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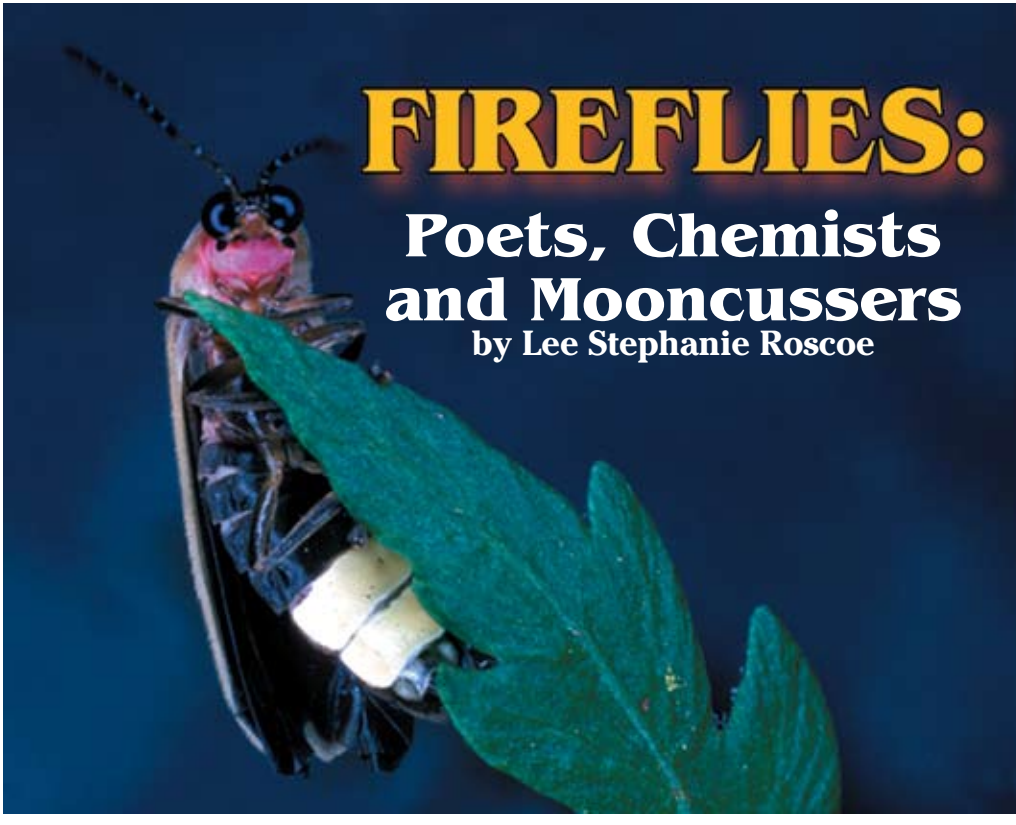
A Male *Photinus* firefly, about 5/8 inch in size.



FIREFLIES:

Poets, Chemists and Mooncussers

by Lee Stephanie Roscoe

Photo © by Dr. Jim Lloyd

Midsummer Night's Eve. Mercury is a mosquito bite against a hot pink dusk sky. As the light subsides, handfuls of midget meteors swirl through the clover-perfumed grasses, bazooka into the lower limbs of trees, draw evanescent arcs of light on the darkness. They are fireflies, their glory and glamor cast into the scrubby field like bushels of eldritch gems. Fireflies define summer when they are alight; when they shut down, so too does the season.

As might be expected, anything so universal, inexplicable and seasonal as fireflies has long been of mythological and utilitarian interest to the people of many cultures. Gathered into lantern houses (and even worn in nets around ankles), fireflies have been lighting the way for rice farmers and poor students in Asia for centuries. In Latin America, fashionable women wear the flashing insects under special nets in their hair. In Japan, where firefly festivals are a summer ritual, fireflies are said to be the souls of lovers and warriors who died while still young and beautiful. Medieval Europeans thought them to be the souls of dead babies. Hindus believe fireflies are the eyes of a god. The Aztec and Blackfeet Indians look upon them as metaphors for wisdom and for life itself.

