

Fireflies in Kansas

Lawrent (Larry) L. Buschman



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Front Cover: A male *Pyractomena lucifera* (Melsheimer) firefly on glass, flashing at the camera (From author's dissertation research, University of Florida).

Back Cover: A 12 sec time-laps photo of fireflies at Baker Wetlands, Lawrence, KS. The long streaks are flashes by the Slow Blue and the dot flashes are unidentified single flashers which could include Slow Blue, but there probably are other species present.

All photos are by the author, except Figure 1 and Figure 5 (egg and adult) which are from Lynn Faust—used with permission.



About the Author

Dr. Lawrent (Larry) Buschman attended Tabor College, Emporia State Teachers College (now Emporia State University) and University of Florida. He was employed as an agricultural research scientist in the Department of Entomology, Kansas State University, and was stationed at Garden City, Kansas. He worked to help farmers deal with insect pests such as spider mites, corn borers and corn root worm in corn, soybean stem borers in soybean and Hessian fly and other pests in wheat.

When he retired, he was not able to continue agricultural research, but he found that he could continue his graduate school projects on fireflies. He has worked with fireflies for over 20 years (12 years in retirement). He is currently rearing fireflies in the genus *Photuris* (as seen in Figure 1). *Photuris* fireflies seem to mate only once. He needs video recordings of courtship flash communication which can then be analyzed. This will help us develop decoy flash signals that we can use to better identify *Photuris* fireflies.

Fireflies in Kansas

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Those charismatic insects that produce a mysterious light as they fly in our yards and in our parks are called “fireflies” by some people and “lightning-bugs” by others (Cover photo). Audiences are usually split on those that use each of these terms. Entomologists usually call them “fireflies,” so I will be using this term in this discussion. The terms “flies” and “bugs” may refer to “insects” in colloquial English, but in the entomological sense fireflies are not flies or bugs—they are really beetles. When flying they hold the protective leathery first pair of wings, also known as ‘elytra,’ up and out of the way but fly with the membranous second pair of wings. They also have chewing mouthparts—like all beetles!

Firefly bioluminescence

The first question I often get about fireflies is: “How do fireflies produce the light?” To answer this question, we first must understand that firefly light is different; it is produced biologically in a chemical reaction that we call “**bioluminescence**.” This light is produced in specialized cells of the **light organ**. The light organ is usually located under the tip of the abdomen (Cover photo). Light production comes from a chemical reaction that involves **luciferin** and **luciferase** acting together with oxygen, ATP, water and various enzymes and cofactors (Buschman 2019). The energy for the light comes from ATP (the energy molecule in cells). This light production is so efficient that there is little heat released. Fireflies produce this light as glows, flashes and flickers. This will be discussed later.

This leads to a related second question: “Why do fireflies produce the light?” This question has fascinated scientists, naturalists and many people for several years. Many scientists and naturalists have offered opinions on why fireflies produce bioluminescence. I have summarized these opinions and speculations and developed an overall description of the various functions of bioluminescence along with a sequence of how bioluminescence may have developed—starting from a non-light producing chemical reaction to the complex glows and flashing behavior observed in today’s fireflies (Buschman 2019). In this discussion, I will only mention the three most important functions of bioluminescence. First, the bright flashes and glows that we can see are **courtship signals** between males and females. These courtship signals will be described in more detail later. They are important in identifying different species of fireflies.



Figure 1: Adult of *Photuris* spp.

Much bioluminescence is **not** associated with courtship. We believe that most forms of bioluminescence serves as a **warning signal** to potential predators (bats, birds, mice etc.) that this insect has defensive chemicals that the predator will not appreciate—stay away! This is known as an “**aposematic**” signal and is the initial and still most widespread function for firefly bioluminescence. Fireflies have toxic defensive chemicals, including “**lucibufagin**”—a heart toxin (Buschman 2019). In

this case bioluminescence is used as a passive defense—it is used continually in a prophylactic way—to warn predators. We are more familiar with brightly colored butterflies—like the Monarch Butterfly (*Danaus plexippus* (Linnaeus)), which like some other butterflies, uses bright colors to warn birds and other predators that they have defensive chemicals. Bright colors work for butterflies because they are active during the daytime. Bright colors do not work at night because colors cannot be seen in the dark. Therefore, fireflies use bioluminescence.

