimentally and that the type of soil is important to the behavior and the survival of the larvae. Observations of larval behavior also suggest some areas for additional study.

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