Tales about spirits and animals express the kind of relationship humans have with the natural and spiritual world, but the story of the light-bearing tricksters we call fireflies sparks big questions and illuminates big answers. Scientists have long been entranced by the soft-shelled beetles many of us still refer to as "lightning bugs." Appearing on earth some 300 million years ago, fireflies are beetles of the family *Lampyridae* ("shining fire"). There are about 175 - 200 North American species, about 40 of which are found in New England. Our most common species are of the genus *Photinus* (Greek for "light within"); *Photuris* ("tail-light") and *Pyractomena* ("fire producer") species are less common. New England also supports *Ellychnia* and *Lucidota* species that lack light producing organs and are, interestingly enough, the only kinds of fireflies that are found west of the Rocky Mountains.

Soft-bodied, elongate beetles, most fireflies are equipped with functional wings that are sheathed under protective *elytra* (wing covers) when not in use. While they are quite maneuverable, fireflies tend to be fairly slow and lumbering in flight, and the females of some species are entirely flightless. The head is shielded from above by a thoracic shelf called the *pronotum.* Somewhat reminiscent of Darth Vader's helmet, it often bears a central corona of yellow or orange-red (depending on the species) and brings to mind the color dab on a kinglet or the sun symbol of the great Sioux chief, Red Cloud. Drab *Ellychnias* have no corona.

The physical appearance of our firefly species is often very similar, presenting even the experts with identification challenges. As with many insects, minute differences in male genitalia are often the key to accurate identification. Even this doesn't work to distinguish between some species, however, which differ only in number of chromosomes or even just the ordering of their DNA molecules. Aside from its use in species identification, DNA sequencing is also key to understanding the mystery of firefly ancestry (phylogeny), which reveals the probable evolutionary paths taken by these remarkable insects as they descended from common forebears.

Poets of Light

The lightless *Ellychnia* and *Lucidota* fireflies find their mates through "traditional" insect means, tracking the scent of species-specific aromas called pheromones. The lantern-equipped fireflies are veritable "poets of light," however. Those searching for mates are guided not by perfume alone, but by species-specific flash semaphores that the male uses to entice the female, and the female uses to direct the male to her location. They use timing (length of flash, length of pause between flashes, time of night when active); flash intensity (brightness); and flash color, height and shape (flight path of the flasher) to distinguish their own species from all others.

On a humid summer night when hundreds of individuals of several species may be signalling to one another, the lights seem as indistinguishable as the camera flashes at a rock concert. Trying to decode who's who can be difficult. It's almost a matter of style: There is something deliberate about *Photinus*, daring about *Photuris*, and flighty about *Pyractomena*. Like the songs of crickets, the soundless flashing of fireflies varies with temperature. They won't flash if it gets below 54°F, and the hotter it gets, the more they flash.

The flash sequences of *Photinus* species typically involve one or two quick spikes of yellow light with a pause between flashes of a second or so, and an interval between flash sets of a few seconds. *Pyractomena* tends to go "full automatic" with strings of rapid, flickering pulses followed by a pause. *Photuris* is the lime light linguist, frequently changing the speed and sequence of its flash patterns.

Researchers using sensitive oscillographs have discovered modulations in light intensity within firefly flash sequences that are not discernible to the human eye. Fireflies can clearly perceive them, however, and females of all species apparently find males with the brightest flashes to be the most attractive. It appears that female fireflies use light intensity as an indicator of vitality, much as female song birds use bright feathers and singing ability to judge the quality of their suitors.

Aside from the sequence of flashes and pauses, the patterns fireflies "paint" as they fly across their dark canvas are also species specific and serve to attract mates. The so called "Big Dipper" (*Photinus pyralis*) makes a "J" shape; another is reported to draw a pattern like a bow tied in the middle. When multiple species are at work on a humid night, the combination of light patterns and pulses can create spectacular shows. On one memorable evening I watched *Photuris* above me in the shrubbery by a marsh trying to lasso in love with yin and yang symbols, while another species configured a Cassiopeia beneath, while in a nearby field a "chorus" of low *Photinus* lights twinkled in the long grass like a garden of Christmas tree ornaments!

The primary incentive behind the light show is to allow males to find receptive females. The thing that knocks me out about fireflies is that they really do make poetry, for the rhythms of poems are measured in binary short and long beats in many combinations. With poems of light not created consciously, but hard wired by evolution, the male entices the female, and she guides him to her.