There are also other flashes and glows that appear to serve as a more active defense. They are used during an actual predator attack. These flashes may startle the predator, or they may direct the attack to a different part of the body, perhaps to where the defensive chemicals are located. This appears to be the third function of bioluminescence.

Fireflies in Kansas

People are usually surprised to learn that there are many kinds of fireflies. There are over a dozen firefly species in Kansas, around 200 species in North America and approximately two thousand worldwide. There are three types of fireflies—that is—insects that belong to the firefly family “Lampyridae.” There are **dark fireflies**, **glowing fireflies** and **flashing fireflies**. The dark fireflies do not have light organs as adults but use chemicals (pheromones) in courtship and are often active during the daytime (Lloyd 1972). The glowing fireflies have light organs on the females only (males are dark). The females glow in the dark to attract the males who are flying around looking for them. The flashing fireflies have light organs on both males and females. The males fly around producing a species-specific flash code. Females rest on the vegetation and answer the male with response flashes in a species-specific courtship dialogue. The flash dialogue guides the male to the female. She may choose which male flashes to answer.

In Kansas there are three common genera of flashing fireflies: *Photinus*, *Pyractomena* and *Photuris*. They can be identified using photos in Figures 2, 3, 4 and by using the characteristics in Table 1. Knowing the genus reduces the number of species under consideration. There will normally be only a few different fireflies of a genus at any time and place. This then allows someone to state that they have a “double flashing *Photuris*” or a “single flashing *Photinus*”. If you can give the time intervals for the flashes, you will usually be able to identify the firefly species. We should understand that some fireflies can only be identified by observing the flash behavior in the field. Other fireflies need to be identified by examining the male sex organ under the microscope.



Figure 2. *Photinus* fireflies. A. This is a larva B. Adults of *Photinus* (with cm ruler). The large male is the Common Eastern Firefly, *Photinus pyralis* (Linnaeus)—six-eighths of an inch long; the smaller male is the Brush Single Flasher, *Photinus curtatus* Green—two-eighths of an inch long.



Figure 3. *Pyractomena* fireflies (Photos from PhD research in Florida, *Py. lucifera* (Melsheimer): A. Larva feeding on a snail; note the “caudal (tail) grasping organ” at the tip of the abdomen. They use this organ in locomotion. B. An adult *Pyractomena dispersa* with a large head-shield and the center longitudinal ridge in the head-shield.

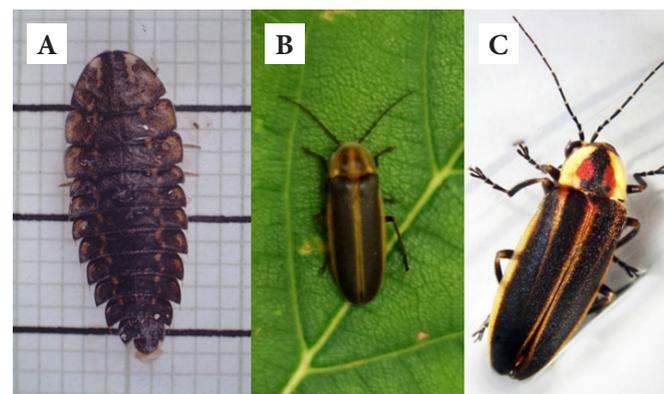


Figure 4. *Photuris* fireflies. A. A *Photuris* larva—the head is retracted under the head shield. B. Kansas Double Flasher *Photuris divisa* LeConte; C. A typical *Photuris* firefly, *Photuris quadrifulgens* Barber—these fireflies can only be identified to species by observing their flash patterns (see Plate II).

Table 1. The three genera of flashing fireflies in Kansas.

	<i>Photinus</i>	<i>Pyraclomena</i>	<i>Photuris</i>
Head Shield	Medium size, half-moon shape, center black bar, red & yellow/tan markings	Larger size, pentagon shape, center & two side black bars, red & yellow/tan markings	Smaller size, half-moon shape, center black bar, red & yellow/tan markings
Body	Flattened	Flattened	Cylindrical and hump-backed
Legs	Short (0.1 in—0.2 inch)	Short (0.1 in – 0.2 inch)	Long (0.20 in – 0.4 inch)

As stated earlier, flashing fireflies use light signals for **courtship communication**. The simplest signal system is where the female has the large light organ which she lights up after dusk. These fireflies are known as ‘**glow-worms**.’ Males fly about in the dark looking for glowing females. They are attracted to the glowing female, and they will fly to her and mate with her. Glow-worms may also use a pheromone (a perfume) to help attract the male from a distance (Lloyd 1972).

