The firefly gives light to its pursuer. Oemaru

Fireflyer Companion & Letter

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Fireflyer. firefly + er. *n.* abbrv. for firefly chaser. A person who thinks a lot about lightningbugs

Fireflies At Risk – Update

FIREFLIES USA — 1/VI/98: Ah, dear Fireflyers, there is good news tonight. I recently read that a poll taken among highschool students indicated that a higher proportion of them than in the past is placing emphasis on things other than "making money" as a goal in life. They did not equate a "quality life" with things, "stuff" as George Carlin calls it . . . on family TV . . . in spite of what their culture has been telling them every 10 minutes on TV all of their lives. I want to believe that among the real life adventures that they will find time to take up will be firefly chasin'. Their choice, their emancipation proclamation would certainly seem to go against the mainstream, for much in their culture, especially the [so-called] academic milieu is arrayed against them. Never-the-less, though we must hold onto our optimism, we must also prepare for the quality of firefly life to get much worse, as humans continue to demonstrate that even they, for all of their intelligence and conscious awareness, heed a universal imperative and breed in whatever numbers their ecology allows. *jl*

Letter III

Luminescence in the Field – Flash Patterns & Other Emissions

Dear Fireflyers, Fields and woods of flashing fireflies are not only beautiful, and inspirational to the silent poet that resides in us, they are an endless mystery in nature that we will never understand but may always pursue. After an initial philosophic moment . . .

A firefly flitted by:
"Look!", I almost said, —
But I was alone."
Taigi

Hail to thee bright firefly;
Insect thou never wert.
(a variation on Shelly)

. . . one may next recall reading that nearly all of the flashes seen over such Elysium meadows are emitted by flying males . . . that each male is signaling with his species' own flash pattern . . . that each is seeking an answering signal from a female of his species. . . and that some males get caught and eaten by large predaceous fireflies, the females of several (*Photuris*) species that signal to them as would potential mates . . . Then, possibly after brief contemplation of this perpetual pursuit by males — which exists throughout much of the animal Kingdom—, and, perhaps, of the distracting and consuming responsibilities of Motherhood, most viewers pass on to other things. Let us stay a while, and look a little closer at the sparklers and glowers of the fields and woods, and learn how to distinguish different categories of their emissions.

Light emitters that you see in the field are not all sexually signaling males. There are other categories of light emission that can be recognized, though they are uncommon or rare, and little or nothing is known about most of them. These "superfluous" categories must eventually be distinguished by a fireflyer, first, so that they will not be **confused** with the (male) flash patterns that will be used to identify different firefly species, and second, because they may be **interesting** and deserve special attention themselves. Some of these "other" emissions can be recognized because the fireflies that are emitting them are in some distinctive, often unfortunate **situation**, or are juveniles. The annotated list I have sketched below begins with a few categories that are easy to distinguish, but then their differentiation becomes more difficult. It is easy to see the firefly emitting light — problems arise because there may sometimes be few if any clues as to why (to what personal [or is it beetleal] advantage) the firefly is doing so, and you will either not see any reason for it, or will be unable to choose among possible explanations that you have heard or dream (**notion**) up yourself. — here i must say: Keep track of all your notions; your ideas are priceless, and a good one may not flash twice!; so what, if they are more often wrong than not? Placer gold does not often occur in piles, to be "discovered," but must be dug and panned out of the sand and gravel, little by little. In this firefly experience you will begin to see beyond photic noise to make out the sexual signaling that is our primary (first & major) interest, and in doing so will learn more about what it is to be a firefly, bright spirit that it is. It might help to begin a "life–list" to see how many different categories you eventually are able to see, how many are new (undescribed) ones, and what you are able to learn about them! (I should note here that there are other, **non firefly** sources of luminescence that you will see in the field; I will take these up later, and remind you of them by numbering them 00 in the category list below.)

On firefly–chasing field trips you might make frequent deliberate surveys of the luminescence categories and/forms that you see. At each site (1) walk about slowly, (2) with your head lamp **off** (as it nearly

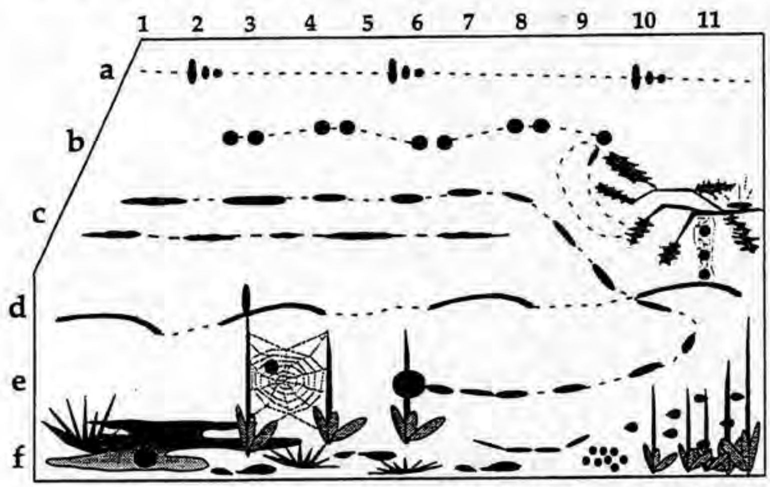

Figure 1. How many apparent categories of emission (enumerated in the catalog list) can you find in this drawing? I think I see nine. Of course I am certain to be wrong.

always should be!; a fireflyer's batteries should last a year), and hands in your pockets, (3) looking for flashes and glows, especially (3a) those that occur in unexpected places, or that (3b) look odd or wrong in usual places, and (3c) ones that occur in the different contexts described below. Find as many as you can, which I predict will always be few, but those "kinds" that you miss on one trip you will anticipate for future field trips. The ones you will see in the field definitely are not listed below in the order of their visibility or frequency of occurrence in nature, or of the likelihood of anyone seeing them. And, it would seem likely, that some of the flashing that you see occurring in different situations may eventually be shown to be the same <u>for the fireflies</u>. This is to say, (1) the **stimuli** for the flashes, (2) the **neural mechanisms** that are fired, (3) the **adaptive features/ consequences** of the emissions, and/or (4) the **pat-terns** of the flashes may be the same for some of the categories distinguished and enumerated here. Figure 1 illustrates emissions in a few of the contexts.

Here is an attempt to list "conceptual categories" of light emission:

00. Non-Firefly Sources of "Luminescence". Remember, in damp woods and meadows at night you will eventually see others sources of light: fungi, bacteria, giant glowworm beetles, click beetles, larvae of fungus gnats, earthworms, springtails, ctenophores (sea shore), and a miscellany of even rarer real and imagined (ghostly) glowers.

1. Spider Web Emissions. Spider webs are aerial seines that are stretched across spaces (Fig. 1, @e3), and they catch male fireflies as they fly about in the dark seeking mates. They occasionally catch females too, as they fly to find oviposition (egg laying) sites. Possibly some spiders specialize on fireflies during certain seasons, and put their webs across spaces that are most likely to be used by fireflies(?). Male fireflies in these nets sometimes **flash** or **glow** as they hang from the sticky silk. Sometimes these poor fireflies emit continuous glows with occasional bright pulses superimposed on them, and sometimes the flashes are emitted in continuous rhythmic trains. I have seen trapped males flash in response to a penlight flash or the flashes of passing males — I have even experimented with some of these flashes, and can say that they are more complex and interesting than might be presumed, and a Grimm tale it is! (see *FC* #3)

2. Water Puddle Emissions. Related to category 1 flashes, these flashes and glows are emitted by fireflies that are caught, often on their backs, in films and puddles of water (Fig. 1,@f1). They differ from those in #1 in at least one major feature; we can know with almost perfect confidence that these emitters have not been injected with poisons or sedatives, and thus, that pharmaceuticals are not partly responsible for their "aberrant" photic behavior — flashing fireflies in webs with living spiders **may have** been injected! (see *FC* #3)

3. Grasping–Predator Emissions. Fireflies being grasped by predators, such as wolf spiders, sometimes emit bright flashes. Perhaps these are stimulated by the same mechanical triggers as the above two categories. I once saw a wolf spider holding a flashing male *Photuris congener* LeConte, and the firefly's "erratic" flashing attracted additional *P. congener* males, some of which the spider also grabbed. (Note the firefly name in this last sentence; **rule to learn**: at first appearance in a text, the **scientific name** of an animal should be completely written out, and include the genus name [*Photuris*], the specific epithet [*congener*], and the author's name [LeConte].

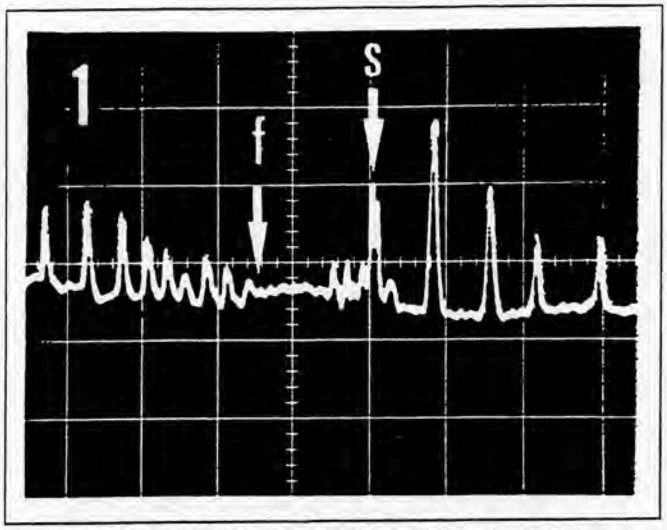

Figure 2. Landing flashes of a *Photuris* female. f shows approximately when the female touched down, and s shows the first of five bright flashes she emitted after she had perched. The time span on the horizontal axis is about 4 seconds. The vertical axis shows relative intensity of the flashes.

In this case, John LeConte named *Photuris congener.* Note from the forgoing that a generic name is italicized and capitalized, and a specific epithet is italicized but **not** capitalized; the author's name is not italicized. When writing longhand or with a typewriter, italics are indicated by **underlining**. For example, Photuris congener LeConte.)

4. **Grasping–Hitchhiker Emissions.** Perched *Photuris* females and males emit flashes when they are being grasped by **phoretic** pseudoscorpions. These pseudoscorpions — which are usually easily found between the paper-like laminations of the bark plates of some pine trees in Florida — apparently are only phoretic for a 3-week window in early summer, and may be using the fireflies to move to another "homestead." This arachnid species is social, and will be the subject of an *FLB* in the future.

5. **Maze & Labyrinth Flashes.** Fireflies (*Photuris* species primarily) that are walking through tangles and mazes, on paths in three dimensions such as inside a snarl of Spanish moss (Fig. 1, @c11), or inside a fireflyer's bottle (?), emit trains of irregular(?) flashes. They may be using their light to illuminate pathways to follow, or the stimulus that they are responding to may be the same as when they are "caught" (spider web, surface tension of water). ("A despairing firefly syndrome?")

6. **Ground Walking Emissions.** These are of two sorts: Adult fireflies that are "merely" walking over the surface of the ground emit irregular (?) flashes — ovipositing *Photuris* females, and females of the *Photinus consimilis* complex (Fig. 1, @f9). Larvae of *Photuris* and *Pyractomena* species, and rarely those of certain *Photinus* species, emit glows while walking over the surface of the ground. This may occur in the juveniles of most lampyrids.

7. **Stomping Ground Glows.** Sometimes footfalls of humans, and especially stomps and thumps, stimulate nearby *Photuris* larvae to begin glowing (Fig. 1, @f8). Sometimes stomps cause glowing larvae to extinguish their lights.

8. **Shaking Substrate Flashes.** When a fireflyer walks through deep vegetation, *Photuris* fireflies that are perched there begin to flash and twinkle, and their luminescence marks the path of the intruder as clearly as does bent timothy and goldenrod. When a firefly is on a leafy bough that is shaken by the wind or hand, it often emits twinkling flashes. Such(?) flashing can be used to find *Photuris* fireflies that have been dropped or cannot be found on the ground where they have just been seen flashing — to do this, gently run your hand low atop or through the vegetation tips, brushing gently as you might survey a flattop haircut, and a *Photuris* firefly there will sometimes begin to flash. And, nettles may inject you with their loaded and bent hypodermic syringes, but so what?

9. **Stem & Twig Walking Flashes.** Adult fireflies emit light as they walk along stems

Figure 3. *Photuris* females mimic (pretend to be) females of other species, attract males of these other species to them with the false sexual response flashes, then grab and eat the males. Often the prey males belong to other genera, but in this case the duped male is of another *Photuris* species. (They "just don't get no respect" either.)

and blades of herbs and grass, and on twigs and branches of woody plants. *Photuris* females flash as they climb up stems before taking flight.

10. Stem & Twig Walking Glows. Larvae of the genus *Pyractomena* often climb up in trees and shrubs, especially on drizzly nights, and glow as they walk along twigs and branches (Fig. 1, @c11). I suspect that this behavior also occurs in tropical members of this lampyrid tribe (tribe Cratomorphini, note tribal ending), including species in the genera *Aspisoma* and *Cratomorphus.*

11. Hanging Prepupa Glows. I once saw a *Pyractomena* larva that had taken the pupation position up on a small tree glowing continuously.

12 Tickled Juvenile Glow. When the pupal chamber of a *Photuris* firefly was opened and the reclining pupa tickled gently, and when hanging *Pyractomena* pupae are tickled, they emit light from their larval (and still operating) light organs.

13. Landing Flashes. (Fig. 1, from c1 through e11, to e6; Fig. 2). Sometimes flying fireflies emit flashes when they approach the ground to land. These fireflies are nearly always females of the genus *Photuris*, but I have occasionally seen male *Photuris* of unnamed species "A" (close kin of *Photuris bethaniensis* McDermott) and females of *Photinus consimilis* Green do this.