Photo © by Dr. Jim Lloyd

A short time exposure photo taken in good habitat on a warm, humid night reveals a host of the highly variable, species-specific flash patterns that allow fireflies to recognize potential mates. Most of these lights are produced by "trolling" males.

Most females view the show from perches in grass or low vegetation, although some species may settle well up in trees. When a receptive female sees the particular flash sequence that denotes an attractive male of her species, she waits for a precise time interval (what a poet would call a *caesura*) and responds with her own signal.

When the male detects this signal, he turns in her direction, alters his flash sequence, and begins a flashy dialogue with his intended. The female guides the male to her through multiple exchanges, assuring him that they are of the same species and that she is interested. This dialogue also allows her to judge his fitness, and to reject him if she detects another suitor with a more attractive flash. If either insect fails to receive the correct sequence of flashes and pauses, the affair is immediately called off. If the male gets the right message, he lands nearby, clambers to the female's location, and mating occurs.

Lanterns are also turned on for purposes other than courtship. *Photuris* males may use their light to illuminate a landing area, and may shine it while mating, perhaps to dazzle the female and prevent her from seeing any rivals. (Firefly eyes are roughly 20,000 times more sensitive at night than in daylight.) Females may even light while ovipositing (laying eggs). Fireflies may also signal to warn compatriots of danger, much as deer flash their white tails. They flare when they are captured by spiders or humans; the "talkier" *Photuris* light up more when handled, while some *Photinus* shut down their lamps entirely.

Fireflies also flash their lanterns when they feel thunder and see lightning, hence the "lightning bug" moniker. Like birds advertising their ownership of turf by loud calls, rival male fireflies sometimes seem to engage in competitive flurries. A male that detects another's courtship may attempt to horn in by synchronizing his flame with the rival's. Males may land and engage in physical battles when in competition for a female's attention.

Making Light

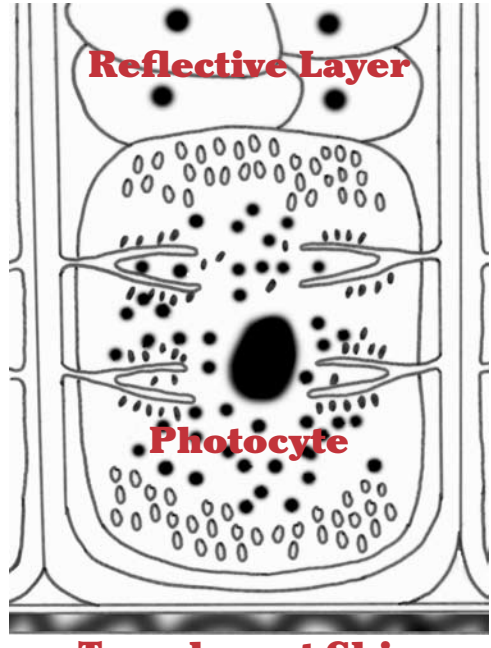
It has been said that the light from 40 fireflies equals that of one candle, but the firefly emits cold, not hot, light. Nearly all (96% or more) of the energy used to create this cold light is released as luminance (photons); very little is given off as heat. This is outstanding efficiency when compared to a standard electric light bulb, which expends about 70% of the energy it uses as heat.

Firefly light is emitted through "windows" in one or more abdominal segments. The glow is broadcast from a special three layered light organ or *photophore*. This consists of the outer transparent skin layer, a layer filled with

light cells, and an inner layer filled with uric acid crystals that acts as a reflector. The light cells, or *photocytes* contain two chemicals produced by the firefly: *luciferin*, a complex compound, and *luciferase*, an enzyme. When the molecules of these two chemicals are combined with the help of a catalyst called ATP, a dash of magnesium, and a healthy dose of oxygen, they rapidly degrade to *luciferyl*, releasing energy in the form of light photons. (Many bioluminescent organisms such as jelly fish, squid, ocean worms, tunicates, certain plankton and fish, bacteria, and other beetles also use luciferin/luciferase to create light, but the chemical composition is slightly different in each of these organisms.)

It was recently discovered that NO (nitric oxide) acts as the on/off switch for the flash. It apparently inhibits oxygen consumption in the area around the light cells, which allows oxygen to flow into the photocytes and generate the flash. There is still much to be learned about the firefly's production of cold light, but we have found many uses for what we already understand. Firefly luciferin/luciferase is so sensitive to ATP — a key energy molecule found in all living cells — that it lights up on contact with it. Noting this reaction, scientists have used it to determine cellular health, and even to detect cancer. It is also used in various genetic research techniques and, perhaps most famously, to test for the presence of life in outer space.