The **flashing fireflies** use a flash-answer signal system. The male flies about producing the species-specific advertising flash pattern. The female waits quietly on the vegetation and when she sees the right flash signal, responds with a species-specific response flash. If the male sees the response, he will repeat the flash pattern, and the female continues to respond—thus guiding him as he flies and/or crawls towards her. This is the courtship system that is common in North American fireflies: *Photinus*, *Pyraclomena* and *Photuris* fireflies. Scientists from Europe had a hard time trying to understand what was going on with North American fireflies. In Europe, their fireflies were glow-worms and only the female was bioluminescent (Lloyd 1971). The flashing of North American fireflies did not make sense until Frank McDermott, one of the first firefly scientists in North America, figured out that these fireflies were using a flash-answer signal system (Lloyd 1971). Understanding these courtship signals is important when studying fireflies (see **Field Guide section Plates I & II**).

Another famous firefly scientist, Jim Lloyd, reported that female *Photuris* fireflies were “aggressive mimics”—that is the females answer the flashes of other firefly species to lure them (Lloyd 1975). When these males come close enough, the female will pounce on them and consume them as prey. Lloyd called these females “*femmes fatales*”—fatal females. Lloyd reported that aggressive mimicry occurred in several but not all *Photuris* fireflies. In Kansas, aggressive mimicry is observed only in the eastern third of the state. In the scientific community there has also been controversy relating to the precision of this mimicry and exactly how the mimicry relates to courtship communication.

Jim Lloyd has also documented that *Photuris* males produce several different flash patterns as they fly about in their habitat (Lloyd 1969). This is unusual because most other fireflies produce only a single species-specific flash pattern. For example, the Slow Blue, *Photuris caerulea* usually produces a long leisurely flash pattern that lasts 0.5-1.5 sec long (Plate II). However, when a female responds, the male shifts to producing an equally long crescendo flash. However, at other times the male produces a simple single flash and at other times it produces a “flash-bulb flash” (a very short and very bright single flash). The role of these alternate flash patterns remains mysterious and controversial. Some secondary flash patterns seem to function as dedicated aposematic signals—warning predators that the firefly has toxic or deterrent chemicals while others seem to be defensive in nature (Buschman 2019).

Life Cycle of Fireflies

The firefly life cycle is considered “complete” in that adult and the larvae live in different habitats and have different ecological requirements (Figure 5). The adult is winged and lives above ground and can fly. Adult fireflies live for one or two weeks—long enough to mate and lay their eggs. Eggs are placed in wet soil and hatch in 25-30 days. The larvae live in the leaf litter in wet habitats and feed on snails, earthworms and other soft-bodied organisms. In spring larvae develop a cell in the ground and pupate for about 10 days. The pupa develops into the adult stage and the life cycle starts over. Note that the larvae may take several years to develop, depending on how fast they can find enough food. Note the two small round light organs near the tip of the abdomen of the pupa (Figure 5). Larvae have similar small light organs located underneath (the photo in Figure 5 is the top view of the larva).

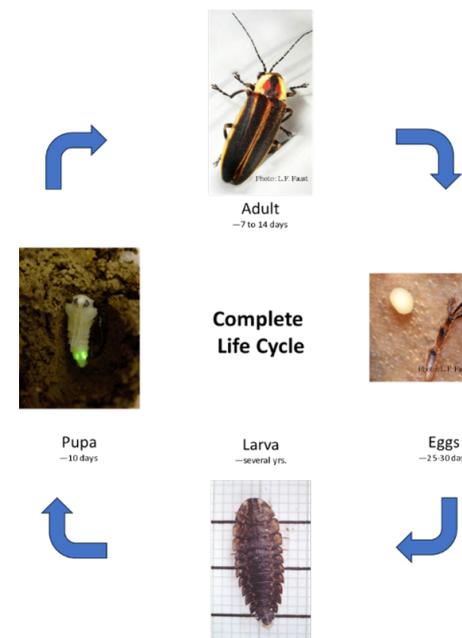


Figure 5. Complete life cycle of a firefly.