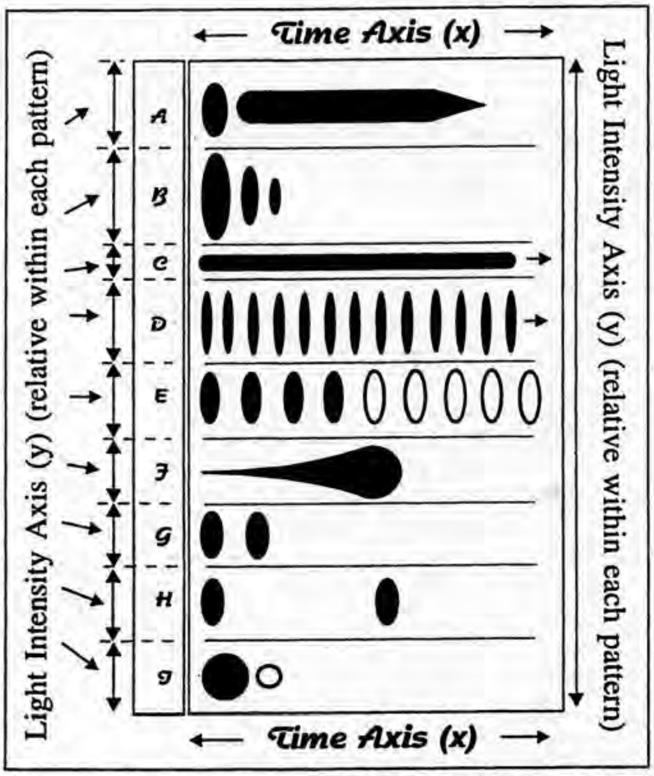

Figure 4. Some distinctive flash patterns of nine species of fireflies. When: (i) a distinctive pattern of emission, (ii) is emitted by several flying individuals, (iii) at fairly regular intervals, (iv) at the same time of evening, and (v) in the same site, the chances are very good that the emitters are males and that the emission pattern is a species specific flash pattern. The patterns illustrated were selected because they are distinctive, with certain limitations. The species occur in Florida (B, C, D, E, G, H, I), Tennessee (B, C, D, F, H, I), and upstate New York (A, E, I). Open symbols show pulse/pattern variations.

14. Semi-Cruising Flashes. Females of the genus *Photuris* occasionally are seen emittingt trains of flashes during horizontal flight (Fig. 1 from c1 to c7). These trains usually terminate within a few seconds after first being noticed, and I suspect that such females are either continuing flashing following the take–off mode, or are briefly in a landing mode, and then "change their little beetle minds." These flashes are those most easily confused with male flash patterns because they are emitted by flying, seemingly cruising/mate–searching individuals. However, with practice they can be distinguished after a flash or two, perhaps because they are generally longer, with gentler ON and/or OFF transients, and are less regular in timing, than are the emissions of mate-seeking males.

15. Female Response Flashes. Rarely, female response flashes to passing males are seen — unless you deliberately arrange to see them by setting out females in glass cages. And, as rare as it is to see this in *Photinus*, species, it is even less likely to be seen in *Pyractomena* and *Photuris* females. *Photuris* interactions apparently "always" occur rapidly, and unless you chance to be in the right spot at the right moment, for a 5-10 second window(?), you will be out of luck. Apparently, in most *Pyractomena* species, after males receive a single answer from a female they stop signaling, drop out of the air, perch, and wait up to several minutes before flashing again.

16. Mimicry Response Flashes. (*les femmes fatales*) *Photuris* females take perches in the sites of other species, answer the flash patterns of males with answers like those of their own females, attract them to within a few millimeters or so — and then spring upon them, seize them, and eat them (Fig. 3). These interactions may take longer than sexual attractions, and several "hopeful" but cautious males may gather around an answering female. Such **aggressive mimicry** appears to be more commonly seen in southern States but apparently (as a working guide) it occurs in all *Photuris* species, except for those in the demure branch of the genus that includes only a few North American species, such as Florida's *Photuris brunnipennis* (Jac. DuVal.) and *Photuris congener*. If you see that a male's signal appears yellow or orangish, and responses to his flashes appear to be green, you may have a predation "event." Avoid shining a bright light on the signalers; instead wait, and watch the proceedings (you can check the female's ID with a red– or a crack–between–the–fingers– filtered head lamp). In South America such predation is found in *Photuris*' relatives (other genera in the subfamily Photurinae), including a species of *Bicellonycha* and one in an unnamed genus that I observed in the Andes Mountains, west of Cali, Colombia. One or two species in the genus *Bicellonycha* occur in sw U.S., but little is known of their biology.

17. **Aerial Attack Flashes.** Experiments indicate that some *Photuris* females attack flying males in the air. They probably are more likely to attack slow flying, glowing males and flashers with lanterns that dimly "leak" photons between flashes. Experiments suggest that these females also attack approaching males that hover near them, when the females are in the "mimicry response" mode (category 16, above). When these females attack decoys they sometimes **emit light** just before they strike (Fig. 1, @b9). Possibly this illuminates their prey for the strike, though I suspect females may use other cues as well — such as the pulsing breeze from the target's wings(?).

18. **Aerial Rapprochement Flashes.** On one occasion, at the tip of the mitten in Michigan, I saw a flying flashing male and female of the same *Photuris* species simultaneously approach and land on the trunk of a tree several feet above the ground. This may have been an undescribed/unknown sexual flash interaction and rapprochement.

19. **Male Mate–Seeking Flash Patterns.** The sexual signals of flying males take many forms and are sometimes briefly confused with other emissions. But, with a season or two of experience a fireflyer will not only know the **flash patterns** of the common species in his region, but will be able to distinguish each new (to the fireflyer) flash pattern (Fig 1, @f10-11, from a1 to a10, and from b2 to b8; from d1 to d11; and Fig. 4). Usually you will see several, many, or even hundreds of individuals flying and emitting patterns of light with approximately identical timing characteristics. — However, I have occasionally seen up to a dozen *Photuris* females flying and landing along a damp roadside by a lake, at about the same time (see category 13). I presume they had just mated in the tree tops where their males were active and the females were flying down to the ground to lay eggs or hunt. Even when seen in such numbers as this, the emissions of landing and flying females are not easily be confused with the **flash patterns** emitted by mate–seeking males.

20. **Rival–Confusing Emissions.** When *Photinus macdermotti* Lloyd males (Florida's *P. macdermotti* "subspecies", +others?) have landed near responding females, both predator (*Photuris* females) and conspecific (their own *mac*) females, they will emit a variety of flashes when other *P. macdermotti* males try to "horn in." For example, when the female they are closing in on answers the flash patterns of a passing male, perched males sometimes emit false female responses. The timing of other flashes emitted in this situation indicate that they are part of a complex and very tricky and de-

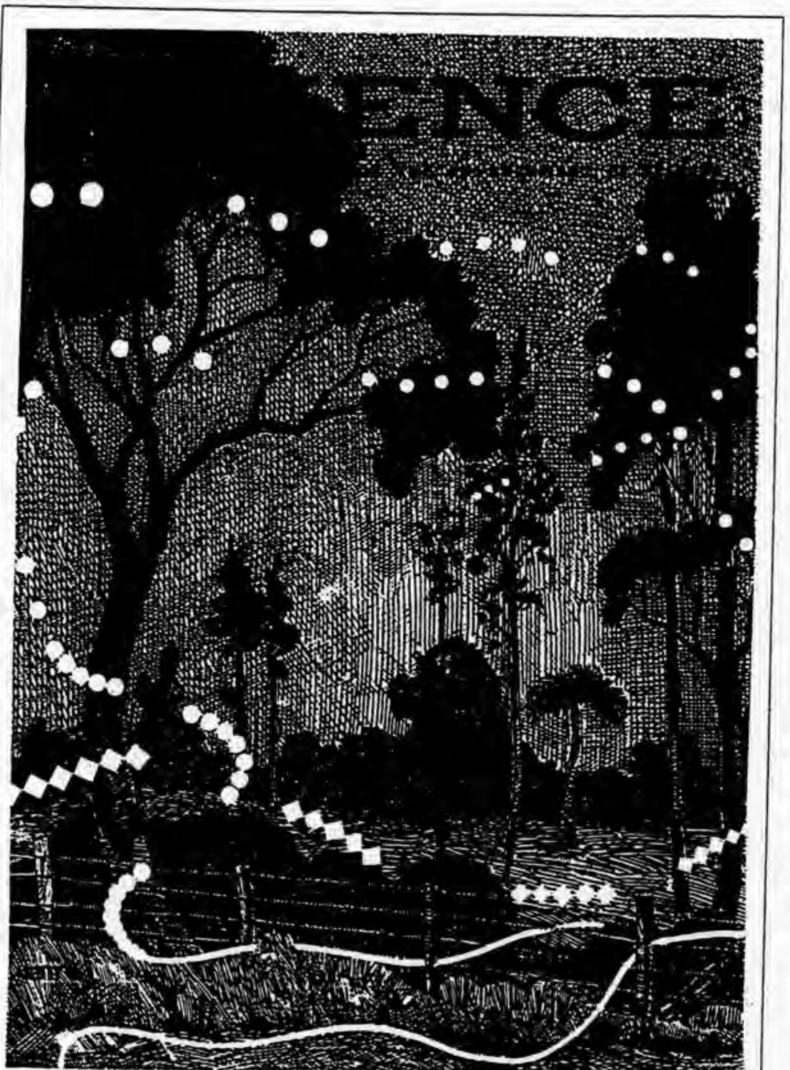

Figure 5. In many *Photuris* species males emit more than one distinctive **flash pattern**, and they switch among them — according to rules that are only poorly understood. In this drawing, the males of *Photuris* "VR", a spring species in the big bend region of Florida, emits a pulsing pattern, a glow pattern, and a flicker pattern, the last two being copies of patterns emitted by males of coactive *Pyractomena* species. VR's first pattern may be considered the species "own" and "default" pattern, as a working generalization (notion).

ceptive mate competition. Several subcategories of these flashes can be recognized. Their analysis may require computer driven simulations and interactions!

21. Supernumerary Flash Patterns. (Fig. 5) Males of several *Photuris* species use two or more **distinctive** flash patterns during mate-search flight. A clue to the significance of their versatility is the fact the these patterns can usually be recognized as **copies** of flash patterns of other species, often species that the *Photuris* males' own females are known to prey upon. This Byzantine phenomenon is the major reason I have remained on the firefly chase for 30+ years. (With hopes it never ends.)

"**Concludingly**" — now, I can imagine a pie chart that graphically illustrates the proportion of these bioluminescent categories a fireflyer might actually see in a fireflying summer Fig. 6). Obviously, one will see almost exclusively the mating signals of males, category 19 — the flash patterns that we write poetry about, and use to identify species, at night, in the woods, in the dark.

Quiet and mysterious trails,
firefly doc

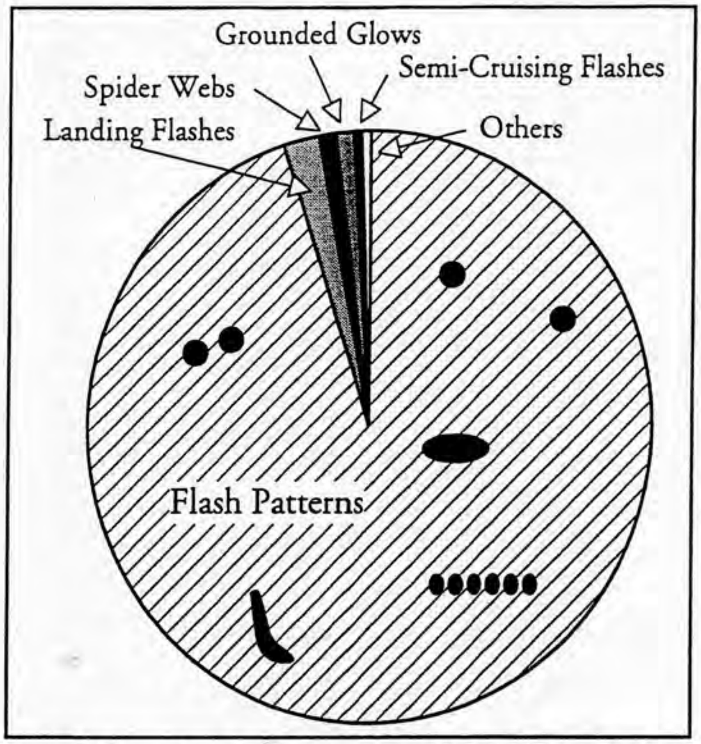

Figure 6. Categories we sometimes see on class field trips. To show any other than "Flash Patterns" in the pie they had to be exaggerated. Proportions shown are worse than crude estimates, and none have ever been quantified for any night or site!

Loveliness:
The fireflies
Light
Our meeting's footpath.

Ryan Robbins, UF

(a poem from a termpaper that will be be published here in a future issue)

A glowworm

Sister?
Does that tiny head
See beauty in his light?
What an ugly question
On such a lonely night.

John Sivinski,
Gainesville FL

Unsigned untitled bug poetry

The lightningbug seems brilliant
But he has not any mind;
For he stumbles through existence
With his headlight on behind.
The measuring worm is different;
When he starts out for pelf
He reaches to his limit,
And then he humps himself.

Author unknown

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The Fireflyer Companion & Letter is available to interested students, parents, teachers, and naturalists. Write: Fireflies, Department of Entomology, Bldg. 970 Hull Road, Univ. of Florida, Gainesville FL, 32611.

[A Glow For You In Winter]

"We share the same biology
Regardless of ideology" Sting

The human is not a minimal animal
In impact, number, need or ingenuity.
Yet they watch a crepuscular shade of natural resources diminish
Not ready for a preliminary, nonmilitary delimitation.
How long will the walls crumble after we have gone?
Far before the sun dons darkness and destruction.
Most discussion disgusts or obstructs justice;
He who has seen will tell you
How He strived to achieve hopes and dreams
Only to watch them melt like wax on hot concrete.
But fortified by his strife, He rose
As a full placid moon on a summer evening,
shedding light on the truth of form and reason
and illuminating the shadows of conspiracy.
And I will scream aloud with my last gasping breath
That this man shall not fight alone.
For even now, I see the sentinals gathering
And can hear their whispers of dissention.

Cory Lewis, Athens GA

Inside the Mason Jar

i watch others cry
little children who
watch others die
inside the mason jar
i often ask why
pain for pride
small hands reach
inside the mason jar
sweet caress i hold
my breath for those
big eyes looking at
all the souls
inside the mason jar

Kim Houck, Todd NC

Angie's Journal

Feb 2, 1996. Well, today I have finally got it all together and I can actually start writing in my journal. I know that perhaps I should have started this sooner, but procrastination is definitely part of my nature. Oh well, at least since I have now started this, I will actually keep this up, and I will be faithful!

Anyway, on to firefly stuff. Today was also our first "outing" as a class since the new semester started. We went to a place called Millhopper which is here in Gainesville about 20 minutes from the Entomology building. It was the home of someone in Entomology – actually, it was the woods outside the home.