It is theorized that firefly bioluminescence arose first in their egg and/or larval stages, and only later evolved as an adult sexual signalling device. Many toxic animals (such as monarch butterflies and red efts) have evolved bright "warning" coloration that advertises their danger to potential predators. Many species of fireflies are also quite toxic (the chemicals of bioluminescence may in fact have evolved originally as biotoxins that made their owners unpalatable). However, because firefly larvae live underground in darkness, warning coloration would provide no benefit: a predator that broke in upon them couldn't see it to be warned! A predator suddenly exposed to a light in the darkness of the underground would certainly perceive it, however, and after one or two unpleasant experiences, would learn not to eat the owner. It seems a plausible explanation.



Translucent Skin

The reaction that produces the firefly's cold light is initiated when oxygen enters the energy- and chemically-rich photocytes. The photocytes are sandwiched between reflecting cells and the translucent "window" of the skin.

Natural History

The ratio of male to female fireflies is typically reported at about 50 to one. This skewed sex ratio makes competition for females intense and allows the girls to be quite choosey when picking mates. Males alter their flash "trolling" techniques if they fail to locate females, and females may change locations frequently if they aren't getting enough male attention. "Love is a battlefield" for male fireflies, and they have evolved many strategies for defeating rivals and inseminating females. They may synchronize their flashes with rivals, delay their flashes, or even mimic female response flashes (a technique known as "transvestite" flashing) to confuse the competition and/or redirect a female's attention to themselves.

Photuris females usually mate on a well elevated branch, while *Photinus* females typically set up shop near the ground, often on a blade of grass. Males fly along

Photo © by Dr. Jim Lloyd

trolling their flashy lures at heights appropriate for their species. Here in New England, brief synchronous flashing may occur if several males gather in a "love knot" around a female, but this is hardly comparable to the spectacular synchronous flashing practiced by some tropical fireflies. Thousands of males may assemble in a single jungle "fire tree," flashing on and off in unison to create a beacon that can be seen for miles! Like the choric calling of certain species of male frogs, flashing together amplifies the beacon enormously, making it easier for females to locate mates.

Female fireflies may mate with several males over successive nights. Prolonged copulation from 9 PM to dawn may occur, behavior that likely evolved to assure males their sperm would not be supplanted by a rival's. In the flashless species, mating may last longer than a full day. (Talk about the "light of love"!) Males have been observed turning around after releasing from mating, perhaps to ward off potential rivals.

Like all firefly larvae, this red-eyed Photinus pyralis *glows continuously, though not as brightly as a flashing adult. Depending on the species, firefly larvae may live in soil, decaying wood or aquatic habitats, where they are voracious predators of earthworms, snails, slugs, and other soft-bodied prey.*

Male fireflies may resort to various combative, stealth or even mimicry strategies to defeat potential rivals and convince a female to mate (left).

Two to six days after mating the female seeks out an egg laying site and deposits eggs no bigger than the size of a pencil point. Some fireflies lay upwards of 500 eggs, some lay only 10; some species lay eggs singly, some deposit them in clumps. *Photinus* eggs are typically placed on leaf litter in damp meadows or by streams, while *Photuris* eggs are inserted into rotting logs and dank debris. *Pyractomena* eggs are stashed in the occasionally inundated soils of floodplains, or even underwater on plant stems. *Ellychnia* and *Lucidota* eggs may be set in the ground or in tree crevices.

Eggs usually hatch in about two weeks. A bit like pipping birds, the segmented larvae bite their way through the egg shell and pull themselves out with their legs. All fireflies glow with bioluminescence as eggs and larvae (even *Ellychnia*), hence the common name of "glowworms" even though they have six legs and bear no relation to true worms. They look more like small, armored caterpillars armed with sharp mandibles.