Natural History

The natural history of some fireflies has been described in some detail (like *Pyraetomena* and *Photuris* fireflies) (Buschman 1984, 2014, and 2019), while the natural history of other common fireflies remains largely unknown (like *Photinus* fireflies). Firefly larvae are known to be predators of snails, slugs, earthworms, ants, various soft-bodied insects and some even feed on ripe fruit. Some firefly larvae are specialized snail predators (like *Pyraetomena*) while others are general predators (like *Photuris*) (Figure 4a) (Buschman 2019).

Most insects with chewing mouth parts simply chew up the food and swallow the pieces and digestion is done internally. Firefly larval feeding behavior is unusual because they have mandibles that are hollow and appear to be able to inject a toxin into the prey to kill it. Once the prey is subdued they regurgitate digestive juices from the gut to start the process of digestion externally. They then chew the prey to loosen sections of tissue, suck the partially digested food into the mouth where it passes into the gut where digestion is completed (Buschman 2019).

Adult fireflies are generally active and observed during the spring and summer. Most fireflies do not feed as adults, except to drink water, nectar or honeydew. In the laboratory I give them a slice of apple so they can suck its juices. As previously mentioned, females in the genus *Photuris* are known to be predators of other fireflies—aggressive mimics. They appear to gain some defensive chemicals, in addition to the nutrients, by feeding on other fireflies. Adult fireflies live only long enough to find a mate and lay their eggs, which usually takes one or two weeks. The eggs are laid in moist soil, and they hatch after 25 to 30 days. This means that the very small and vulnerable larvae must survive during the late summer, in July and August. Drought conditions during the late summer can be devastating for firefly populations (unpublished observations). Since it takes one to two years for larvae to grow to maturity, the effects of a drought will show up one or two years later. It will then take several years for the populations to recover.

Firefly larvae are usually found in wet or moist habitats. In eastern Kansas these habitats can be found in riparian forests along rivers, meadows and pastures and even in the tallgrass prairies. These are also the areas where we find snails, earthworms and other prey of these larvae. In western Kansas, there are fewer perennial wet habitats which are usually limited to springs, larger ponds and perennial streams. Most fireflies spend the winter in the larval stage. In northern climates, like Kansas, most larvae appear to require one to several years to complete development depending on availability of food. My observations suggest that larvae do much of their feeding after significant rain events. These rain events are more frequent in eastern Kansas than in western Kansas so this could explain why there are more species and larger populations of fireflies in eastern Kansas than in western Kansas. In the laboratory, when fed once per week, fireflies can complete development in as little as six months. In the field, development appears to be slower. There may be only one or two rain events during the late summer and fall when larvae are feeding, so larvae would not be expected to do much development. It appears that many larvae may require several

years to grow into a mature larva. Firefly larvae appear to hide in the soil, in cracks or in soil cells, during cold or dry weather. When the weather is favorable, they emerge and continue feeding. Most fireflies pupate in soil cells which they build about half an inch deep in the soil. They are prevented from pupating by short day lengths, and they are stimulated to develop into pupa and then adults when they are large enough and they receive the long day signal. They appear to be able to receive the light signals while underground. In fall, they appear to go into a kind of “diapause”— where the larvae remain active, weather permitting, and they continue to feed and move about (Buschman 2017, 2019). This is unusual among insects because most insects that go into diapause become inactive and do not feed. The lengthening days in spring indicate that summer is coming. This stimulates the development of pupa and then adults which emerge in June and July. This light signal breaks the diapause and helps time the emergence of males and females to the same time of the year and allows them to find each other for mating (unpublished observations).

The larvae of all known Lampyrids are bioluminescent, they glow from a pair of oval light organs near the tip of the abdomen. This bioluminescence in larvae appears to function as an aposematic signal (Buschman 2019).

Firefly populations

Many members of the scientific community and public would agree that there are fewer fireflies now than there used to be. While historical population data are limited, studies have found some species that have significantly declined (Lewis et al. 2020). The IUCN has listed 18 fireflies as being at risk of extinction (Fallon et al. 2021). The discussion then quickly moves to possible causes of the decline of fireflies. Here I will discuss a few of my observations on this subject. First, people who grew up in more rural situations often mourn the fact that there are no fireflies in our current urban situation. I think this is an unfair comparison. There still are fireflies in rural pastures, meadows forests and wetlands—but these habitats are gradually being displaced.

