Allegheny National Forest

June 2012 Firefly Survey

Forest and Warren Counties, PA

In cooperation with the U.S. Forest Service, Department of Agriculture, Allegheny National Forest
Under the Secure Rural Schools Act, P.L.110-343 and
Forest Service Agreement 12-DG-11091900-011

Conducted by the FIRE Team:

(Firefly International Research and Education)

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Summary

From June 14-June 27, 2012 the FIRE (Firefly International Research and Education) team of 5 biologists conducted firefly surveys in and around Forest and Warren Counties, PA in the Allegheny National Forest. Our primary emphasis was determining if the synchronous firefly *Photinus carolinus* or a related species existed in this area and its relative abundance through surveys, nightly observations of the male flash display, comparative studies and DNA sampling (p. 10-12). Our secondary goal was to get a snapshot of the firefly species diversity in this same area. June 14 and 15 consisted of a day at the Carnegie Museum of Natural History examining their PA firefly collections and day and night time sampling from neighboring Butler Co. PA for comparison to ANF. The remaining 12 days (10-16 hour days) were spent in the ANF conducting intensive daytime and nightly visual and sweep-net surveys and flash timings as well as daily microscopy, dissections, vouchering and experimental comparisons in the lab we set up at our local accommodations at Kellettville. We chose this time period in advance because mid to late June (and early July, depending on the relative accumulated temperature of that specific year) is historically the time of maximum firefly activity and species diversity. Very early or late appearing species may have been missed by our survey, but probable species are noted in the firefly chart (pp. 21-23) and photographs (p. 17-20). This survey was conducted with support and in cooperation with the U.S. Forest Service, Department of Agriculture and Allegheny National Forest, under the Secure Rural Schools Act, P.L.110-343 and Forest Service Agreement 12-DG-11091900-011.

Members of our FIRE team, whom have all worked together with the Great Smoky Mountains National Park *Photinus carolinus* populations, confirmed via field studies, flash timings, microscopic exams and DNA analysis, the robust and widespread existence of *Photinus carolinus* throughout the ANF in Forest and Warren Counties, PA. Especially on warmer nights (65°F+) and when the population was at peak numbers (June 17-22, 2012), these fireflies displayed synchrony in the light and dark cycles of the male multi-pulse flash trains (a series of regularly recurring pulsed flashes strung together) used for mating. We also documented an additional 15+ firefly species in this rich species-diverse area (pp. 6, 17-23). These species were characteristically found in specific habitats (e.g., open areas, deep forests, wet, open marshes, tree margins,) and flying at specific times of the day or night. Non-flashing day-active fireflies (depending on species) were found flying in the forest or, more commonly, perched on grass and low vegetation in open fields or along trails and forest roads. The variety of habitats (p. 5) within the ANF proved ideal for observing species diversity of all kinds.

In 2012, at least 2 of the local species (*P. carolinus* and *Photuris sp*. "Chinese lantern") easily reached the **"WOW!"** level of nighttime display, meaning people would most likely come from near and far to experience peak nights and return year after year. An **"amenity tree"—**a term from urban forestry— is a tree that provides, instead of commercial value, the "human-centered" attributes of beauty, charm, contentment, and comfort to the landowner or community. Fireflies are **"amenity insects"** in that the intangible benefits they provide are difficult to measure, but are nonetheless extremely important in increasing the quality of human experience within (and outside of) our National Forests.

General Firefly (Lightning Bug) Biology

Fireflies are beetles that universally glow as larvae and undergo complete metamorphosis, meaning they have an egg stage (~3 weeks), a larval period (~1-2 years, predacious & longest stage), and pupal stage (~2-3 weeks) prior to adulthood (see photos pp. 19, 29) . There are thought to be over 2000 firefly species worldwide and over 125 species in North America.

As adults, most fireflies live 2-4 weeks (*Ellychnia* species are exceptions) and exist solely to find a mate and lay eggs to assure the next generation. In many firefly species, males and females look similar and are both capable of flight; however, some species have larviform (grub-like) females without functioning wings and are therefore incapable of flight. Most firefly species, including *Photinus carolinus*, do not eat as adults. However, some members of the predatory firefly genus *Photuris*—and then females primarily—eat as adults. It is believed this predation is not so much for nutrition, but instead so that females can "steal" the defensive chemical compounds that other "prey" species of fireflies produce. Female *Photuris* then may use these defensive compounds to endow their eggs with chemical defenses that help protect their offspring from predation.