Photo © by Terry Lynch

Photo © by Dr. Jim Lloyd

One of the mooncussing Photuris *"femme fatales" enjoys a nutritious, toxin-enhancing meal provided by a hapless* Photinus *male she lured to her table by mimicking the flash pattern of a* Photinus *female. Note large size of the predator.*

The larvae are voracious predators, feeding primarily on slugs, snails, earthworms and other beetle grubs, and will even gang up to subdue large prey items. They will follow the slime trail of a slug, and when they catch up with the maker inject a poison through their syringe-like mandibles that anesthetizes the prey for devourment. After such a slimy meal, they clean themselves with an anal appendage that surely evolved specifically for this purpose.

Fireflies molt 10 or 12 times during their larval period, splitting open and discarding their old skins and emerging larger each time. Most fireflies in New England apparently overwinter twice as larva, becoming dormant to survive the cold. Following the second winter they reach their largest size, then pupate (not unlike butterfly caterpillars) as they undergo transformation into adults. Some *Pyractomena* species climb out of the water and pupate in trees, while the *Photuris* and *Photinus* larvae remain underground, creating an "igloo-like" chamber in which to metamorphose. Two and a half to three weeks later they shed their pupal mantles and emerge as adults.

Newly emerged fireflies are soft and pale at first, but harden and gain their coloration within a few hours. They will live for only two or three weeks as adults, so it isn't surprising that all they seem to have on their minds is mating. But some of them may not get to reproduce. Some will fall prey to bats, birds, frogs, toads and other insectivores. Some will be lured and ambushed by other fireflies.

Mooncussing

It is said that on moonless nights in colonial New England pirates would place lamps on the backs of small boats, or even set signal fires on certain beaches, to lure merchant vessels into grounding on rocky reefs or sand bars where they could easily be looted. This nefarious practice, known colloquially as "mooncussing," had been perfected by female *Photuris* fireflies long before humans came along. The *Photuris* girls are born experts in mooncussing, and use their siren beacons not only to guide potential mates, but also to lure *Photinus* males in for dinner! They may be the only native fireflies that are predators as adults: the others all appear to eat nothing, or perhaps only a little nectar or pollen. A *Photuris* female can potentially consume many *Photinus* males in one evening, but at least one study shows that although many are called for dinner, few are successfully recruited.

While *Photinus* females have shortened wings and are nearly or entirely flightless, *Photuris* females can and do fly. When mooncussing, these "femmes fatales" perch in the grass like *Photinus* females and mimic the correct flash response sequences (including the all important response delay) of up to a dozen different

Photo © by Bill Byrne

Photinus hot dates. *Photinus* males approach to investigate this alluring display, but instead of finding a sweetheart, they are suddenly set upon by a much larger predator that flies up to intercept, capture and eat them!

Researchers have shown that by eating *Photinus* males, *Photuris* females gain two major rewards: a nutritional boost that can be used for egg production, and additional "lucibufagins" — steroids with heart accelerating qualities similar to digitalis and the bufodienolides that toads carry in their skin. When disturbed, *Photinus*, *Ellychnia*, and the *Photuris* which eat them will "reflex bleed," releasing a drop of blood abhorrent to bugs and birds alike. Acquiring higher concentrations of this effective repellent by eating a nutritional food is obviously a good thing for *Photuris*, but it certainly presents *Photinus* with a survival challenge.

Having to avoid *Photuris* may have contributed to the minimalist flash codes used by *Photinus* (and may have helped select for the difficult-to-duplicate wavering flash of *Pyractomena*). Professor Jim Lloyd of the University of Florida, widely acknowledged as the top guru of *Lampyridae* study, suspects that the simpler flash rhythms may be more effective in getting a mimic to reveal itself, by confusing it. Evolution may also favor simple flashes in *Photinus* because long, complex ones increase the visibility — and therefore the vulnerability — of the maker. Lloyd thinks that *Photuris* mimicry may not be "as effective as it once was" because of the tactics the victim species have evolved to foil it.

Evolution in Real Time

The "aggressive mimicry" schemes of the *Photurus* widowmakers have created all sorts of complicated evolutionary drives. *Photinus* males are obviously under the most direct pressure, but they are not the only ones. It is speculated, for example, that *Ellychnia* and other lightless species may have abandoned their light organs and become diurnal to avoid aggressive mimics like *Photuris*. *Pyractomena* males take immediate evasive action, dropping straight out of the air, if they detect the predator's flash. *Photinus* males may have developed their large, hypersensitive eyes not only to spot mates, but perhaps to recognize *Photuris* in time to make an escape.