My second observation is that in western Kansas—and western North America in general—water is the key to life. It is the key to everything including firefly survival. There is fierce competition for the available water resources. For example, the mighty Arkansas River once flowed so full that it was steamboat navigable all the way to Garden City, Kansas. Now, so much water has been diverted that it runs dry for some 70 miles in western Kansas. This has clearly had a major impact on the firefly populations in the wetlands that used to line the length of this river—they have not been observed in these areas for many years. The water table along the Platte River in Colorado and Nebraska is still relatively high and the fireflies can still be found along this river. The transfer of water from the western slope to the Platte River (after use in the cities) probably has helped in preserving this system.

Dams and other impoundments also have a significant effect. They prevent flooding so the marshes and wetlands along the river dry up. The marshes and wetlands associated with the first impoundments on the river system may get populated by fireflies. However, the marshes and wetlands downstream now dry up and the

fireflies disappear. Future impoundments built along that river will not have firefly populations because they are no longer present in marshes along the river.

There should be several marshland fireflies in Kansas. However, nearly all wetlands in Kansas are currently managed for duck hunting and are drained for the summer. The marshland fireflies are no longer present in these Kansas habitats (personal observation). We have also withdrawn so much water from the Ogalala and other aquifers that many springs in the area have gone dry. This means that the firefly refugia habitats that used to exist around these springs no longer exist. The fireflies are gone too.

Extended episodes of drought may also have contributed to the loss of firefly populations. In the east the loss of a population can be restored by re-colonization from neighboring more stable populations. However, firefly populations in the west are relic populations that have little chance of re-colonization from neighboring stable populations.

Excess artificial light during the night, light pollution, is also thought to be harmful to firefly populations. Unfortunately, it is difficult to separate the effects of urban development (habitat destruction) from the effects of light pollution. It is important to remember that some fireflies are adapted to be active at dusk—when there is significant light in the environment. I would expect the effects of light pollution to be greater on fireflies that stay in the deep woods and also those with very dim lights. Glow worms and fireflies with flightless females may also be more impacted than other winged and/or bright flashing fireflies. They are not able to move away from the light. There is need for more research on light pollution.

Additional considerations

People sometimes ask if fireflies are economically important. Fireflies are certainly charismatic and innocuous (not-pests). We enjoy having them around. They are also key predators in the environment, feeding on snails, earthworms and other soft bodied insects (Buschman 2019). Some fireflies are voracious snail predators and there have been attempts to use them to reduce pest snail populations. However, to date these efforts have not been successful.

Lewis (2016) gives a more detailed discussion of how fireflies were used for light at night before there was electricity. She also discusses how fireflies and their chemicals have been used in a number of different medical and health research.

Back in the 1950s and 60s a company offered money for fireflies (a penny apiece) (Lloyd 1966). Children and adults collected thousands—maybe millions—of fireflies to sell to this company. The company then sold the light organs to scientists who were using the bioluminescence reaction to measure energy in different tissues. My brother-in-law did some of this work (personal communication A.D. Friesen). The company wanted one specific species, so many collected fireflies had to be discarded. I have not found that specific species in Kansas, but my friends say they have them in Iowa and Missouri. Now they are able to manufacture luciferin and luciferase

chemically, so they no longer need to kill fireflies to get these chemicals.

In China and southeast Asia, they commonly release fireflies at weddings and other celebrations (personal communication). Large numbers of fireflies are collected and sold for these celebrations, and this has had a negative effect on firefly populations in this region. Scientists are trying to develop rearing facilities to meet this demand, but it is difficult to compete with the wild caught fireflies.

More recently, scientists have used the genes for bioluminescence when they wish to transfer a new gene into a new cluster of cells (personal communication). The bioluminescent genes are attached to the new gene and the package of genes is inserted into the new cell line. Bioluminescence is used to identify which cells have successfully received the new gene. It also verifies that the new gene is functioning properly. They then remove the bioluminescence genes so that the converted cell line is no longer bioluminescent.

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