Fireflies around the world at every life stage are vulnerable to light pollution, soil and air pollution, pesticides, habitat fragmentation and destruction. Little is known of the ideal larval habitats and conditions required by each species, yet the majority of a firefly's life (1-2 years as larvae vs. 1 month as adults) is spent unseen (to humans) either in or on the soil or water. Larvae, depending on the species, prey on snails, slugs, earthworms and/or other soft-bodied invertebrates. The conservation of adult populations hinges on the health of both adult and larval populations. Although most, if not all, organisms are affected by these threats of habitat destruction and pollution, bright lights can virtually shut down the courtship and mating of many firefly species. The bright glare of lights can affects the females' ability to see or respond to her courting males, and can hinder the males' attempts to locate the much dimmer, cryptic answering flashes given by receptive females.

Of 15+ firefly species in 6 genera (*Photuris, Photinus, Pyractomena, Ellychnia, Lucidota, Pyropyga*) (pp. 6, 17-23) found in the Allegheny National Forest, at least 5 species are day active (diurnal), lack a functioning lantern, and do not flash or glow. Instead, they are thought to use long-distance pheromones (sex perfumes) to attract mates. Other firefly species present use species-specific flashes or glows as means of attracting mates. The vast majority of the flashing or glowing that most people enjoy watching on summer evenings is made by flying or perched males advertising for females who are usually hidden in the ground vegetation or up in trees.

The fireflies we encountered in the ANF during June 2012 are described with thumbnail sketches on pages 17-23 and are accompanied by a photo for each species (pp. 17-20) and a flash description/habitat chart (pp.5,6, 21-23). Please note that when you read the word "complex" or "group" after a species name, it means there is still considerable uncertainty among experts as to how many species are actually represented by this species name. So much remains to be discovered in the firefly world!

A Sampling of Ideal Firefly Habitats of the Allegheny National Forest: Forest and Warren Co.

- The Branch and Salmon Creek-*Photinus carolinus, macdermotti, marginellus, Lucidotas*;
- Tionesta River banks- All species. Chinese Lantern *Photuris* display especially spectacular

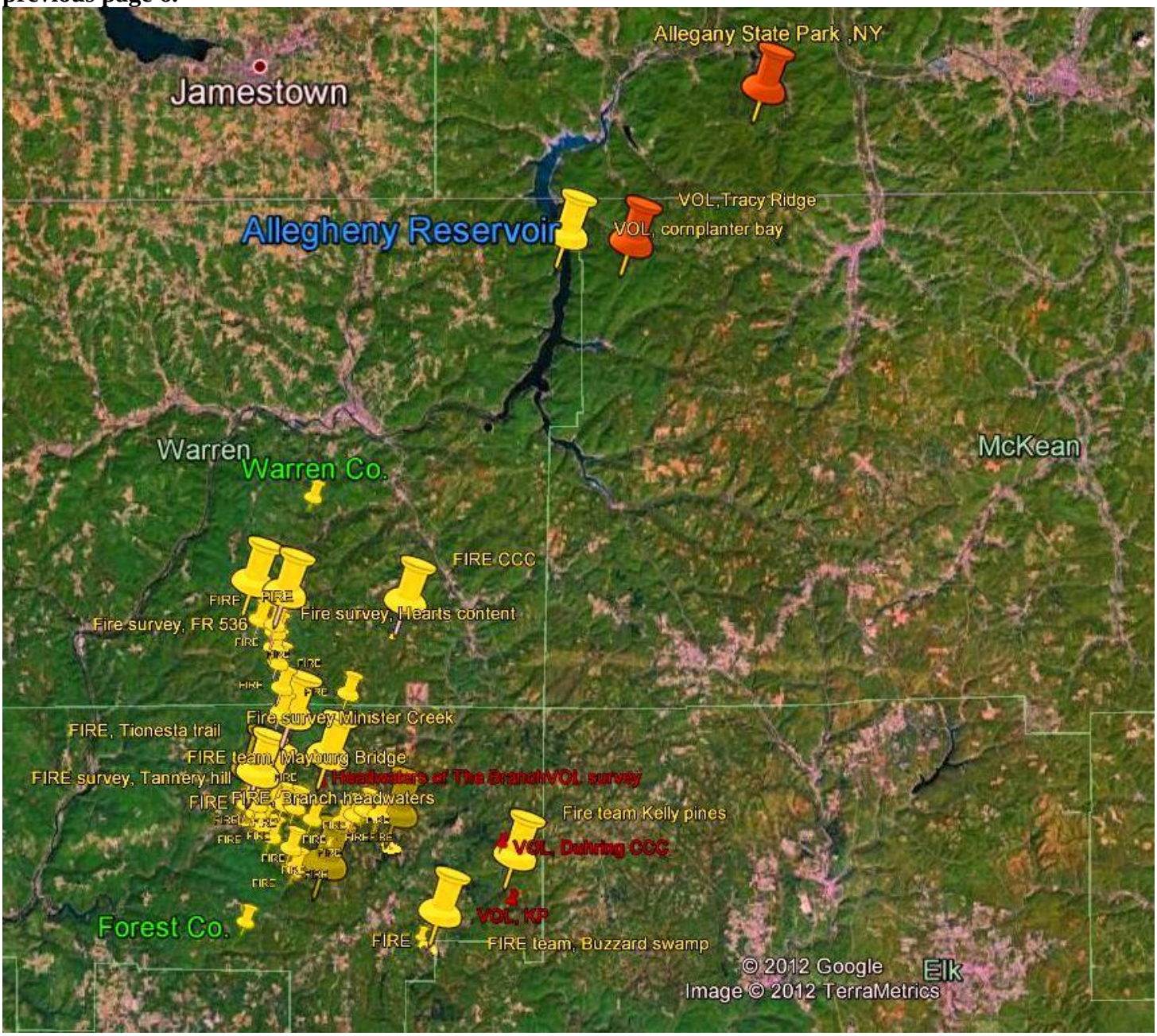
- Dr. Stanger-Hall sweep netting at Buzzard swamp- *Photinus obscurellus, Pyractomenas,* Chinese Lantern and single flash *Photuris. P. carolinus* in the wooded areas.
- Tionesta River snowmobile trails- rich in all species, but especially Chinese lantern and single flash *Photuris, P. carolinus, P. macdermotti , P. marginellus* and all the diurnals.