While all firefly larvae are bioluminescent, common species of the genus Ellychnia *are diurnal and have no light organs as adults. They may have given up light signals to avoid predation.*

Such hypotheses are the stock-in-trade of evolutionary biologists who are interested in the pressures which drive evolution: how such factors as weather, food, mates, predators and place interact with the behavior and bodily designs of a creature to allow its species to stay in the running over time. Fireflies are particularly attractive subjects for evolutionary study. According to Professor Lloyd, "Firefly behavior does not fossilize, but through a comparison of related living species we can see the sorts of changes that occur in evolution and often get some notion of why and how these changes come about." Among Lloyd's many achievements was to show how one species, *Photinus ignitus*, evolved from its suspected precursor, *P. macdermotti*. Where the vintage bug uses two brief flashes to signal females, the newer uses only one.

This differentiation evolved because light signals must be seen: if thick vegetation short-circuits the signals by concealing them from potential mates, the two sexes will never connect. As vegetation frequently obscures signals in the shrubby habitat where these fireflies live, some *P. macdermotti* females increased their chances of mating by responding to just one flash in the double flash sequence. Over time they gave rise to a new species which no longer responds to the double flash sequence. Thus an alternative mating strategy resulted in the evolution of a new species in a very competitive environment!

Fireflies have evolved several ways to improve their reproductive efficiency by avoiding confusion with other species. Obvious examples are unique signals and restriction to certain habitats and flight elevations. Through "competitive exclusion," they also restrict their mating activities to certain times of the season and day. *Ellychnia corrusca*, often called the "winter firefly," ecloses in late summer and fall and sits out on bark (allegedly with "tiny piles of snow" on its back) until courting season the following April and May. *Pyractomena* emerge in May or

If you already have fireflies on your property, plant low, overhanging trees and create rain gardens or other damp areas to enhance the habitat. Don't broadcast pesticides over your greenery. Try to minimize outside lighting. If you can't give up the lawn, reduce it and allow border areas (especially damp areas) or interior "islands" to go wild, cutting once a year or less just to prevent woody vegetation from taking over.

Don't have a yard that supports fireflies? Go find them. Firefly hunting on a balmy evening can be pretty exciting — just remember that mosquitoes share the same love of moist habitats that fireflies do! Look for open areas where a high water table saturates the ground under low pastures and meadows, old fields and open woods; by bogs, stream banks and cattail marshes. Many of the DFW's Wildlife Management Areas contain multiple examples of these habitats, untouched by pesticides, and maps are available online at **www.masswildlife.org**. My personal favorite around the summer solstice is the Westborough WMA behind the agency's Field Headquarters.

Cover yourself with insect net or clothing from head to toe, carry a blue light (fireflies can't see blue) for watching, and a penlight for flashing attracting codes to trolling males. (The tough part is getting the pause right. You may need a stopwatch for that.) You can collect fireflies in baskets or jars, but don't leave them in dry containers overnight or they will desiccate and die. Better yet, leave them alone, enjoy the light show, and have some fun trying to identify species by their flash codes.

June before the fray between *Photuris* and *Photinus* heightens. Individual species of *Photinus* only court during their own fortnight portion of the summer. Some are active only for an hour after dusk and then shut down; others for an hour or less later in the evening. *Photinus* are generally active between dusk and midnight, while *Photuris* are nightowls, flying until well after midnight.

While dividing the night among themselves helps prevent confusion and competition between species, it also leaves fireflies with very small time windows in which to mate. Think of the pressure: You have one hour a night for two weeks in which to find a mate and reproduce before you die!

This pressure is presumably responsible for the development of *Photinus* spermatophores that contain not only sperm, but also a "nuptial gift" of nutrients the female can use for egg production. Researchers at Tufts University have shown that the females, in turn, pick suitors with the biggest spermatophores (No snickers, this is science!) by soliciting males with longer (but not too long) flashes. The better the flash, the bigger the mass of the male, and the more hefty (and presumably effective) the spermatophore. Females can apparently store sperm from multiple matings, and there is a startling possibility that, through "cryptic sexual choice," they can differentiate between sperm specimens and use only the best from among their stores!