The weather today was gorgeous – probably around 50°F – 60°F, the sun was shining, and the night before it had been really cold (19°-25°F). Our objective for the day was to find, measure, and record firefly pupae that had been sighted in the forest before. Our luck turned out to be very good because within seconds we had sighted some pupae. There were two species that we found in the forest: Pyractomena borealis, the first could be described as larger, wider, longer, and more colorful than the second species, Pyractomena limbicollis. We found both species on the same tree, and we proceeded to measure 1) their length 2) their height (from the bottom of the tree) on the tree 3) the circumferance of the tree. After gathering the data of about 20-25 pupae, we all sat down in a circle on the ground and discussed some of the things we had observed. The following are some things we observed & some questions we raised:

1) The firefly pupae of both species ocurred on the same tree at times, but P. borealis was almost always higher from the forest floor. Why?

2) The pupae seemed to stop appearing on the trees after a certin point in the forest – why? Are they trying to avoid something further back in the forest (or does our point of reference matter?)

3) Do the pupae appear only on certain types of trees w/ special types of bark? Smooth vs rough?

4) Are the pupae higher up on the trees than we can observe? Why do they go only so far up on the trees & stop climbing higher?

5) How long do they pupate?

6) Did the freeze the night previous affect them at all?

7) I notice one pupa on the underside of a piece of plastic wrapped around a tree. Does this indicate that the pupa wanted shelter of some sort & bark on trees is something that doesn't matter.

There were more points raised, but for now that's probably enough. Overall, the trip was very enjoyable for me. It was a pretty, peaceful and calming afternoon.

Also, on the way back, FD. said that he had an experiment that I could research. It involves flies (swarm ones), microscope slides, photography, and even a little bit of electronics – my favorite stuff. I am really relieved that now I have some direction for my research. I just feel better about the whole thing! [Angie Odle is an Accounting major at UF, took the Firefly course in spring 1996, and is now a senior, fd]

Firefly's Choice

by Lauren Brown
UF Honors Program

This story is based on events that could take place in the life of an adult male firefly. The format of the story was inspired by studying dichotomous keys in firefly class. The story starts at chapter I. There will be two choices for the reader to make at the end of each chapter. The choice that is made determines the chapter to be read next.

I. Picture yourself as a *Photinus consanguineus* LeConte firefly. It is twilight, a cool evening in the fall. You drift through the woods a few feet off the ground. As you have done every night of your short adult life, you begin search for a mate. You emit two yellow flashes separated by about half a second, pause for about four seconds and then repeat the pattern. You contiunue to flash, staying alert for the characteristic response of the females of your species. You . . .

. . . do not see a *P. consanguineus* female . . . go to II

. . . see a *P. consanguineus* female . . . . go to III

II. Because you cannot find a female, you decide that it might be best to move to another location. While still flashing you allow the wind to carry you across a clearing in the woods. As you approach the other side the wind stills and you must decide where to fly. In your opinion . . .

. . . the thick woods to the left look awfully appealing . . . go to IV

. . . there seems to be more activity to the right . . . go to III

III. In the distance someone has noted your efforts! A yellow flash timed to your pattern is visible ahead. You signal again. She waits (is she playing hard to get?). She responds! You repeat your message as you approach her. She continues to answer your patterns; you are a master of seduction. You get closer. . .

. . . and the light doesn't seem to be the right color . . . go to V

. . . and anticipate the moment . . . go to VI

IV. Your sense of adventure has always gotten you into trouble, but the excitement you feel from exploring this section of the forest renews your determination to pass on your name (which is ridiculous because fireflies don't have such names. Really, all you will pass on is your genetic information). But suddenly you are stuck in midair; you beat your wings frantically, wave your legs, struggle for freedom. You feel sticky. With horror, you understand that you have flow into a spider web. You see the predator approaching. Enormous legs, furry body. All you can do is glow dimly as you are devoured.

The End

V. Your enthusiasm for this female is shadowed by the color of her flash. It isn't quite yellow. Still, you persist and land . . . on a penlight. A hand scoops you up, you hear squeals of delight. In your anger you refuse to glow. Bored by the lack of demonstration, your captors release you. A group of your friends, absent until now, fly by and laugh. You are incredibly embarassed. But twilight is passing quickly and you must find a mate. . . Go to I.

VI. Finally you reach your true love. You have always pictured her to have a yellow elytral margin, black elytra, a rounded pronotum with red accents, and a retangular vittigram.

. . . If she is everything you hoped for. . . go to VII

. . . If she is somewhat a disappointment . . . go to VIII

VII. Such patience in finding a mate has paid off. She is the most perfect *P. consanguineus* you have ever seen. Even better, she allows you to inseminate her. You feel as if your entire reason for living has been explained. However, the moment ends very soon. You fly away. You are tired and are ready to retire for the night. You land . . .

. . . on a tree branch. . . go to IX

. . . on a rotting log . . . go to X

VIII. This is one strange looking female. She is a little larger than you would have expected. Each of her elytra have a pale mid-line stripe and her vittigram is not rectangular. How could this female, when obviously not of your own species, manage to respond like a *P. consanguineus* female? Your mind flashes back to stories you heard when you were just a larva, about cunning women with the ability to pretend to be your mate. They knew all the right flash patterns to lure you to them. They got your hopes up and then, when it was too late to escape, they killed you. Just as you realize the gravity of your situation, you are pinned to the tree branch you landed on. You have become prey for a *Photuris* female.

The End

IX. Your decision to rest on this tree was excellent. You have a quiet, restful night and uneventful day. Twilight returns the next evening and you are once again ready to find a mate. . . . Go to I

X. This log seems to be the perfect haven for the night. There are a few others of your species and you stay up telling one another of your evening's successes and failures. After sipping some nectar from a woodland flower you fall asleep.

You are awakened by the most horrific sound you have ever heard. It is morning; the sun is rising and a thin layer of dew blankets the forest floor. This should be the most peaceful time of day. You creep out of your log to find out where the sound is coming from. It is an animal unlike any you have seen before, with hairless fluorescent orange skin, sharp angles, jerky movements, and shiny protruding mandibles that are consuming your log. It is the size of four bears. And that sound! You scurry to a neighboring tree. Within minutwess nothing remains of the log, and the animal is not even finished. It begins eating live trees, bushes, flowers, fallen branches. There is nothing that can stop it. You look for your companions and find only one. He informs you that the others did not wake up in time. They, too, fell prey to the assailant. Although you survived, you are deeply shaken. You wish to never see one again, but you will see two before you die. In the weeks to come, there is word that the animals are not actually eating; rather, they are intentionally ripping the forest apart in order to flatten the surface. You cannot imagine what was wrong with the forest floor to begin with.

However, you must continue with your life. As twilight approaches you prepare to . . .

. . . go to I.

[Lauren finished her freshman year in the UF Honors program in spring 1998. In this piece, which she wrote while taking *BNHFF* in the autumn 1997 semester, she takes many many literary liberties with scientific fact and expectation. I hope she will again! fd]

Letters
from fireflyers

Dear fd, During August in recent years, I have spent several days at an inn on West Street in Manchester, Vermont. In the early evening hours the fireflies put on a spectacular show in a large, wet field on the west side of West Street between the inn and the Southern Vermont Arts Center. I often go there after dinner, park the car, and enjoy the fireworks! It has crossed my mind many tiimes that this display warrants being preserved and protected by the acquisition of the field by some local conservation group or the very active Vermont Land Trust. Someday, this may happen, I hope. Christopher P., Waterford CT.

Dear ff Chris, Me too. Your fireflies may be *Photuris fairchildi* Barber. Most of the common and conspicuous species of North America have dropped out of the picture by the time one travels north to Vermont. *illuminating trails, fd*

Dear fd, Thank you for publishing my poem. In regards to what the poem means — the poem is about the spiritual crossroads we find ourselves on between the past, present and future of our environment and of our culture. The lightningbug serves as the vehicle. The reference to the Rain Forest and to Zen came about because of an article I had read in a 1947 edition of *Compton's Pictured Encyclopedia*. [the article discussed the use of click beetles in Tropical America, and the capture of fireflies in Japan for various reasons] The additional flier that you enclosed with the *Fireflyer Companion* showcasing the infamous Mason Jar has inspired me to send yet another poem for your consideration. Kim H., Todd NC.

Dear ff Kim, Thanks for sending your poems. The second one is in this issue. Over the years I have heard 100+ stories of fireflies dying in Mason Jars. In the literature there is mention of the use of luminous click beetles for midnight meetings (trysts) being made illegal; during the Firefly Festival in Japan apparently thousands and more were released outside the Emperor's Garden. This and stream pollution were given as reasons for the near extinction of once common aquatic species. Stream cleanup and artificial breeding (hydroponic farming) have apparently saved the fireflies. *philosophic trails, fd*

Dear fd, Here are a few Proverbs I have run across. Perhaps the other FFs will enjoy them too. Gene G., Gainesville FL.

He sees a glowworm and thinks it a conflagration.

If a lightning bug [sic] *comes into the house, be sure that an old friend will visit.*

If a firefly comes into the house, on the following day there will be one person more or one person less in the house.

Dear ff Gene, Thanks for sending them. I had seen the last one. I read somewhere that the reason that there are so few references to fireflies/glowworms in Old and Middle English literature is because lampyrids were understood to be bad or evil omens. *philosophic trails, fd*

Dear fd, I am conducting a survey of coleopterists, and I have a question for you. "What is the most interesting beetle that you have ever studied?" Joshua. G. Port Washington NY

Dear ff Joshua, Your question is almost impossible to answer. I have studied fireflies in many foreign countries and in most of the United States east of Colorado, and found many of them to be "especially" interesting. I put two in my personal final runoff. One is from northeastern United States and is presently unnamed. I refer to it as *Photuris* LIV. Males emit two basically different flash patterns during an evening's flight, and the proportion of each pattern varies in a population across the span of evening mate-seeking activity. Males also switch from one (a mimicked pattern) to the other (their species own default pattern) when they are answered with a flash that simulates the response flash of their females.

The other species is the Jamaican firefly Photinus *pallens* (see the photo on page 76. Males and females gather in sometimes tiny and sometimes huge sedentary mating congregations on various plants, feeding on the blossoms, and signal almost continuously to each other from dusk till dawn. At other times males seek females in the "old fashioned way" common to our *Photinus* species in North America. This species is perhaps one of the best in the entire world to study what seems to be a "resource oriented" mating congretation (lek). Later this summer I will have an article published on this species in *The Florida Entomologist*, the journal of the Florida Entomological Society. This journal is electronically published on the internet. The article will include color photograph attachments.

Illuminating and puzzling trails, fd

Sorry to be so late getting this issue out. Have had a number of unexpected chores. Will do better next time, but I do need more Letters! fd

Reports & Observations

Observations on *Photuris* Feeding

by Arwin Provonsha

Department of Entomology Purdue University, West Lafayette, Indiana

On July 24, 1997, while collecting fireflies at his farm in rural Tippecanoe County, Indiana, Dr. Tom Turpin and I observed five male *Photinus* (three *Photinus marginellus* LeConte and two *Photinus curtatus* Green) caught in separate spider webs along the margin of a woods. We located them by their constant glow. In one case, the trapped firefly was being fed upon by the owner of the web. However, in three of the cases, the fireflies were being fed upon by a female of the genus *Photuris*. In each of these instances, the spider had retreated to the far reaches of its web.

In the fifth case, we observed a female *Photuris* cautiously hovering near a trapped *Photinus*. She did not emit any flashes during this time. After several seconds she landed on the web, chased the attending spider away, and began feeding. In each instance the long and nimble legs of the *Photuris* females seemed to have no difficulty negotiating the web without becoming stuck.

Female *Photuris* fireflies seem to be attracted by the constant glow of dead or dying fireflies. Since four of the five *Photinus* fireflies that we observed in spider webs were being fed upon by female *Photuris*, it would appear that this is a fairly common feeding strategy for these *Photuris*, at least in this particular locality. We were unable to identify the Pho*turis* females to species with any certainty since the males of at least three species were flying that night.

Earlier that month on July 7, 1997, while collecting in Purdue University's Horticulture Park, I discovered a male *Photuris* with its mandibles locked onto a male *Photinus pyralis* (L.) which was almost as large as he was. He never did let go, even after they were placed in alcohol. I was also able to locate these specimens by the constant glow of the dead *P. pyralis*. The predator was most likely *Photuris lucicrecens* Barber,which is common at that locality. It is unknown whether the prey was captured on the wing or if it was taken on the vegetation where I found them.

[Dr. Provonsha's observation of a male *Photuris* firefly eating a *Photinus* firefly in the field are especially noteworthy: though they have been known to eat fireflies when confined in a bottle with them, and had been observed in the field answering simulated and actual male flash patterns as an aggressive mimic female would, none had ever been found with prey; yet, field-collected males have been found to have certain defensive compounds (lucibufagens) it seemed that they could only have obtained from such predation. Would a male *Photuris* in the field take a *Photinus* firefly from a spider web and get its defensive compounds that way? . . . now there is an experiment my firefly class can do this fall! fd]

Hot humid summer nights, goatsuckers, and cryptic fireflies

by Bo G. Svensson

Department of Zoology,Uppsala University
Uppsala, SWEDEN

The scenario. Jim Lloyd has a considerable interest in firefly flashes and of course he showed some to me during my first sabbatical summer in Gainesville some years ago (I had never experienced fireflies before). We went to an area near the Gainesville Airport. Goatsuckers [nighthawks] were displaying in the sky just before the first *Photinus collustrans* LeConte started to flash, shortly after sunset. The flashes continued for nearly half an hour. Thereafter we drove a couple of miles to be enlightened by *Photinus tanytoxus* Lloyd. "This one I described some years ago, and *P. collustrans* and *P. tanytoxus* are very similar (cryptic or sibling species), just differing in flash duration, onset of flight display and on some body-colour patterns. They are morphologically difficult to distinguish" (Table I). "Are there no other visible differences between the species", I asked. The answer was typical for Jim, "Maybe, try to find out." I took up his challenging answer.

Character	*collustrans*	*tanytoxus*
Duration of male flash	0.25 sec	0.5 sec
Start of flashing after sunset	15 min	40 min
Yellow colour on sutural bead	entire	< apical 1/2
Flash (bioluminescence) colour	yellow	green

Table 1. Summary of differences between the two species in Lloyd (1966).