- Warren County former CCC camp- diurnals, *P. carolinus* and other margin and woodland species
- Beaver Meadows- rich in all species especially *Pyractomenas, Photuris Chinese Lanterns, Photinus indictus, Photinus obscurellus,* the diurnals in the open areas and *P. carolinus* in the forested areas.
- Forest Road 536 unusually dense with *P. carolinus* females and other woodland species.

ANF study site locations and most commonly found local firefly species

ANF study site location	Primary firefly species present	Comments
Kellettville and along Tionesta	Chinese lanterns, single flash and Fast Five *Photuris, P. carolinus, P. macdermotti, P. marginellus, P. indictus, Pyractomena angulata* and *Pyractomena sp.*and Ellychnia, Lucidota, Pyropyga (the diurnals)	A very rich area with huge diversity of habitats and species
Hearts Content	Chinese lanterns and single flash *Photuris, P. macdermotti, P. carolinus, P. indictus, Pyropyga dicipiens*	The forest species displayed in the open fields
Buzzard Swamp	*Pyractomena linearis, marginalis, Chinese lantern Photuris, Photinus obscurellus* and *P. carolinus* and diurnals	Unique habitat with species thriving in swampy conditions. *Photinus carolinus* display in forest areas near parking lot.
Kelly Pines	*Photuris sp, Photinus carolinus and Lucidota atra*	Daytime sweep
Beaver Meadows	All species present, flashing, glowing and diurnals	Incredible diversity of habitat and species between the marshy areas and the forest and margins.
Mayburg Bridge	Chinese lantern Photuris	
The Branch	*Photinus carolinus* and P. *macdermotti, Lucidota punctata and atra*	Deep forest species primarily
The Headwaters of The Branch	*Photinus carolinus, Photinus macdermotti, Photinus obscurellus, Pyractomena sp.*	Forested area adjoining swampy area
Forest Road 536	*Photinus carolinus and Lucidota atra*	Open maturing forest
Forest Road 127	Chinese lanterns, Single flash and Fast 5 *Photuris, Photinus carolinus and Pyractomena angulata*	In and around openings along this road down near Kellettville
Minister Creek	*P. carolinus* and *Lucidota punctata*	Daytime sweep net survey
State Rt. 2002, Austin Hill Rd, old CCC camp	*Diurnals-Lucidota & Pyropyga, Ellychnia*	Daytime sweep net survey

FIRE team and volunteer study sites (yellow and orange pins) in Forest and Warren Co in the Allegheny National Forest. Unfortunately, the final 4 nights were too cold for flight and our planned northern Warren Co. and Allegheny Reservoir studies were thwarted. See also study site chart, previous page 6.