Competition for mates is so intense that *Photuris* males don't always wait for their ferocious females to finish their mooncussing and ascend into the trees to look for real mates. Taking great risks, *Photuris* males sometimes try to get the jump on their competition by pretending to be unsuspecting *Photinus* males! They flash the signals of the prey species during their approach, then switch to the correct *Photuris* signal at the last moment. If the timing is perfect and the female is receptive, they may get lucky. But if they carry the mimicry too far, or her hunger overcomes her instinct to offer the reciprocal signal, they had best beware or they will soon be joining the Dead Poet's Society through the portal of her eager jaws!

Photo by Bill Byrne

There are three major genera of flashing fireflies in New England. The most common in terms of both numbers and species is Photinus (above left), which typically uses "minimalist" flash codes. Little Pyractomena (right) has flickery signals, is often the first to flash in spring. Photuris (below) is bigger and has longer legs than the others, and the largest, most variable "vocabulary" of flash signals.

Photos © by Dr. Jim Lloyd

Fading Lights?

"Imagine, before the days of electricity, how bright the flash of a firefly was," says Lloyd. Even with electricity, there were few children who grew up in rural or suburban environments who did not gather fond memories involving fireflies — lots and lots of fireflies. Unfortunately, many of today's children never have the opportunity to experience the natural light shows that previous generations took for granted. Almost everywhere it seems, there are alarming reports that the former hordes of fireflies once observed are no more.

Many factors are implicated in these declines and disappearances, not the least of which is suburban society's pervasive fetish for that alien, high maintenance monoculture known as lawn. Lawn pesticides are very effective at killing beetle larvae, which of course include firefly larvae. Between the pesticides applied directly to the lawns and the pesticide run-off that flows into the street sewers and commonly winds up in the neighborhood wetland, suburban firefly populations are sustaining a continual series of major body blows.

Now add continual mowing, the draining of swamps, the lowering of water tables by over consumption and drought, predatory wasps and flies, and the elimination of farm fields and wet meadows by development, and it is a wonder that even remnant populations are managing to hold on under the onslaught of urban sprawl. On top of all that, our ubiquitous artificial lights may short-circuit firefly signalling activities. Towards the end of their mating time, female fireflies may respond impetuously to airplane, traffic and car lights as if they were males (I have seen mica chips winking off the pavement under a dim street lamp, as well as ship lights out to sea, as fireflies), so glare from urbanization and highways may also be a problem.

When a breeding population of fireflies is eliminated from an area, there is not much hope for natural re-colonization. The *Photinus* species that comprise the bulk of evening light shows are poor fliers (some females are entirely flightless) and simply lack the ability to move easily from one location to another. The predatory *Photuris* species are much better fliers, but if *Photinus* has been eliminated from an area, there is little incentive for *Photuris* to move there.

There is evidence from Japan that the reintroduction of firefly larvae into depopulated areas can be successful in restoring individual species. That may provide hope for those who miss the neighborhood light shows of their childhoods, but such an effort would be logistically difficult and expensive, and while it might work for one lost species, restoring a lost *community* of firefly species would likely be impossible. It is always preferable to retain wildlife populations, rather than allow them to be lost and then to try to restore them. So we must ask ourselves: Is rampant development and endless acres of manicured lawn worth the price of losing the natural fireworks of summer? I vote to keep the "hexapod pulsars" dancing at the edge of the known universe, leading us on.

Lee S. Roscoe is a naturalist, poet, author and playwright. She has written articles in previous issues on tiger beetles and invasive marine species.

Suggested Firefly Websites & References

http://firefly.ifas.ufl.edu/
www.colostate.edu/Depts/Entomology/courses/en507/papers_1999/nevins.html
www.colostate.edu/Depts/Entomology/courses/en507/papers_1997/stous.html
www.burger.com/firefly.html
www.purdue.edu/UNS/html4ever/980626.Turpin.fireflies.html
http://home.att.net/~y2kvault/firefly_notebooks.html

* - * * * - - * Firefly Flash Codes * - -* *** -*

The skills of a master cryptographer are needed to decipher firefly communication, but it is sometimes possible to identify fireflies by their flash sequences, flash shape, when they fly, and how high they fly. Flash codes for most species are not fully documented or remain incompletely known, so there is plenty of room for backyard research. The codes listed here for selected species that can be found in New England were compiled from (sometimes conflicting) data acquired from Tufts University, the Montshire Museum in Vermont, Jim Lloyd's *The Fireflyer Companion*, and other sources. There are literally dozens of species that are not listed here. Keep in mind that flash shape can vary substantially depending on the angle from which it is viewed. Have some fun and see how many species you can identify in your area this summer!