Data recorded. During that summer I collected both species, identifying them by their flashes and time of evening they were active, at the site near the Airport and a large pasture site a few miles west of Gainesville, near Jonesville (Table 2). Measurements and colour characteristics were recorded from each male. **Measurements,** in millimeters (mm): diameter of eye, pronotum breadth (see Fig. 1), pronotum length, pronotal disk length, and elytral (wing cover) length. Total "body" length was calculated by adding pronotum and elytra lengths. **Colours:** scutellum colour: 1) brownish black; 2) brown; 3) yellowish brown; 4) yellowish. **Proportion** of disc that is pale (versus dark; from posterior edge of the pronotum, anterior to the dark area) (see Fig. 1). **Proportion** of the elytral sutural bead that is yellow (entire in *P. collustrans*, <1/2 in *P. tanytoxus*).

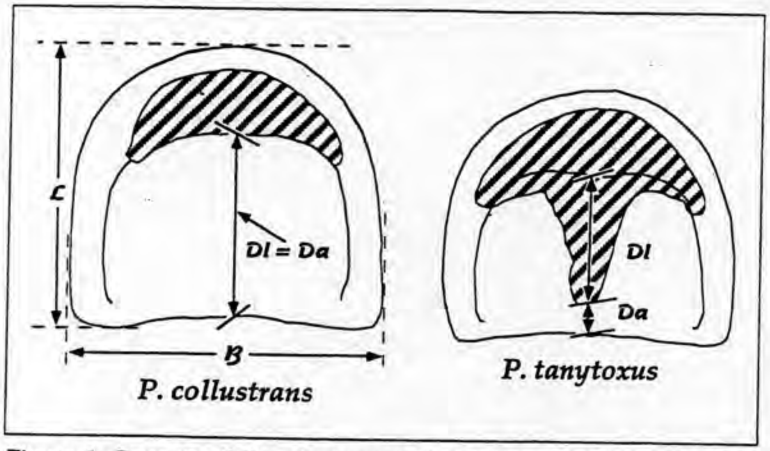


Figure 1. Pronota of *P. collustrans* and *P. tanytoxus*. I have sketched specimens that most clearly illustrate the difference between the species. In *P. collustrans* (specimen C31) the pale area is 100% and in *P. tanytoxus* (specimen T8) it is 25%. L=length of pronotum; B=breadth of pronotum; Dl=midline length; Da=pale length along midline of disk)

Results. Were there morphological differences? Yes, I found some additional differences that will help to distinguish -between *P. collustrans* and *P. tanytoxus*. Generally, *P. tanytoxus* is smaller and darker than *P. collustrans* in all measurements except pronotum breadth and size of the eye (Tab. 3). The breadth/length ratio of the pronotum appears to be especially good for identification (Fig. I, Tab. 3).

Locality	*collustrans*	*tanytoxus*
Airport	42	38
Jonesville	7	4
Total	49	42

Table 2. Number of specimens collected at the two localities.

Measurement	*collustrans*	*tanytoxus*	*t*	*p*≤
Diameter of eye	0.90 ± 0.04	0.89 ± 0.07	0.83	NS
Pronotum breadth	1.86 ± 0.12	1.83 ± 0.15	1.18	NS
Pronotum length	1.55 ± 0.10	1.43 ± 0.11	5.54	0.0001
Disk length	1.00 ± 0.08	0.86 ± 0.09	8.15	0.0001
Elytral length	5.57 ± 0.33	5.23 ± 0.38	4.56	0.0001
Total length	7.11 ± 0.42	6.65 ± 0.48	4.92	0.0001
PN breadth/length	1.21 ± 0.03	1.29 ± 0.05	8.90	0.0001

Table 3. Measurement data for several characters of the two compared species. Measurements, given in mm (millimeters), are the mean ± standard deviation. T-test statistics are also given.

Character	*collustrans*	*tanytoxus*
Flash duration (sec)	1/4	1/2
Flash color	yellow	green
Start of evening flashing flight (min after sunset)	15	40
Yellow of sutural bead	entire bead	< apical half
Pronotal B/L ratio	1.21	1.29
Length (mm)	7.1	6.6
Colour of midline region of pronotal disk	mostly yellow	mostly dark
Scutellum colour	usually yellowish	brownish black to yellowish

Table 4. Summary of characters for distinguishing *P. collustrans* and *P. tanytoxus*.

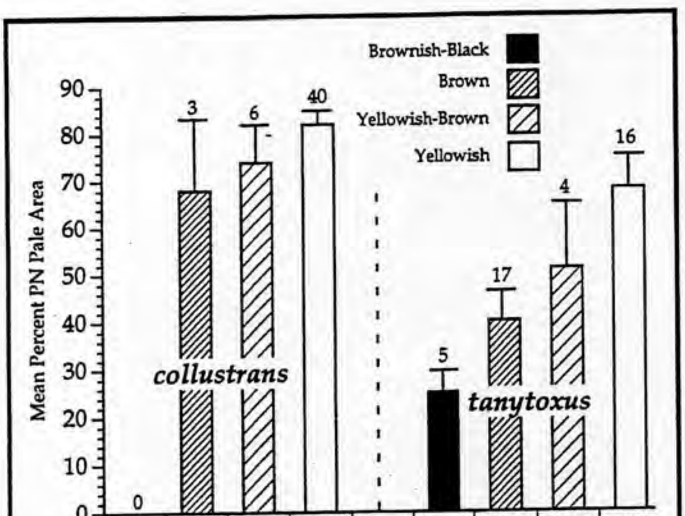
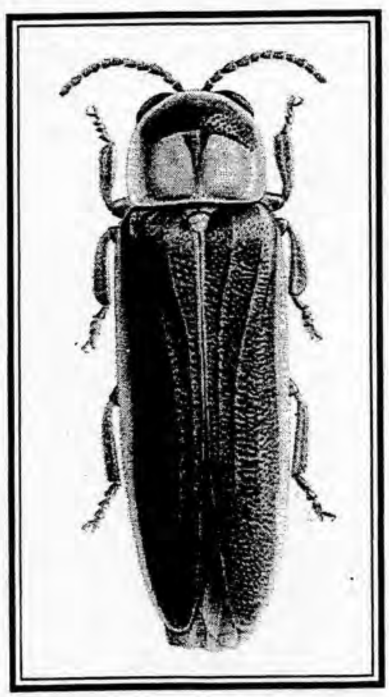


Figure 2. Histograms showing mean percentage of pale area of pronotal disks in *P. collustrans* (left) and *P. tanytoxus* (right), split upon the four scutellum colour categories. Staples show standard errors, numbers above columns show number of fireflies in the sample. Percent in pale area = 100(Da/Dl).

The extent of dark and yellow coloration is quite variable, except for the elytra. In *P. collustrans* the yellow color extends the entire length of the elytral sutural bead but in *P. tanytoxus*, it extends less than half the length as noted previously (Lloyd 1966). *P. collustrans* also has more yellow coloration on the scutellum and on the pronotal disk. The darkened central area (vitta) in *P. collustrans* is generally short while in *P. tanytoxus* it commonly extends posteriourly some distance (Fig. 1), though there is considerable variation. It is interesting to note (Fig.2) that a brownish black scutellum was only found in *P. tanytoxus*. The most usable characteristics for identification of *P. collustrans* and *P. tanytoxus* are given in Table 4. I also noted that no size difference was found in specimens from the two localities in *P. collustrans* (Mann-Whitney test), and all size variables were highly correlated in both species ($p<0.0001$, in all cases).

Acknowledgments. I would like to thank Jim (fd) for introducing me to fireflies, for encouraging me to write up this note, for discussions on "whatever" (mostly science and teaching), and our mutual interest in double anchovy pizza; and my fireflyer daughters Tora and Åsa for adding specimens to my collection.

Reference. Lloyd, I E. 1966. Two cryptic firefly species in the genus *Photinus* (Coleoptera: Lampyridae). The Coleopterists Bulletin 20:43-46.



SPECIES ID QUIZ: Which of ff Bo's two species is this one? A carbon dust by Laura Line (fd).

Other "Fires" — Other "Flies"
Earthworms (Annelida: Oligochaeta)

Earthworms lead underground lives. There are a number of good, though often unappreciated reasons for an animal to bear lights in the soil (see previous issues of *FC* for discussions of phengodid beetle larvae). For example, light might protect a luminous animal from its enemies; a subterranean predator may innately be repelled by light, because light would be an indication that it was about to breach the surface and enter an alien and dangerous world. Similarly, luminescence could startle a hunter that suddenly stumbled into a glowing mass, or overload (temporarily blind) eyes adapted to profound darkness. Bioluminescence is the sole visual means of advertising distastefulness (termed aposematism) in the absence of reflected light.

Given these advantages, it should not be too surprising that various earthworms are luminous. Yet, amazement is the most typical reaction when one is confronted with worm light. Although naturalists have commented on luminous earthworms since 1670, only a century ago one expressed astonishment upon stumbling across such a creature: "The air was sparkling with fireflies, and the earth at my feet was bristling with phosphorescence (sic). Had time sped backwards twenty centuries, and were the vestal fires lighting around me?" "Such puzzlement is a testament to how little we know of the ground only inches below our feet.

In fact, at least 33 species of earthworms in 16 genera are bioluminescent. Every continent has at least one published record of a glowing worm. The southeastern United States is particularly rich in reports (perhaps rich in observers, luminous earthworms, or both). An impressive species is found in Gainesville; *Diplocardia longa* reaches lengths of over a foot. But this pales beside a New Zealand species, *Ochtochaetus multiporous*, which reaches a length of 18 inches, and is reputed to live at depths of up to 40 feet! Bioluminescent worms are most commonly noticed when heavy rains force them to the surface. This was what gave me my first experience.

A colleague, Tim Forrest, found luminous patches on a sandy farm road, at a gate he was closing on a wet night. Investigation revealed that the glows came from earthworms that had been crushed by his tires. The species he had run over was *Microscolex phosphoreus*, a skinny and delicate worm, little more than an inch or two in length. A more dramatic exploration was undertaken by a Capt. Lane in 1686, who "casually fell" into an English ditch during a nocturnal ride. Lane was rescued by a friend and ". . . having stirred the mud and dirt pretty much in performing that good office" they found their gloves, bridles, and horses smeared with mashed earthworms and "all in a kind of faint flame, much like that of *burnt brandy*" (perhaps a particularly good metaphor considering the circumstances).

The substance that illuminated Capt. Lane's horse was the typical source (sole source?) of earth worm bioluminescence, coelomic (body cavity) fluid. This viscous fluid is expelled from the mouth and anus of worms when they are disturbed, and flows from wounds as well. J. D. F. Gilchrist made careful observations of a South African *Chilota* species in 1917. He saw that ". . . after a time, it began to exhibit very lively movements, and, by a series of strong flexures of the body to throw itself about, scattering masses of luminous substance in all directions." The substance covered the worm's body, but sometimes was flung far enough to decorate Dr. Gilchrist's clothing. Once out of the worm, coelomic fluids can continue to glow with colors that range, depending on species, from orange to blue-green for several minutes to more than an hour.

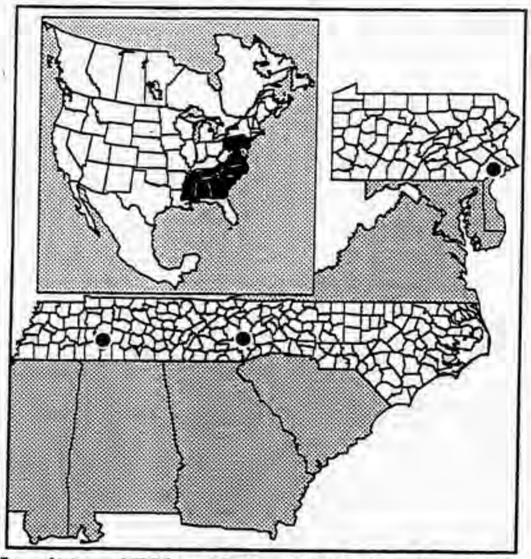
Worm lights appear to function in defense, at least they are emitted when the worm is irritated (attacked), and there is no indication of sexual signaling. There is little experimental evidence to confirm suspicions. In one small trial by Tim and me, we exposed *M. phosphorus* to various predators. Earwigs and lycosid spiders ate the worms without hesitation even though they were smeared with luminous fluids and their jaws were frequently alight. However, a subterranean carnivore, the mole cricket, *Scapteriscus acletus*, did react to the fluid. It repeatedly withdrew from its prey,and rubbed its head with its forelegs. One interpretation of the different reactions is that a subterranean animal, such as the mole cricket, would be more disturbed by light — that is, be negatively phototropic. As noted earlier, for an animal that lives underground, light is evidence of the open air and the perilous surface. There was certainly little indication of the worm being unpalatable and its lights a signal of its distastefulness. There are other reports of luminescent worms being eaten by frogs and spiders. John Sivinski, Gainesville FL.

Further Reading. Gilchrist, J. D. F. 1919. Luminosity and its origin in a South African earthworm (*Chilota* sp.). Transactions Royal Society South Africa. 7:203-212. Jamieson, B. and J. Wampler. 1979. Bioluminescent Australian earthworms II. taxonomy and preliminary report of bioluminescence in the genera *Spenceriella*, *Fletcherodrilus* and *Pontodrilus* (Australian Journal Zoology. 27:637-669. Wampler, J. 1981. Earthworm biology. pp 249-256 in Bioluminescence and Chemiminescence. Academic Press NY. Wampler, J. 1982. The bioluminescent system of *Microscolex phosphorus* and its similarities to those of other bioluminescent earthworms (Oligochaeta). Comparative Biochememical Physiology. 71A:599-604. Wampler, J. and B. Jamieson 1980. Earthworm bioluminescence: comparative physiology and biochemisrty. Comparative Biochemical Physiology. 66B:43-50. **Note:** As always when dealing with bioluminescence the bible is E. Newton Harvey 1952. Bioluminescence. Academic press NY, and the New Testament is P. J. Herring (ed.) 1978. Bioluminescence in Action. Academic Press, NY.

The Hikers' Spheres Mystery

If you spend several days in a library with an accumulation of musty old reference books, looking up "luminescence," you will eventually run onto stories of strange lights of undetermined and mysterious origin. Perhaps such fantastic tales were counterparts to today's reports of extraterrestrial visitations? Among the unfamiliar and enticing names that I found were *Will-o'-the-wisp*, *ignis fatuus*[1] and *foxfire*[2]. When I began chasing fireflies as a serious habit I hoped I would eventually see flaming globes of light or clouds of cold phosphorescence, or other ancient magic up close, something that only those who go abroad in dark damp places at night are likely to see. I heard about modern mysterious lights near a little town in northern Alabama, and others in the sky near Marfa, Texas, so I knew <they> were still around, out there, somewhere . . .