Photinus carolinus, the synchronous firefly

An important goal of this study was to determine if the synchronous firefly (*Photinus carolinus*)—or closely related sibling species—inhabited the ANF and, if so, how common they were**.** *Photinus carolinus* is a member of the *Photinus consimilis-ardens* complex of fireflies, all of which (possibly as many as 4-6 species) share male flash-train behaviors and very similar physical characters. Over 50 years ago, Dr. James Lloyd, a noted firefly researcher from University of Florida, reported the presence of *P. carolinus* from the mountains of north GA to western PA, just north of Pittsburgh, yet other members of this complex share much of the same range. Discussion and research in the scientific community continues on the exact taxonomic relationships within this complex. We found two members of this group in the ANF—*Photinus carolinus* and *Photinus obscurellus.* These two species proved easily distinguishable because they flew in completely different habitats, had distinctly different flash patterns, and physically differed in both size and color pattern. Thus, *Photinus carolinus* and Photinus *obscurellus* may represent the two extremes of this complex (p. 10, 12).

Unlike *Photinus carolinus*'s more famous relatives in Asia—*Pteroptyx* fireflies, who flash a simple synchronous pattern of single rhythmic flashes while perched on trees—*P. carolinus* has a more complex and sophisticated pattern, though it is a slightly less exact manner of synchrony. *Photinus carolinus* males fly in the dark forests in June and early July flashing a "flash-train" (series of pulsed flashes strung together) and repeating the train at predictable intervals. What makes this species so special is that all the males time their flash trains to coincide with their nearest closest neighbors, thus creating a pulsating spectacle of hundreds of flashes in the forest followed by 6-15 seconds of dark (with average flash/dark cycles slower and longer in cooler temperatures), repeated again and again by the mate-seeking males. This on-off rhythm of flashing (a train of ~ 6 pulsed flashes for 3-4 seconds followed by 6-15 seconds of dark), is termed the *Light Show* and continues for 2+ hours a night on peak nights. The more dense the numbers of males, the more breathtaking the rhythm and synchrony appears to the human observer.

Our survey found *P. carolinus* to be abundant and widespread in appropriate habitats at all surveyed locations. Please see map (p. 7, 16) and tables (pp. 6, 21-23) of primary study sites and all firefly species encountered within Forest and Warren Cos. in the ANF. While there were areas of greater abundance, especially in maturing second growth forests near running water, we were surprised to find healthy populations flashing far from water on the drier ridge tops. One explanation might be that the relatively open (caused by deer browsing and age) extensive maturing forests of the ANF are conducive to the male display, because males must have a clear line of sight to synchronize with their neighbors—difficult to accomplish in younger forests with dense underbrush.