Single Flashers

Photinus pyralis (the "Big Dipper") — Flies about 3 feet off the ground, usually over fields. Fires a $^1/_2$ second flash that paints an ascending "J" pattern on the dark every 5-8 seconds; after 2-3 seconds the female responds with her own flash.

Photinus marginellus (the "Northern Twilight") — Usually in understory trees or short grasses, flies 4 feet high or less; fires $^1/_2$ second flash every 3-4 seconds. Female waits a second then responds with her own flash. Flies 8 to 9 PM.

Photinus aquilonius — Trolls on a horizontal flight path over fields; fires a $^1/_3$ second flash every 4-6 seconds at 70°F. Flies 9 to 10 PM, June and July.

Photinus ignitus — Fires a $^1/_5$ second flash (that almost quavers) every 5 seconds or so; female fires a $^1/_2$ second response after a long (3-8 second) delay.

Double Flashers

Photinus consanguineus — 2 pulses, each $^1/_{10}$ of a second long, about $^1/_2$ second apart at 70°F, every 4-5 seconds at 67°F. Female responds with $^1/_3$ second flash after 1 second delay.

Photinus greeni — low grasses and understory shrubs, 2 pulses of $^1/_{10}$ second each, a second plus apart, every second and a half at 70°F, every 4 to 6 seconds at 67°F. Female response about a second, very short flash.

Photinus macdermotti — 2 pulses of $^1/_{10}$ of a second every 2 seconds at 70°F. Female $^1/_3$ second flash at 1 $^1/_2$ second delay.

Photinus ardens — Flies over wet pastures in late July. 2-3 flashes of $^1/_3$ plus seconds each every second or less, with an interval of up to 20 seconds. Female responds after about 7 seconds with a single or double flash.

Photinus obscurellus — Flies over fields with "short and snappy" 2-3 pulses of $^1/_5$ or so seconds, $^1/_2$ or so second apart, repeated frequently with a 5-7 second sequence interval. Females double flash 2-4 times after a delay of 3 seconds or less.

Photinus fairchildii — over grass and up into trees, 2 flashes $^3/_4$ second apart with 5 or so seconds between sets.

Multiple Flashers

All *Pyractomena* have amber lights; with practice, this alone will distinguish them from the more yellowish (*Photinus*) and greenish *(Photuris)* flashes of other species. Professor Arwin Provonsha of Purdue University reports that they remind him "of air-born embers from a campfire." Spring turkey hunters often observe *Pyractomena* when heading to their stands in the wee hours before dawn.

Pyractomena angulata — often in treetops and around lake shores; fires 8-10 very rapid pulses (like a flickering candle) in less than a second on an upward angle, repeating every 3 seconds at 70°F. Female response is $^1/_2$ a second later, over low wet ground, may rise.

Pyractomena dispersa — 4-6 amber pulses every 3-4 seconds.

Pyractomena linearis — spectacular 3 second "yellow flare."

Pyractomena sinuata — a dim glow held for 3-10 seconds, then off 3-10 seconds.

Erratic Flashers

Decoding *Photuris* is difficult because it changes its flash patterns through the evening and the season, and is not as well studied as *Photinus*. Because of their large size, *Photuris* generally flash bigger and brighter than all our other species.

Photuris pennsylvanica — fairly ubiquitous especially around marshes and ponds; fires a dot-and-long-dash pattern; break between dot and dash sometimes indiscernible; may emit dots early in evening, then switch to dot-dash over next half hour.

Photuris tremulans — flashes every 2 seconds in trees or over meadows.

Photuris versicolor — rapid flashes, almost always in tree tops, flickery quality. *P. quadrifulgens*, reported to fire 3-4 flashes one second apart with 5 second pause, is closely related; may be the same species.

Photuris sp. (unnamed species discovered by Jim Lloyd) — old fields and wood edges, Plymouth, Wareham and Cape Cod; starts with 2-4 pulse flashes; as evening progresses, fires 8-15 pulses per set; flickers an hour after sunset.