Years have passed, and I must have at least 3000 nights afield in the dark. . . all over the eastern half of this continent, with occasional peeks in dark places on others . . . and I have never seen even one of these wonderful things . . . or something I can later imagine just might have been one. Once I saw a flickering yellow light half way up a dark mountain in New Guinea, accompanied by the haunting notes of a wooden flute — obviously only a campfire. . . But I do have two spooky stories to pass along. One is about what I shall call Cracker Fire, for the lack of a better term, or until I find that the phenomenon has already been described and given another name. I shall save that story for another time. Suspense. Here I will tell you about "Hikers' Spheres."



Localities of "Hikers' Spheres" sightings, in central Tennessee, western/montane North Carolina, and eastern Pennsylvania. Inset gives a continental perspective.

Some time ago a colleague in the Ent' Department told me that he knew of two backpackers from Gainesville that had observed something weird and beyond their comprehension. They were not eager to share this with their friends, but they would tell me about it. We met for lunch at the student union. They had seen low-flying, luminous spheres at three localities (see map) in eastern United States. The sites were: (1) near Hohenwald, Tennessee, in a campsite in the Meriweather Lewis Park, during summer in the early 1970's; (2) near Westchester, Pennsylvania, which is a little west of Philadelphia, at the Buck and Doe Valley area (originally King Ranch), in early summer; and (3) at the Peck's Corners shelter on the Appalachian Trail, in western North Carolina, at an elevation of about 6000', on 1-2 July 1990.

At the Appalachian Trail site several spheres, perhaps twenty of them, entered the campfire area after the hikers had retired to the shelter for the night and the campfire had died down. The spheres moved slowly and smoothly, about two and a half feet above the ground, glowed white, and were about the size of a half dollar in diameter — somewhat smaller than a ping pong ball, they said. At any slight vibration, movement in the shelter, or whispered comment, the lights were immediately extinguished. The glowing spheres were observed by several hikers who were hiking the trail independently, and sharing the shelter for the night. Such spheres had been seen before, was explained to the hikers by a park ranger in the Peck's Corner area.

Since, in some respects, the lights resembled the glows of *Phausis reticulata* (Say) males (see *FC*#3:36), I cautiously asked the Gainesville hikers whether the spheres might not actually have been tiny points of light made larger by poorly focused eyes, say, due to the lack of eyeglasses that were usually worn, or perhaps foggy air. I must admit I felt like a Scrooge, asking whether Marley was only a fragment of undercooked potato. Such explanations were politely not thought to be correct. Later, upon retelling, an Ent colleague, one who deals with the mysteries of chaos theory, remembered that the Kingston Trio had sung about the "Brown Mountain Lights," perhaps, he seemed to recall, a story about the ghost of a slave wandering the mountains of North Carolina. Could this be what the hikers saw? Surely someone must have written about them, or him, in some detail by now — it is almost the 21st century and well into the space age! Anyway, I hope I get a chance to see Hikers' Spheres. Have you seen them? Is there another name for them? What should I do to be prepared when I meet them? Are they photogenic as well as being photogenic? Let me know what you know, please.

Here are some notes on mystery lights of the past:

(1) ***Ignis fatuus.*** (foolish fire) A light sometimes seen hovering or flitting over marshy ground and sometimes attributable to the burning of gas (e.g., methane) released from decomposing organic matter. Sometimes called **Will-o'-the-wisp** and **Jack-a-lantern**. The *OED* says that this used to be a common phenomenon but is now rare. "When approached the *ignis fatuus* appeared to recede and finally to vanish, sometimes appearing in another direction." The *OED* also gives these interesting mentions: 1563 ". . . hurteth not, but only feareth fooles."; 1658, ". . . a kind of slight exhalation set on fire in the night time, which ofttimes causeth men to wander out of their way."; 1663, ". . . leads Men into Pools and Ditches."; 1688, ". . . tho there may be many boggy Swamps and Marshes, are seldom, if any seen there."; 1774, "Floating bodies of fire [. .] the *ignis fatuus*, or wandering fire."; 1814, "To avoid being led astray by the *ignis fatuus* the most secure method is to carry a lamp."

(2) **Foxfire.** An eerie light on damp decaying wood, actually emitted by luminous fungal "roots" (mycelia) growing there. Possibly it gets its name from its silvery color, which was thought (by someone) to resemble the color and sheen of silver fox pelts. fd

On the Arkansas Trail of Thomas Nuttall

by Josh Trotter

[Somewhere on this trip botanist Nuttall collected a firefly that to this day remains a taxonomic mystery. fd]

On the 2nd of October in the year 1818, botanist Thomas Nuttall rode from Philadelphia to Lancaster, Pennsylvania, in a mail carriage. This was the first small step of a journey to the Arkansas Territory to collect new plants. From Lancaster he traveled on foot to Pittsburgh, through a country of calcareous rock, deep and narrow valleys, and "steep hills everywhere presenting shale devoid of impressions." He had traveled to Pittsburgh twice before, but still he found different specimens to collect, including the seeds of the cucumber tree (*Magnolia acuminata)*. He arrived in Pittsburgh on the 15th of October.

The Ohio River was just then too low to descend, and Nuttall remained in Pittsburgh until the 21st of October, when he set out in a skiff accompanied by a young man who "for the consideration of passage and provision, undertook to be pilot and assistant." While his companion manned the boat, Nuttall walked along the shore and observed the vegetation. He noted seeing "*Tilia heterophylla* Vent. for the first time near LeTart's rapids, and [finding] a new species of Aster, *Aster amethystinus* Nuttall." He described the river banks as "exceedingly romantic, presenting lofty hills and perpendicular cliffs of not less than 300 feet elevation, everywhere covered or fringed with belts of trees in their autumnal foliage." He remained a few days in Cincinnati before descending on the Ohio River to Louisville, Kentucky, where he arrived on the 23rd of November.

Nuttall's little skiff could not very well carry him to the Mississippi and beyond, and so he was detained for two weeks seeking means of transportation below the Falls of the Ohio. He eventually purchased a flat-boat, and left Louisville on the December 7th with a Mr. Godfrey and his son as his passengers. In his journal, Nuttall detailed the water locust and swamp milkweed which grew along the river, and also noted the "bold and rocky" banks and "gloomy forests unbroken by the hand of man." The trio reached the Mississippi on 17 December but were kept from entering it for a day and a half by floating ice.

The assent of the Mississippi was treacherous, due to the unpredictable channels of the river and the submerged trees which filled the water. Contact with one of these snags delivered such a terrific jar to the flat-boat that Mr. Godfrey's son was thrown into the river. The "gloomy solitudes" which bordered the river were broken by the Iron Banks in Kentucky and the Chickasaw Bluffs in Tennessee. Nuttall described the stratification of the Chickasaw Bluffs in great detail, noting eight different levels of soil, the uppermost bed being "friable, sandy, and argillaceous earth, succeeded by a thinner and more ferruginous bed." He also noted a bed of "brownish-black color . . . which, on examination, [he] found to be lignite." The travelers parted company at the White River on the 12th of January 1819. Nuttall then traveled up the White River to a connecting bayou between the White and Arkansas, where he proceeded to the Arkansas. On 22 January he arrived at Arkansas Post where he lodged with Dr. Robert McKay and spent a good deal of time exploring the Great Prairie which lay to the north of the settlement. Again, he collected a great number of plant specimens.

Nuttall originally planned to hike through the Great Prairie to Little Rock, but, being unable to find passage for his baggage, he sold his flat-boat and on 26 February embarked upriver in a skiff to the Cadron settlement, northwest of Little Rock. On the way he passed the Pine Bluffs which he noted as having the "same parti-coloured clays" as the Chickasaw cliffs, and Pinnacle Mountain, which he sketched in his journal. He arrived at the Cadron settlement on the 27th of March, where, as might be expected, he found more undescribed (i.e., new, unknown to botany) species of plants. Upriver at the Dardanelle Settlement he lodged with Mr. Walter Webber from April 9th to the 20th, drawing pictures of Magazine Mountain and discussing the Cherokees with Reuben Lewis. He then continued on to Fort Smith and arrived on 24 April.

The Commandant of the Garrison at Fort Smith, Major William Bradford, provided Nuttall with assistance and hospitality, and it was while staying there that Nuttall had his most profitable collecting excursions. He made several collecting trips out of Fort Smith, collecting about a hundred new (undescribed) herbs in a few weeks. He took many trips into the Cedar Plain to the south of Fort Smith, where Firefly Doc suspects that he may have collected the firefly specimen that Thomas Say of Philadelphia subsequently named *Lampyris reticulata*. (The correct name for Nuttall's Arkansas firefly is now *Phausis reticulata* (Say)). He also found many species of plants which he subsequently described.

In May, accompanied by Major Bradford and a company of soldiers, Nuttall travelled to the Red River on a trip to order white settlers from lands recently set aside for the Indians. They traveled south along the Poteau River, crossed the Winding Stair mountains, and followed the Kiamichi River to the Red. The company only remained at the Red River for three days before heading back to Fort Smith, but Nuttall stayed behind to collect plant specimens, and never rejoined Bradford's party. Unwilling to travel alone across the prairie, Nuttall was forced to stay with a settler for nineteen days, until he found a party for the return ride to Fort Smith. During this time he collected many more plant specimens.

Nuttall arrived back at Fort Smith on 21 June 1819. Nearly a fortnight later he proceeded upriver to the trading houses of the Three Forks area of the Arkansas, which is situated at the mouths of the Verdigris and Grand Rivers. He remarked that the prairie of the Verdigris River offered "no change in vegetation . . . indeed, rather a diminution of species" and spent several weeks at the settlement exploring the surrounding vegetation. At the end of July, Nuttall was laid low by a sickness which struck the camp, the symptoms of which were a headache, chills, and fever. Nuttall was actually suffering from an advanced stage of malaria, which he "contracted on a collecting venture . . . [in] the swamps along Delaware Bay" some years earlier.

On August 11th, 1819, he and a trapper named Lee set out from the Three Forks area on horseback, planning to ride to the Cimarron River and follow it to the Rocky Mountains. They rode through "prairies full of grass about knee deep" punctuated by small streams which, due to a drought, offered them only stagnant and putrid water to drink. On the third day out of camp they reached a tributary of the North fork of the Canadian River where Nuttall became seriously ill. He spent much of the time in a delirium, unable to eat, and he fainted in the saddle when they tried to ride on. Lee's horse then became lame, making a return to the Verdigris impossible, and maggots infested their food and their clothes, making them even more uncomfortable.

On the 30th, both Nuttall and Lee's horse having recovered somewhat, they proceeded across the prairie towards the Cimarron through "deeply undulated country . . . covered with scrubby oak, except for occasional prairie openings and narrow valleys." They arrived on the banks of the Cimarron on the 3rd of August, but their procession westward was permanently halted when Lee's horse was lost in quicksand. Lee then constructed a canoe of cottonwood and on the 8th they descended the Cimarron, Lee floating downstream and Nuttall riding along the bank. After being pursued throughout the night by a pair of Osage Indians, they separated for the sake of speed. Nuttall struck out across the prairie, arriving at the Verdigris settlement on the 15th of August. He descended to Fort Smith, where he remained to procure specimens of "a very curious *Gaura*, and undescribed species of *Donia*, of *Eriogonum*, of *Achyranthes*, *Arundo*, and *Gentian*", along the banks of the Cimarron.

After regaining his strength, Nuttall descended the Arkansas quickly, departing from the Cadron settlement on 4 January 1820. He collected more plant specimens at Arkansas Post, then decended by barge to the Mississippi, then by flat-boat to New Orleans. Although he had not accomplished his goal of reaching the Rockies, he had managed to discover a "few hundred new species in the Southwest".

Following Nuttall's Trail

To take an automobile trip today, retracing some of Nuttall's Arkansas expedition, here is a suggested route beginning in western Pennsylvania.

From Pittsburgh take route 60 to Beaver, Pennsylvania, then follow route 39 to route 7. Follow 7 to Steubenville, Ohio. Route 7 runs to the Kentucky/West Virginia border, through Bellaire, Marietta, Belpre, and Gallipolis. From the Kentucky border follow route 52 to Cincinnati, through Maysville, Kentucky and Portsmouth, Ohio. Then, take U.S. route 42 to Louisville, Kentucky, passing through Ghent, Lawrenceburg, and Rising Sun. From Louisville, take U.S. route 60 to Cairo, Illinois, passing through Owensboro, Henderson, and Paducah, Kentucky. From Cairo, take route U.S. 51 South to Fort Pillow State Park, Tennessee (the 1st Chickasaw Bluff) and Memphis, Tennessee (Fort Pickering, Chickasaw Bluffs, Graceland). From Memphis, take Interstate Highway 40 into Arkansas, then U.S. route 79 south to Highway 1; then route 1 south to U.S. route 165, and 165 south to the Arkansas Post National Monument.

From Arkansas Post N. M., take U.S. route 165 south to U.S. route 65, then 65 north to Pine Bluffs, and then route 365 north to Little Rock. From Little Rock, take route 10 to Pinnacle Mountain State Park, then 10 to the Ozark National Forest and Magazine Mountain; take route 10 east to Highway 27, then 27 north to Dardanelle, and go west on route 22 to Fort Smith. From Ft. Smith to Red River, take U.S. route 271 south to Talihina and Tuskahoma, then south to U.S. route 70; then go east on route 70 to Fort Towson. Return to U.S. route 271 and travel north through Clayton and Spiro back to Ft. Smith. From Ft. Smith, take U.S. route 64 or Highway 10 west to Muskogee, Ft. Gibson, and Okay (the Three Forks Area). From the Three Forks area, take U.S. route 62 west to Okmulgee and Oklahoma City. Then go north on Interstate 35 to Guthrie (the Cimarron). Take route 33 to Tulsa. Take U.S. 64 from Tulsa to Fort Smith, passing through Haskell and Muskogee. From Fort Smith, take U.S. 64 along the north side of Dardanelle Lake to Morrilton, then U.S. 65 south to Little Rock, then south to U.S. route 80 to Mississippi. Take U.S. 61 to Port Gibson and Natchez, then south to New Orleans.