DNA analysis of ANF *Photinus carolinus*

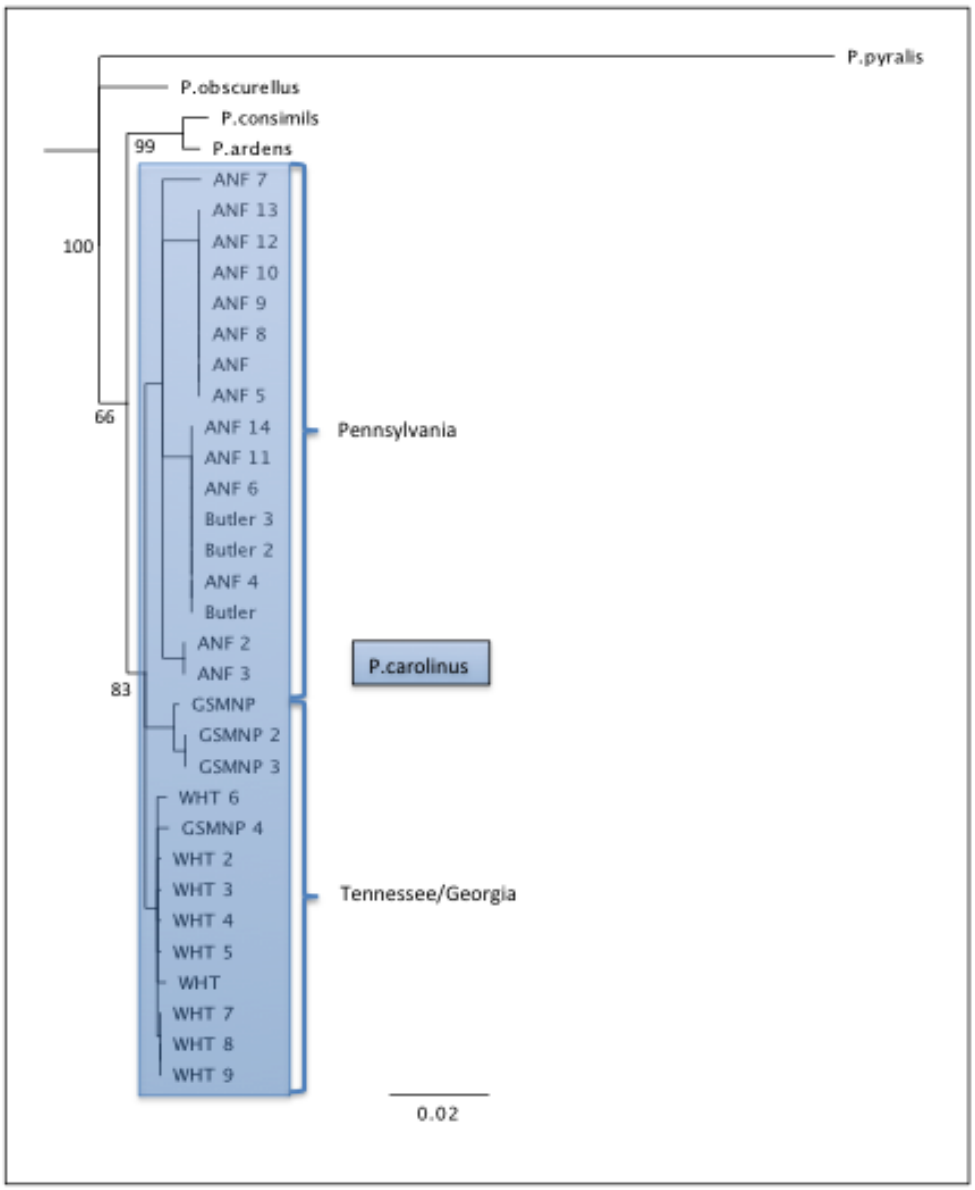
The FIRE team has worked collectively over 25 firefly seasons and is well familiar with the southern variety of *Photinus carolinus* in the mountains of NC, TN and north GA, including its ideal habitat, physical appearance and habits, flash times, group synchronicity, rhythms and behaviors. Upon our first night in the field in the Allegheny National Forest, we were unanimous in agreement that the display and appearance of the ANF synchronous fireflies was virtually identical to what we were used to seeing in the southern Appalachians. However, we all realized that looks can be deceiving and though the ANF *P. carolinus* "walked like a duck and quacked like a duck" (and flashed like a *P. carolinus*!) that genetically, they could possibly instead be more closely related to the related sibling species in the *P. ardens-consimilis* complex which had also been documented in this area. Therefore, our final decision on speciation would have to wait until DNA analysis was complete.

Dr. Kathrin Stanger-Hall of the FIRE team, conducted the DNA analysis of ANF *P. carolinus* firefly material in the Hall Lab at the University of Georgia (July and August of 2012). This analysis included a comparison of suspected *P. carolinus* fireflies from PA with documented *P. carolinus* from TN and GA, as well as a comparison with fireflies from closely related *Photinus* species (*P. ardens, P. obscurellus, P.consimilis*), and a more distantly related species (*P. pyralis*).

Overall we analyzed 14 individuals from Forest and Warren Co., PA within the ANF and 3 individuals from Butler Co., PA (to account for genetic variation due to geographic distance). These PA fireflies were compared to 4 *P. carolinus* from the Great Smoky Mountains National Park, and 9 *P.carolinus* from the north Georgia mountains (to account for genetic variation due to geographic distance in documented *P. carolinus* fireflies). From each individual in this study, DNA was extracted and amplified, and the DNA sequence was determined for a stretch of 585 basepairs in a gene region (mitochondrial COI gene) that is variable enough to detect variation within and between *Photinus* species. These sequences were combined with sequences from the other *Photinus* species (Stanger-Hall unpublished data), and analyzed to determine how the different individuals in this study were related to each other. For this purpose, we conducted a phylogenetic NJ analysis of (confirmed and tentative) *P.carolinus, P.obscurellus, P.consimilis,* and *P. ardens* fireflies, using *P.pyralis* as an outgroup to root the tree (Geneious v5.6, Drummond et al. 2012).

The genetic "family tree" (p. 10, 12) shows the results of this analysis. The lengths of horizontal branches reflect the amount of genetic difference between individuals (the longer the branches the more difference). There was some genetic variation within and between the geographically separated populations, but all the fireflies labeled *P. carolinus*, grouped together genetically, regardless of collection site (GSMNP: Great Smoky Mountains National Park, TN; WHT: North Georgia; ANF: Allegheny National Forest, PA; Butler: Butler, PA).

Our findings indicate that the suspected *P. carolinus* fireflies from ANF, are genetically much more similar to TN and GA *P. carolinus* fireflies than to any of the other *Photinus* species (*P. ardens, P. obscurellus, P.consimilis*) in this species group. This supports the identification of the ANF fireflies (tentatively identified as *P. carolinus* based on morphology and behavior) as *P. carolinus*. However, as expected, the *P. carolinus* populations from PA and GA/TN showed genetic variation. When relying on genetic variation to decide whether one or two species are involved, the question arises how much genetic variation is acceptable before deciding that this might be two very closely related but different species? To answer this question for *P. carolinus*, we conducted an extended DNA analysis.



A genetic "family" tree of *Photinus carolinus* fireflies (NJ tree rooted with *P. pyralis: s*hown is the 50% consensus tree based on 1000 bootstrap replicates; numbers below branches show % support). The lengths of the horizontal lines represent the genetic differences between individuals: The shorter the lines, the more similar the individuals are to each other. The names at the end of the branches identify the location at which the individual was collected: ANF: Allegheny National Forest, PA; Butler: Butler/PA, GSMNP: Great Smoky Mountain National Park, TN; WHT: North Georgia. This figure shows that the *P. carolinus* from PA, TN and GA group together and separate from other *Photinus* fireflies. This supports the identification of the ANF fireflies (tentatively identified as *P. carolinus* based on morphology and behavior) as *P. carolinus*.

Extended DNA Analysis

To determine how much genetic variation was acceptable for the conclusion that the TN/GA and ANF *P. carolinus* populations are the same species, we used genetic variation within another widespread *Photinus* species: *P. pyralis*, as a reference. Furthermore, to eliminate any potential mistakes in the collection process of the tentative *P. carolinus* fireflies from PA, we included closely related *P. consimilis* with flash pattern variants similar to *P. carolinus* for comparison into our analysis. For this analysis we used *P. concisus* as the outgroup to root the tree.

I. Genetic variation within *P. carolinus* compared to *P. pyralis:*

The *P.carolinus* population from TN/GA and the tentative *P. carolinus* population from PA showed genetic variation in the COI gene within and between populations. To assess whether this observed variation was within acceptable limits for the same species we compared our *P. carolinus* data with *P. pyralis* population data (Stanger-Hall unpublished data). *P. pyralis* is a geographically widespread *Photinus* species. It ranges from Texas (South-West) to Michigan (North) and North Carolina (East). We found a genetic difference of up to 13 base pairs (of 585 COI base pairs) between *P.pyralis* populations across a distance of ~300 miles. In comparison, the *P. carolinus* populations from TN/GA and PA differed up to 10 base pairs over ~400 miles. As a result, we concluded that the genetic variation between the TN/GA and the PA populations was within acceptable limits for the same species, and supports our conclusion that the tentative *P.carolinus* from PA are the same species as *P. carolinus* from TN/GA. The results of an extended phylogenetic analysis (NJ) including the *P. pyralis* population samples (and using *P. concisus* as an outgroup) are shown below (p.12).

II. Related *P.consimilis* variants with flash patterns similar to *P. carolinus*

Jim Lloyd (1966) described a fast-pulse flash pattern variant of *P. consimilis* fireflies and noted the similarity with *P. carolinus* fireflies. *P. consimilis* is closely related to *P. carolinus*, and the number of the flashes of the *P. consimilis* fast-pulse variant (up to 9 flashes per flash pattern) could be potentially mistaken for *P.carolinus* flashes (up to 9 flashes in flash pattern) in the unlikely event that they are active at the same time in the same area. To control for a potential misidentification during collection, we included two *P. consimilis* fast-pulse variants in our extended phylogenetic analysis: a slow-fast pulse (SFP) and a fast-fast pulse (FFP) variant (courtesy of Jim Lloyd). In this analysis, all *P. carolinus* from TN/GA and PA formed a monophyletic group, separate from the two *P. consimilis* fast-pulse variants, who formed a monophyletic group with *P.consimilis* and *P. ardens* (see figure below). This analysis confirms that none of the PA individuals were confused with *P.consimilis* fast-pulse variants during specimen collection, and also supports our conclusion that the tentative *P.carolinus* from PA are the same species as *P. carolinus* from TN/GA. However, please note that the inclusion of these *consimilis* variants also resulted in the blurring of the species boundaries between *P.ardens* and *P.consimilis* (based solely on genetic distance in the COI sequence studied).