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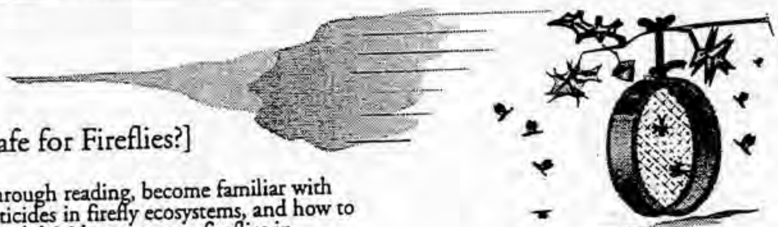
Josh wrote this article as a term paper for the firefly course, in Fall 1995; he took the advanced firefly course in Spring 1996, and has since been an editorial assistant for the *FC* and the insect taxonomy journal, *Insecta Mundi*. This fall he will begin graduate study in English at UF..

The fireflyer teaching manual includes field projects, problems, and techniques that students can do independently or in a small group, or with an experienced supervisor. This example investigates the effects of mosquito control chemicals (adulticides); it requires little knowledge of poisons, only a little of firefly biology, but rather more of local mosquito control operations and schedules, and in particular, it demands careful execution, so that the study does not do more harm than help to local firefly conditions. It also illustrates the importance of experimental controls, the reality of dealing with trade-offs in public health decision-making, and, of special importance, does not require that students themselves measure, mix, or apply pesticides.

Field & Lab 80



Pesticides & Fireflies

[Is Your Neighborhood Safe for Fireflies?]

SYNOPSIS of OBJECTIVES: Through reading, become familiar with some basic information about pesticides in firefly ecosystems, and how to test for the dangers that mosquito adulticides present to fireflies in residential areas and adjacent wetlands. Consider <reflect on> sociological, public health, and scientific problems apropos of experimentally testing for adult firefly death from mosquito adulticides. Make a test–exposure cage and design a way to test it for air movement through it. After carefully considering how to reduce the number of fireflies you will accidentally kill in your experiments, use your exposure cage — with others you make of the same design — for controlled (checked) field experiments in firefly spaces in your neighborhood or elsewhere, where a regular fogging or ULV spraying program is carried out.

Introduction. Pesticides are among the obvious reasons suggested for the loss of fireflies that has been suspected and mentioned to me by many of my correspondents over the past several years. Humans certainly must poison firefly populations that occur in habitats near where they live, work, and play, including fields, meadows, golf course roughs, parks, marshes, and "undeveloped" woodlands and vacant lots. One would think that we must inevitably kill fireflies when we try to kill biting insects and other arthropods. In rural settings, pesticides are sprayed, sometimes from airplanes, on agricultural fields to kill insects that are eating or damaging crops or harming livestock.

The pesticide use that this HPT focuses on has mosquitoes and other biting flies as targets, and makes suburban outdoor living more pleasant or possible. It also is more apt to esthetically displease environmentally conscious residents. In suburban areas, evening "fogging" may reach an assortment of natural and manmade wetlands that harbor fireflies, such as ponds, roadside swails, ditches, canals, catch–basins, borrow pits, springs, sinks, cypress domes, gulleys, and streams. A firefly–poisoning problem that is unique to Florida involves the endangered Fiddler Crab Firefly, *Micronaspis floridanus* Green, a resident of coastal salt marshes. Not only is its coastline habitat subject to destruction from man and the natural forces of winds and tides, it shares its habitat with various biting flies that are sometimes sprayed, or that encourage water level manipulation via drainage, filling, or bulkhead construction — all of which damage coastal marshland. Pest flies found in such coastal habitats include salt marsh mosquitoes (*Aedes taeniorhynchus* and *Aedus sollicitans*) and the minute sand flies of the genus *Culicoides*.

More than merely being an annoyance, mosquitoes can be dangerous, and mosquito–borne diseases have presented major health dangers for humans over a long history. Even now, each year they are responsible through the diseases that they carry, for the deaths of thousands of people around the world. In one view of infectious disease history, diseases that are vectored by wetland inhabiting insects represent an early ecological association between man and the infectious organisms. This stage "flowered" when neolithic man invented irrigation farming, and consequently lived in wetland agricultural areas that provided breeding and transmission conditions for insects and various other parasites (see p. 213 in Garrett). Everyone has heard of malaria and yellow fever, at least through the special consideration that must be given them by travelers to other mostly tropical countries. Less well known is the fact that in the past both of these mosquito–carried illnesses occurred in North America. Even today, though we may think that the spraying of suburban streets with malathion is merely to make backyard living more pleasant, there still is a level of danger from various forms of mosquito–borne diseases, including equine– and other kinds of encephalitis. Several quotations from Laurie Garrett's book The *Coming Plague* (p. 47) will highlight points of the recent history and size of the malaria problem:

> "Between 1958 and 1963 alone, $430 million [worldwide] was spent on a series of failed attempts to eliminate malaria. . . . Between 1964 and 1981, the United States spent an additional $793 million. . . . estimated [that] . . . 1 million people [died during one year] in Sri Lanka, some 100 million in India . . . roughly estimated in the 'hundreds of millions,' in Africa. . . . by the eighteenth century malaria was a serious endemic disease from Montreal to southern Chile. . . At least a million soldiers suffered malaria during the Civil War [in N.A.], and the disease was a major killer in America's southern states well into the 1930s."

It is not difficult to imagine and suspect that thousands if not millions of fireflies are killed each year by pesticides that humans put into their habitats. Figure 1 sketches a couple of short pathways of this delivery, including both directly via chemicals put into the surrounding media (air, water), and indirectly through food chains. Absent from the sketch are the prey of fireflies that have been killed by pesticides and are not available for food. Though I have often been asked specifically about the amount of firefly killing done by pesticide use, and as a result over the years have encouraged entomologist colleagues with special knowledge of insect poisons to look into the matter, until recently we could only suspect and presume a deadly impact on firefly populations. After a long wait, an entomologist from west Florida who was

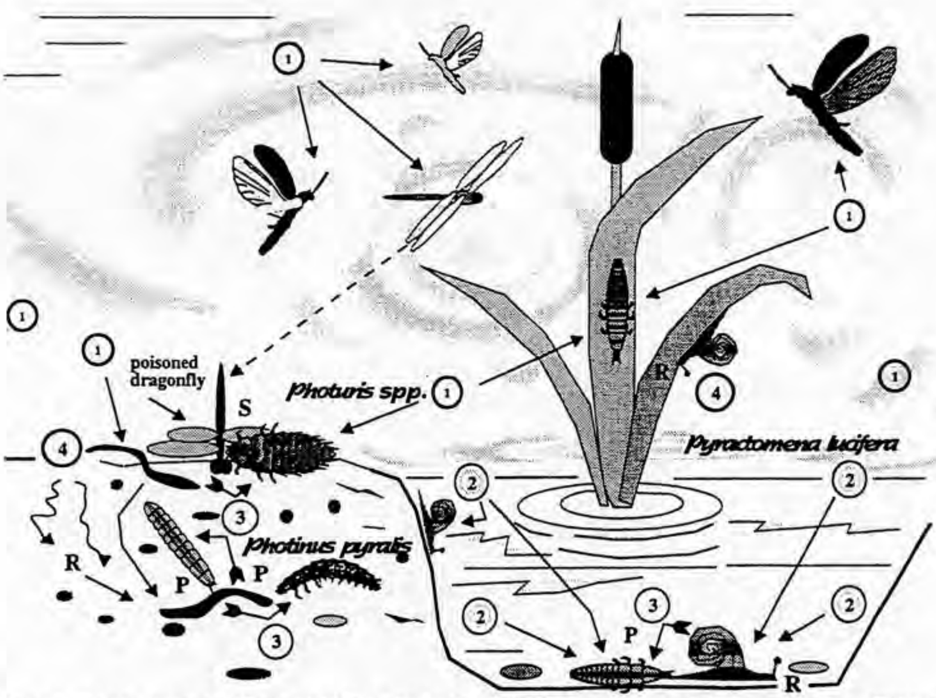


Figure 1. Fireflies come into contact with pesticides, poisons that kill "designated pests" in several ways. Poison droplets that are put into the air (1), such as mosquito adulticides may land upon adult fireflies or juvenile (larvae, pupae) fireflies that are above ground. Poisons that are intended to kill mosquito juveniles and are placed into aquatic habitats (2) may kill *Pyractomena lucifera* larvae that are underwater hunting snails. Firefly larvae may prey upon (P) or scavange (S) poisoned members of their community (earthworms, snails, other insects) and take in poisons (3). Poison residues (R) may trickle into soil or ponds with rainwater (4) and be taken in by earthworms, or remain on leaves and be taken in by snails (4).

specifically looking into the effects that mosquito adulticides have on nontarget organisms, contacted me specifically about fireflies! I jumped at the chance to encourage him and to provide what information I could that would be useful for his observations and experiments on the problem. This HPT is the direct result of my opportunity to work with Dr. Noor Tietze and his lab, and learn some of the techniques of his studies. (Recall that in *FC* 1(3):45 P. G. Hester reported results from tests begun by Tietze.) This prompted me to ask more questions of other control and mosquito experts on the UF faculty, including Profs. John Strayer and Don Hall.

Basic Facts On Pesticides. There have been reports of the occurrence of pesticides in organisms that are intimately connected with fireflies — earthworms and snails (see Brown, 1978). These organisms sometimes accumulate long–lived pesticides as well as various pesticide break–down products. When worms, snails and slugs are eaten by lampyrid larvae their flesh passes along an accumulated ("magnified") store of poison. Because *Photuris* larvae are scavangers too, they probably feed on insects and other animals that have recently been killed by pesticides, and thus can get a poison fix more directly. Pesticides may be lethal, killing a consuming larva, or interfering with its normal competative ability, growth and development, thus taking it out of the breeding population and resulting in its "genetic death."

Malathion is the most commonly used pesticide for controlling flying insects. It belongs to the organophosphate group of pesticides whose mode of action is to interfere with the proper operation of the nervous system (see *FC* 1(3):50). Organophosphates prevent the removal of the chemical link that carries the neural message between neruron fibers after a message has passed. Normally, in the space between the ends of chemically–linked neurons, after a chemical message has traveled across the space and stimulated the next fiber in the chain to carry the message onward, an enzyme sweeps through and removes the remaining traces of the old message. Without clean up? — a quivering roach, on its back at night, in the middle of the kitchen floor, phones off the hook at every neural junction!

Several methods have been used for dispersing poison substances into the air to kill adult biting flies. In the terms of the trade, such devices include mist blowers, thermal fog generators, and ultra–low volume (ULV) machines. Aircraft including helicopters are used, but noisy, yellow–flashing "foggers" passing in front of the house, like the ice cream truck at dusk, is the method Florida residents are probably most familiar with. Today ULV dispensers are usually used, and though they are often referred to as foggers, speaking precisely (thermal) fog is no longer used because the fog was so opaque that it caused major traffic problems. Such fogging also required a "vehicle" such as an oil to carry the poison. In ULV application the virtually pure (technical grade) pesticide is mechanically "atomized" with a spinning "propellor" and dispersed as very fine droplets, typically mixed with a blast of air as they leave the machine. The ULV method eliminates the need for a fluid vehicle to carry the droplets and requires only a tiny amount of poison. Among the problems that mosquito control operations must take into consideration when they treat suburban neighborhoods are the effects of the poisons on people, their pets, their paint, and their psychology; the size and dispersion of poison–carrying droplets, including windborne drift away from the point of emission; the calibration and upkeep of equipment; the population cycles of the local mosquitoes, and the best time of day for application. There is a huge industry built around this service that involves equipment and supplies, technical training of operators, and research.

Test Exposure Of Fireflies. To test for a lethal impact of mosquito "fogging" on fireflies one needs to **expose** healthy adult fireflies to the poison substances that are broadcast in suburban neighborhoods, and compare their subsequent longevity with samples of fireflies that were treated identically **except** for an exposure to the poison. Test exposures should be identical to the exposures that they would receive in treated suburban areas, with respect to amount and type of pesticide and duration of exposure to it. We can put fireflies in cages that are placed on the routes traveled by the source vehicles, at the heights that fireflies would be flying at that time, and at appropriate distances from the truck–borne disseminating nozzles. There are two obvious means of firefly poisoning: (1) flying and perched fireflies may be struck by droplets of poison, and (2) walking fireflies may come in contact with yet–lethal residues that remain on surfaces, such as leaves and twigs, in the firefly sites where the substanes have settled. To test Type–1 exposure, we can put fireflies in screen cages and hang the cages at various distances from the passing nozzles; to test Type-2 exposure, we can put fireflies in cages that have leaves and twigs that were just previously within range of passing nozzles. The results of these experimental **exposures** to poison will be compared with experimental **controls** in which fireflies are treated identically **except for** contact with air-borne and residue poison (also, note the ambiguity of the word **control** in applied entomology!; we wish to "control" [definition #1] pest insects, and we must have experimental "controls" [definition # 2] as checks to compare with experimental treatments).

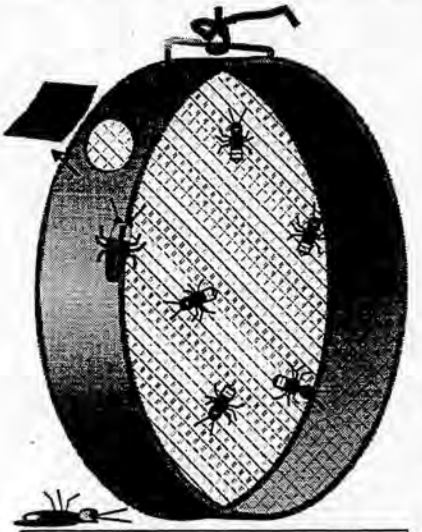


Figure 2. A pesticide exposure cage, with screen soldered to a metal hoop. A piece of tape is placed over the access hole and the cage is hung in the area to be "fogged" to control adult mosquitoes. The cage is about 5.5" in diameter and 1.5" in depth.

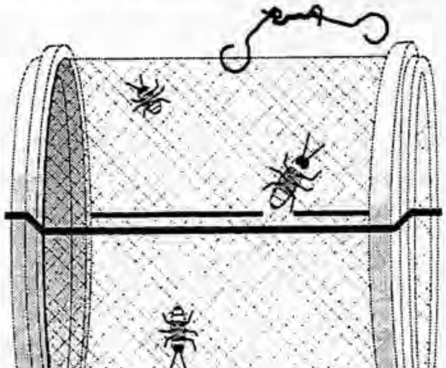


Figure 3. A cylinder can be made from window screening pushed into lids from cottage cheese boxes. The lid tops have been cut out, leaving only the semi–rigid rims, which support screening and are easily removed to release the fireflies into their grass–apple holding cages. Hooks can be made from paper clips. The lids may be held together, with the cylinder between them, by a rubberband, or with hooks held by rubberbands (see Fig. 4).