We conclude that based on all the previously mentioned factors combined with the DNA analysis, the suspected *P. carolinus* from ANF are confirmed as *P. carolinus* fireflies. These findings indicate that *P. carolinus*, widespread, though habitat-specific, has isolated populations that stretch over 550 miles from the Appalachian mountains of north GA, TN and NC, WVA, VA to the forests of western PA and southern NY. (p. 16).

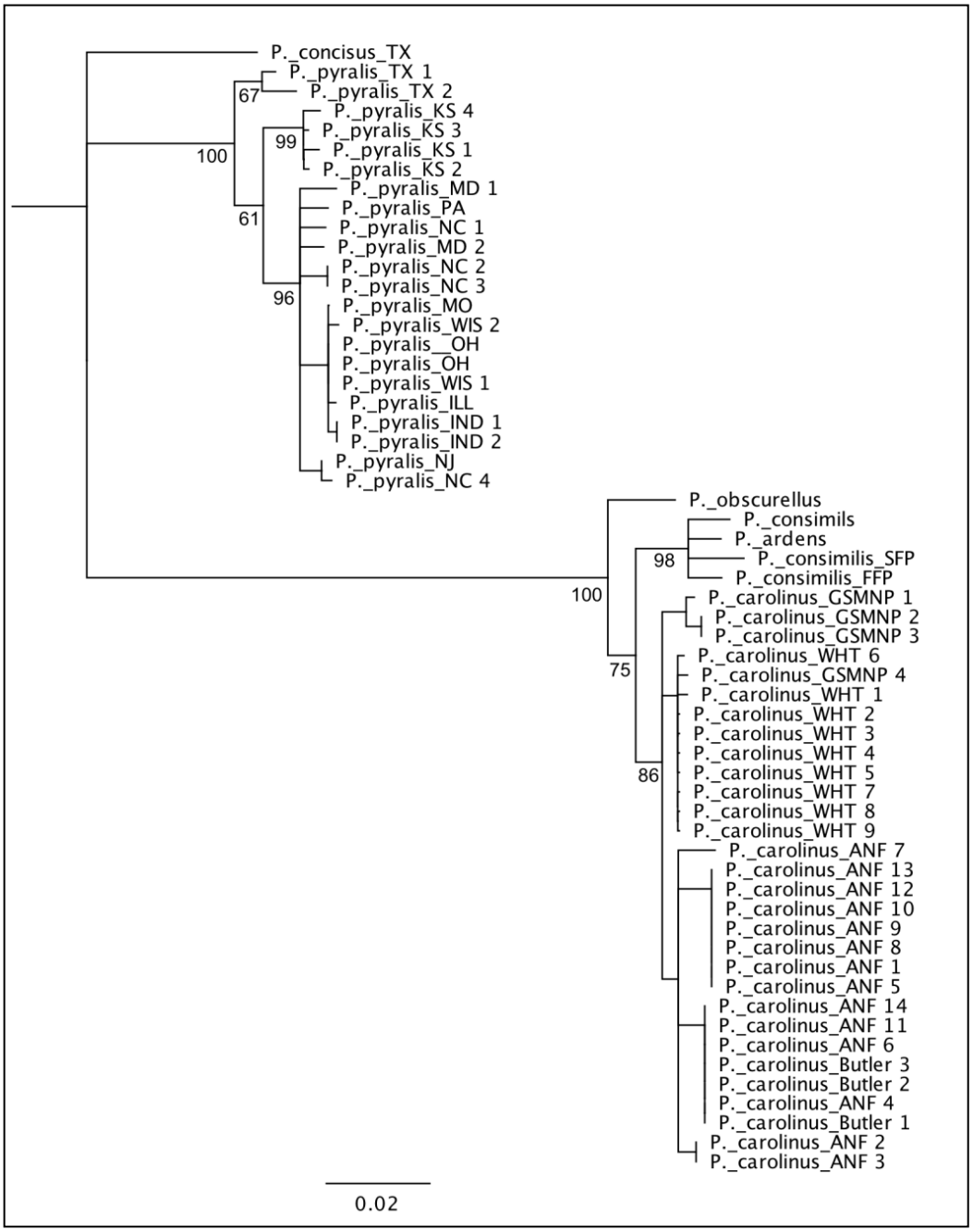


Figure: Rooted NJ tree (rooted with *P. concisus* to facilitate comparison between *P.pyralis* and *P.carolinus* population samples). Shown is the 50% consensus tree based on 1000 bootstrap replicates. Numbers below branches show % support. *P. pyralis* and *P. carolinus* specimen are labeled with their geographic origin (*P.pyralis*: State labels; *P.carolinus*: for locations please see text; *P.consimilis* SFP: slow-fast pulse and FFP: fast-fast pulse variants. Both *P.pyralis* and *P.carolinus* form monophyletic groups (in contrast, the species designation for the *P. ardens* and *P. consimilis* specimen as different species is not supported by our DNA samples).

Comparison of the Allegheny *P. carolinus* to the Great Smoky Mountains National Park *P. carolinus:*

The overall general display, manner of flight, physical characters and synchronic flash trains appear the same at both locations. In the ANF, *P. carolinus* appear widespread throughout the suitable dark forest habitat from 1200'-1600' in elevation. In contrast, 500 miles to the south, *P. carolinus* in the Great Smoky Mountains National Park are generally restricted to elevations above 1,600 ft. (the largest, hardiest populations occur above 2,200 ft.) and then only at specific locations (high, cool mountain river valleys). In the lowland valleys of TN and NC, *P. carolinus* is replaced by more seemingly heat tolerant species. Because of these habitat restrictions, *P. carolinus* appears to be a cool climate firefly. In the ANF of Forest and Warren Cos., we observed this species among low streams and riverbeds to the highest ridge tops, from 1200-1600', all of which sites are lower in elevation than in the Smokies (yet higher in latitude) and are generally cooler.

This widespread presence of displaying males may help in the future if large numbers of people come to view the ANF *Light Show*, because there will be many suitable viewing areas available. Although the ANF *P. carolinus* are far more widespread in area (at least in 2012), it appears that, during peak nights, the flashing display of ANF *P. carolinus* is less dense than that of peak nights in the Smokies. Watching the Light Show during peak season in both places is well worth experiencing, however.