Cages for Type–1 exposure require special consideration. The professional exposure cages used by Dr. Tietze were made of metal with wire screening fastened to each side of solid hoops (Fig. 2). Such metal cages can be treated with strong chemicals and baked after each usage to remove remaining poison residues, and then used again. However, metal cages are expensive to buy and require special equipment for manufacture. Cages can easily be made from plastic food cup covers and window screening. Such cages can be discarded after use or even soaked in detergent overnight and if they survive the treatment, can be reused. Soaked cages can then be tested for residual lethality, though we cannot determine whether they might induce sterility. Figures 3–5 illustrate examples of cages that can be constructed from window screening and food containers.

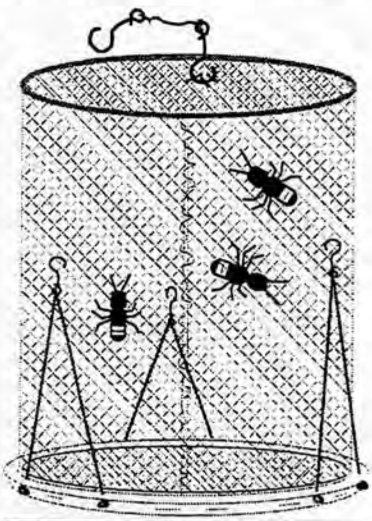


Figure 4. An exposure cage with a vertical window screen cylinder and lid stitched or soldered together, and then fastened to the cover from a plastic yogurt cup by three rubberbands.

For any of these Type–1 exposure cages a key consideration is the passage of airborne poison through the screen walls. Because screening will result in some drag in the air currents that carry the poison droplets to the test fireflies, we must consider the fluid dynamics in the immediate vicinity of hanging cages. It is obvious that fireflies inside such cages will have less contact with airborne droplets than they would were they outside cages in open air, because the air will flow around the cage, to some extent — though the resulting turbulence may cause some around–flowing air to turn and come in the down–wind side of the cage (Fig. 6). When a commercial supplier tested the use of small rectangles of chemically sensitive cards for calibrating chemical impacts, it was found that larger droplets would hit the front of the cards and some smaller ones passed by and turned back and landed on the back sides of the cards. It is obvious that the larger the mesh screening the less it will resist the passage of air through the cage, but too–large mesh will let fireflies escape. After you have built a model exposure cage, consider how could you calibrate it for poison penetration — for example, could cages be placed closer to passing nozzles to compensate for the reduction in impacts caused by their screening (Fig. 7)?

Cages for Type–2 exposure do not require any special construction. The same sort of bottle that is used for holding captured fireflies can be used for testing. Be aware that holding cages can be lethal for fireflies! I have often been told about the deaths of the fireflies that people col-

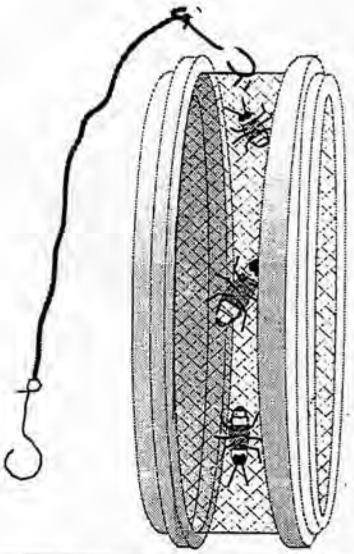


Figure 5. A flat "cylinder" of window screening reduces the distance that any firefly may be from the outside air, with its potentially deadly droplets. If air circulation is reduced through the cage because of the wire screen — it may have a tendency to flow around the cage — a thin (flat) cage with mesh as large as possible would seem to be the "ticket."

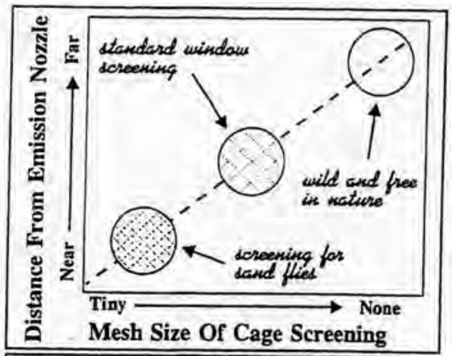


Figure 7. Penetration of wire mesh by minute airborne pesticide droplets is certainly reduced as a function of mesh size. Perhaps decreasing the distance from the source nozzle would compensate, and a corrected distance can be determined for screening through field experiments(?).

lected as children, put in Mason jars, and placed on the nightstand for post–bedtime observation. A major reason for death in such situations is that the fireflies easily desiccate. Such holding cages should have a wad of loose grass to provide additional climbing substrate, a thin slice of apple to put moisture into the cage atmosphere, and **no air holes** in the lid (Fig. 8). In such a humid chamber fireflies can live for several days, even up to two weeks. Each day, remove the lid and blow across the mouth of the jar to circulate fresh air (oxygen) down into the bottle. Wash apples before slicing, and keep the unused part of the apple in a plastic bag in the vegetable bin of a refrigerator where it will remain usable for many days.

One final note, before I make some suggestions for experiments with cages, pesticides, and fireflies. The reasonable assumption has been made that the pesticide treatments of suburban neighborhoods kill mosquitoes, and therefore they will probably also be deadly for fireflies. The nervous systems of fireflies would be expected to be sensitive to organophosphate poisons. But, perhaps they are not! Also, do the poisons actually kill mosquitoes, or are the odors, yellow lights, and truck–nozzle noises mostly propoganda, to appease fly–annoyed taxpayers? During the past three decades I have learned a number of things about entomology and politics, and it might be a good idea to run some experiments on mosquitoes too, at the same time the fireflies are exposed. It is possible that on a given night the pesticide is a bad formulation, too weak or, merely water(?). Larval mosquitoes can be collected and put into emergence cages (Figs. 9 & 10). When adults emerge they can be placed near passing mosquito control trucks near the adult exposure cages, and then . . . Mosquito treatment routes and schedules may be available from a local agency, listed in the phone directory. Try under **City of** ________, heading: **mosquito control**.

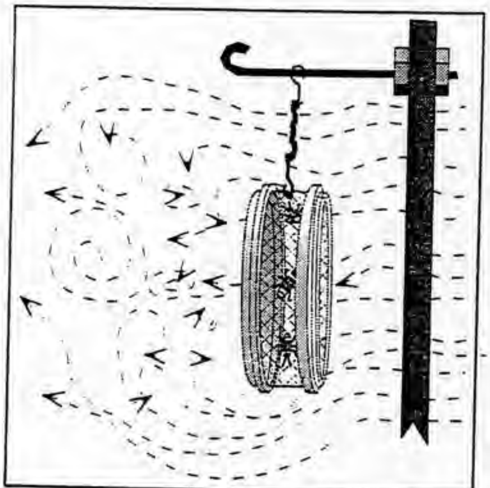


Figure 6. A test exposure cage (Type–1) hanging in firefly space near a passing adulticide nozzle. The cage will present drag even though it has screen walls. It will deflect some of the air current, thus causing turbulence that will result in some smaller droplets entering from the down–wind side. It is a standard problem in fluid dynamics. How can exposure in such a cage be calibrated? Cannot one ever escape the complexities of physics and nonlinear mathematics . . . and chaos theory?

Before catching and exposing fireflies, or testing mosquitoes, carefully **outline** the necessary steps of the experiment in **proper sequence**, including necessary steps for making the experimental **controls** (nontreatments) identical in all respects, except for actual exposure to the airborne ULV droplets. Then, following the outline, design your experiment, with attention to the number of insects per cage, the number of cages, the distances of cages from the path of the nozzle–toting vehicle. Should you calibrate your exposure–cages first (see item 2 below)? Should you remove yourself from the exposure area as the truck passes? What environmental data should you take?: Temperature?; Wind speed and direction?; Time of day?; Habitat type?; Wild and free fireflies present and changes in their numbers and flashing behavior after they are sprayed?; Bushes and shrubs that will cause air turbulence and pesticide–shadows?; Should you select the exposure site well before the experiment, so you can observe the operation at least once before an actual test date?; Do you need permission or cooperation from nearby property owners?; Should you conduct your experi-

Figure 8. Holding bottles for fireflies should have clean grass, a fresh slice of apple, and no air holes (see text)!

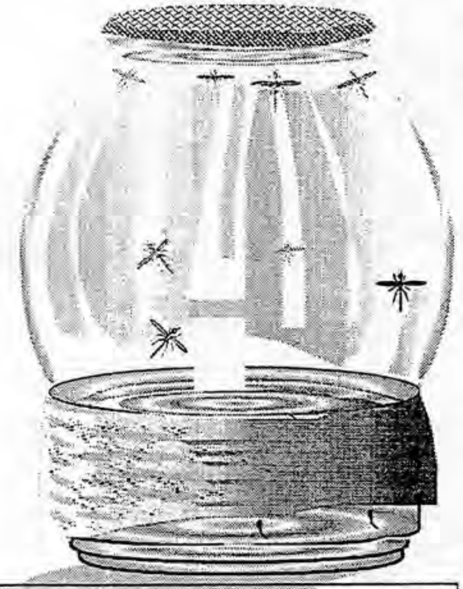


Figure 9. A mosquito emergence cage, made from a finger bowl, the globe from a kerosine lantern with a disk of netting glued over the top, and a short sleeve of rubber pulled over the bowl and folded into it, to make a "nest," hence mosquito-proof seal between the top and bottom glass vessels (see text).

ment without informing the mosquito control company/agency?; How many people should work together to perform the study?

Procedures. 1. Make firefly exposure–cages from lids of plastic food containers — yogurt, cottage cheese, margerine cups — and window screening from the hardware store (see Figures 3–5. Cut the screening with tin–snips. Cages can be held together for brief exposure periods with rubberbands; wire cages (Fig. 4) can be stitched with fine copper wire that is unwound from old electrical transformers, or inexpensive general purpose iron wire.

2. Examine and test air penetration into cages with smoke, incense, or vapor clouds from dry ice in water — pushed with a small fan (Fig. 11)? Also, pesticide companies sometimes sell chemically sensitive cards that will show spots of color change where "impacted" with pesticide droplets. Small pieces of these cards can be put inside and outside cages that are placed in the field near "fogger" routes. Try using small squares of undeveloped and out–of–date, 35mm photographic film, emul-sion side up, to catch poison droplets. After the spray has settled, droplet "footprints" can be seen and quantified with a microscope. Such spotting techniques can also be tried for the calibration of meshes and source distances, and the production of an equivalency line (Fig. 7).

Figure 10. A mosquito emergence cage made from a 2–liter soft–drink bottle. Cut around the circumferance to detach the "larval bath" and cut off the top, a little above the turning point. Invert the top and fit it into the bottom. Glue a disk of screening to the "top" (bottom of the top)!

3. Mosquito emergence cages can be made from squat glass jars, donut–shaped pieces of (washed) inner-tube, replacement globes for small lanterns, and disks of window screening, or even simpler, a 2–liter plastic bottle (Fig. 10). *fd.*

REFERENCES: *Ecology of pesticides*, A.W.A. Brown, 1978, John Wiley & Sons. Public Health Pest Control: Applicator Training Manual, J. Strayer, Pesticide Program Coordinator, UF Cooperative Extension Service, IFAS.

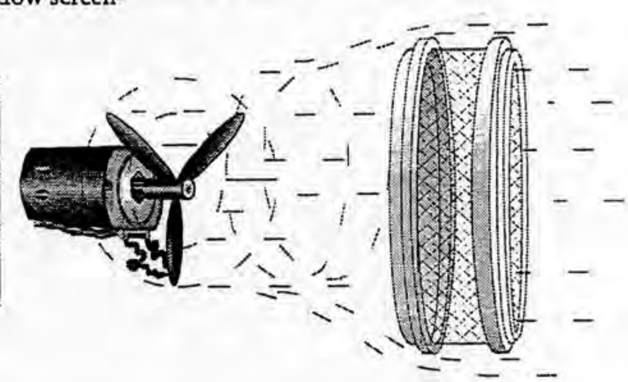
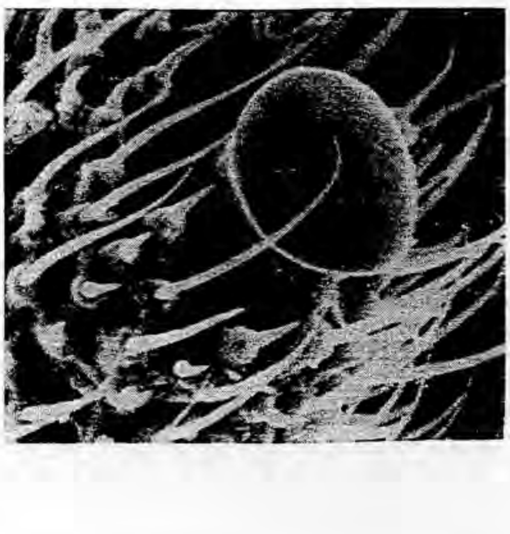


Figure 11. A tiny battery–driven motor with a propellor, would blow smoke through an exposure cage, giving an indication of turbulence and drag. Perhaps a hand atomizer would put micro–droplets of liquid into the air stream and impact squares of film, registering droplet impacts.



Whatisit? The photograph shows a detail of an insect, a firefly as a matter of fact, at very high magnification. Study it. Give it some thought. What is it? Where is it found? What is it used for? What should a poem, say a haiku, say about it? A clue, you say? OK. If you see this on a specimen you will know it is not an immigrant species. *fd*

Arthropod Of The Week: Fireflies (Lampyridae) — Cannibal Capers And The Light Lunch

by Jack Schuster

Sex. That's what it's all about (well, almost all). Passing through a field or forest full of fireflies is like strolling through the red light district (no, I'm not referring to the high concentration of stoplights downtown....). Each little light you see is a sexual advertisement: "Hi, I'm your type and I'm hot to trot". I guess it's also a little like computer sex. You send a message "out there" and maybe someone will answer. Yo, down there in the grass. Did I see a light? Yes! She answered me. Gotta check this out. Maybe we can get together. She keeps answering my messages. I'm going down for a closer look...... Of course, as can happen on, or rather off, the Net, she may not match up to your expectations. In fact, she may be downright dangerous. She may invite you to lunch....and **you** are the lunch! Now, let's analyze this scenario in terms of communication, the firefly scenario, that is. Light, of course, is the medium of communication.

In most species, the male produces a signal characteristic of his species, say two flashes every 3 seconds. The female will answer him, usually with a single flash, in this case immediately after his second flash. The time interval she waits before answering is characteristic of the species. The male recognizes her as belonging to his species by her flash, flies down and lands in her vicinity. Sometimes, however, he is mistaken; she is not of his species. She is a CANNIBAL firefly of a different species that specializes in preying on other species of fireflies! As James Lloyd of the University of Florida discovered, she has "decoded" the signals of various species of fireflies in her habitat and, on recognizing the male of a certain species, will produce the appropriate signal of the female of his species, thus luring him to lunch.

Many nature lovers are bird watchers. I never could get up early enough to get into birds. I'm a late-night person. Fireflies are my bag. One can walk through the woods and spot different species just by their flashes. Very little is known, however, about the flashes of tropical fireflies. In the region of Puerta Parada, where I live, I have gone firefly watching almost every Sunday night for over 8 years. During this time I have found approximately 12 species, each with its own flash pattern, time of night when it is present, flight season, flight pattern, and habitat preference. In my observation area fireflies can be seen flashing all year long, though sometimes only near a stream. One species, present from late January to April along the stream is a synchronous flasher. Early in the evening various individuals will fly over the stream, all flashing in unison. Later it is possible to find 3-20 or so in the vegetation along the banks, also flashing in unison. This is the first time synchronous fireflies have been found in Latin America, though other species, with other kinds of synchrony, are known from Southeast Asia, Arizona, and eastern United States. In Guatemala City, however, things are different. Various species are present that are not found in Puerta Parada, and vice versa. Vista Hermosa has some different species than those in the Oakland area.

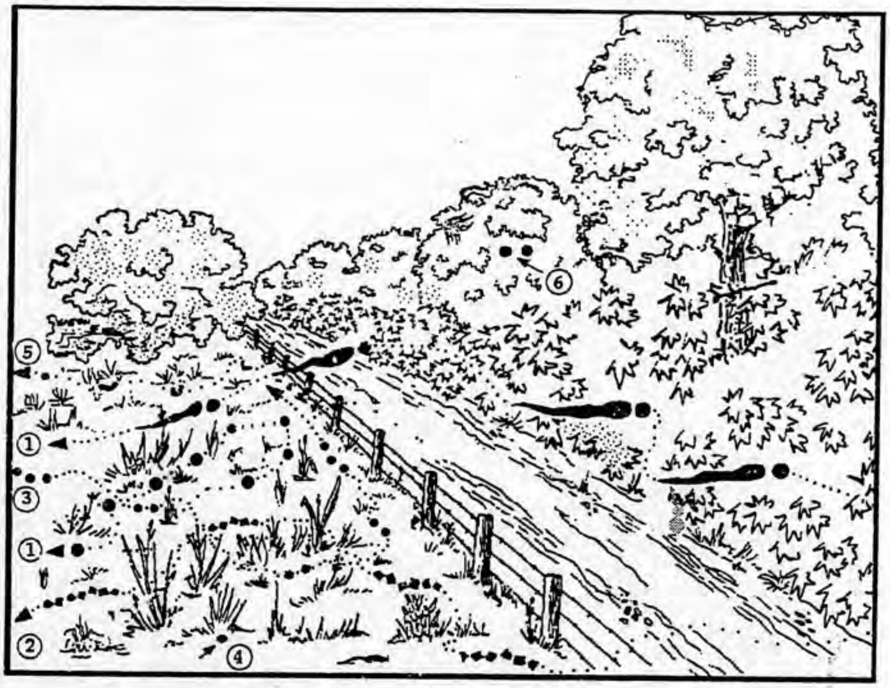
But little is known about the distribution of fireflies in Guatemala. In Peten I even found a firefly that lights up the front part of the body as well as the normal light organs on the underside of the abdomen. Which brings me to an interesting proposition, considering all the talk of fan clubs going around these days. How about a Firefly Fan Club? People can go out at night, watch these beetles flying about (yes, fireflies are a kind of beetle...), decipher codes, determine seasonality, which ones are where, capture specimens to validate information, or even do some experiments. For example, some of my students determined what colors a certain species of firefly can detect by using filters on flashlights and imitating the male signal near a female. If she answered, she could obviously see it. (Apparently, like many insects, they can't see red). We could all meet for show and tell at some appropriate place (such as the Europa in Zone 1? or here at the Universidad del Valle). Firefly sociality! Who knows, you might find the light of your life.......

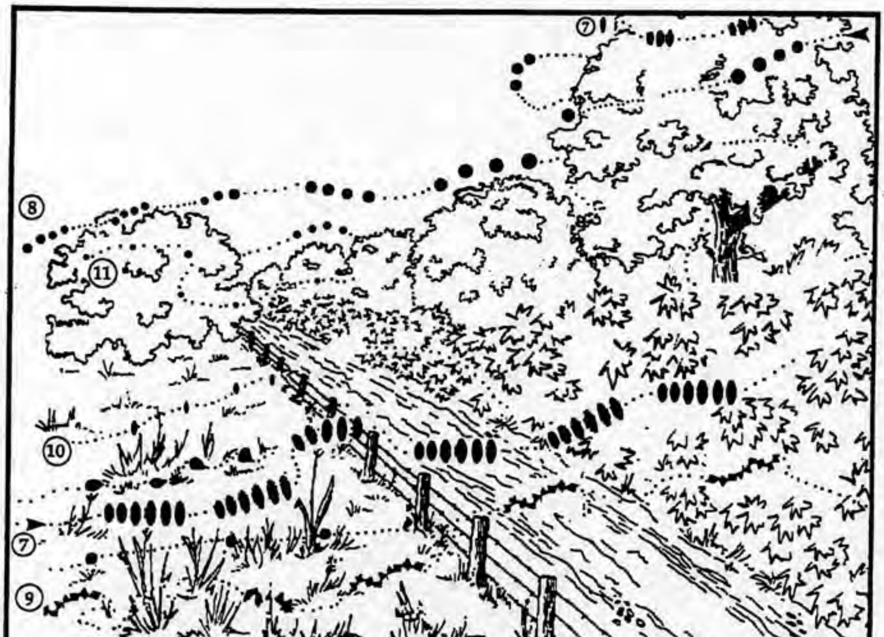
Jack is a Professor of Biology at the Universidad del Valle, Guatemala City. This essay is adopted from an article that originally appeared in his local newspaper.

Legend for photo at the bottom of page 76: In Jamaica *Photinus pallens* (Fabricius) gather in trees, shrubs, herbs, and grass, and remain nearly motionless feeding on flowers. Here several are on the spikes of a jointers tree. In a future number I will describe what I found about their unusual mating system in a ginger lily field in 1985. fd

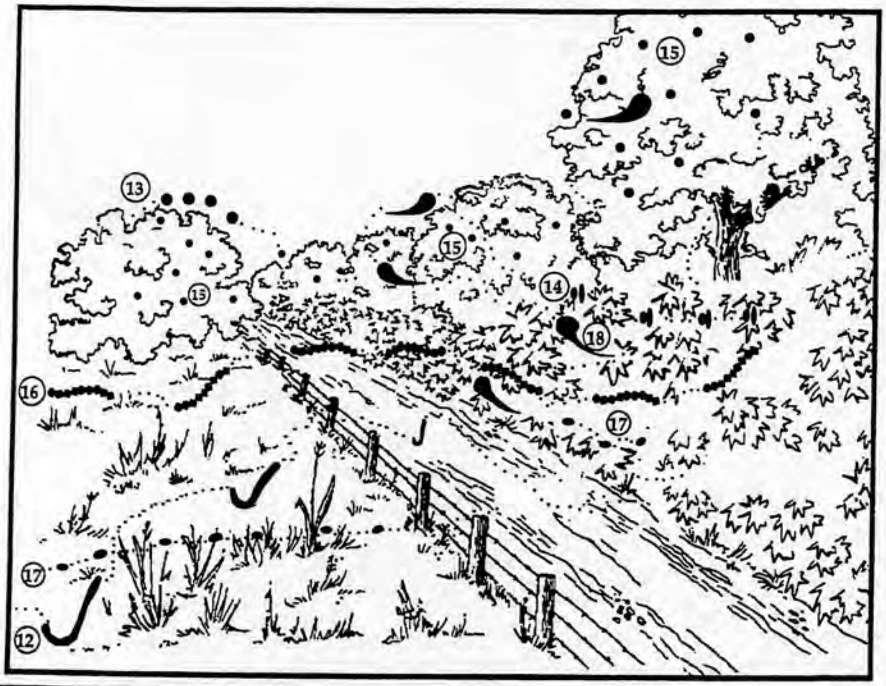
Afield After Dark In Central Ohio

A back country road in central Ohio, with the low damp corner of a pasture on one side and a woodlot on the other, in early June. It must be very early evening because *Photuris pennsylvanica* (DeGeer) (#1) is not only giving its main (dot-dash) flash pattern but also its short (dot) pattern. The arrowhead shows the direction of flight. (2) *Pyractomena dispersa* Green emits 5 or 6 fast yellow pulses in its pattern as it flies low over the ground; (3) *Photinus obscurellus* LeConte emits its 2- or 3-pulsed (yellow) patterns; (4) the occasional glow of a firefly larva is seen on the ground, probably a summer *Photuris* species; and (5) a male of *Pyractomena lucifera* (Melsheimer) emits its yellow dipping pattern. (6) A pair of flashes in the trees probably was emitted by another *Photuris* species, but since no other flashes are seen the species cannot be identified with confidence; there will be more adults maturing (eclosing, "hatching out" from the pupal stage) in a week or so.

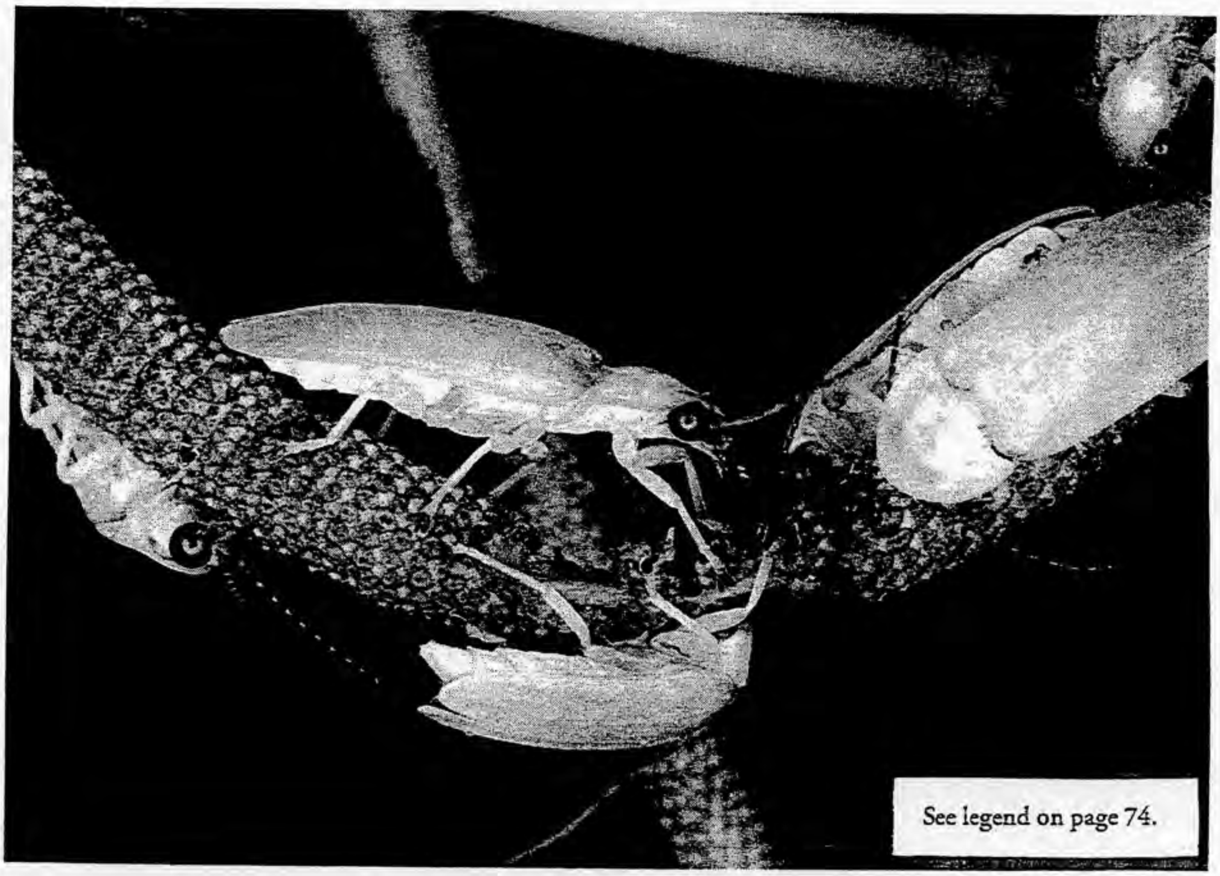




On the same road in mid June. (7) *Photuris* "FRV" emits few or several fast green pulses in each pattern as it flies low over the ground and up in the trees; it hardly pauses between its fast-repeated patterns. (8) *Photuris quadrifulgens* Barber usually emits 4-pulsed (green) patterns; (9) the amber flicker of *Pyractomena angulata* (Say) is similar to the pattern of *Py. dispersa* Green but has more pulses and the pulses are emitted at a faster rate. (10, 11) Sometimes a firefly emitting a very simple pattern is seen briefly but can't be identified with certainty; probably these green flashes are those of *Photuris tremulans* Barber. Usually there are more species present than the fireflyer sees or recognizes. In fact, I can see one here.



Once again we return to our firefly site, this time in the third week in June, and the summer species are going strong. (12) The Big Dipper firefly (*Photinus pyralis* (L.), with its big yellow "Js" at twilight is common over meadows and fields; (13) *Photuris quadrifulgens* Barber is still seen; (14) *Photuris hebes* Barber with its jerky single flashes may be found in isolated colonies; (15) *Photuris tremulans* Barber emits both short green flashes and (16) green flickers; (17) for a half hour at twilight *Photinus marginellus* LeConte emits its short yellow flashes at lawn and woods edges; (18) *Photuris lucicrescens* Barber is common around streams, and emits both crescendo and short flashes — in fact the short green flashes at the tree tops at the upper right may be those of *P. lucicrescens* and not those of P. tremulans. Even an expert may have trouble with such simple patterns, and wait for the wind to bring one down.



See legend on page 74.