Fireflies have little flight or flashing at temperatures between 50-60°F and **no flight or display at temperatures below 50°F.** During June in the Smokies there are usually no or infrequent (1 or 2) nights that are too cool for the flight and display of *P. carolinus*. ANF has a higher chance of cool nights during the prime firefly season because of the higher latitude and generally cooler night time temperatures in June (frequently below 50-55°F). In our 12 days of field studies in the ANF in 2012, 4 were unsuitable for night time flight and display because of heavy rain or low night time temperatures. This 3:1 ratio for suitable to unsuitable nights for viewing nighttime firefly display is most likely typical considering the location and latitude of the Allegheny National Forest. The bright light of a full moon is another consideration that can diminish the impact of a peak night.

Robust displays in the ANF may not occur every year as they did in 2012 because of the above and other yet unknown variables which may combine to make advance planning difficult in the ANF. As in the Smokies, both time and future observations by growing numbers of observers will refine the details of when and where the *Light Show* is best seen and enjoyed in the ANF.

Predicting *P. carolinus* Activity: Degree days and Phenology

Please note that, although the peak nights in the ANF fell in mid June in 2012 (June 10-22) with reduced numbers of fireflies flashing past the first week of July, **these dates may not always be the peak dates**. Over a 20 year period in the Smokies, peak nights have varied by as much as 5 weeks (May 17-June 21). How can these peak times be best predicted in the ANF?

1. Using modified degree days: Degree-days, a predictive tool used in both agriculture and industry, can measure the cumulative amount of heat during a defined amount of time. In this case, degree-days can reflect the amount of days warm enough for fireflies to develop and become active, no matter their life stage (p. 19-21, column 6) .This method factors in abnormally early or late springs and summers and is a more accurate technique for prediction than using calendar days from past firefly seasons . Each week the National Weather Service publishes lists of accumulated modified (corn) growing degree-day values (mGDD) for cities all over the country. Bradford, PA is appears to be the best overall fit for the ANF and is the station on which we based our planning and research dates. Judging from 2011 and 2012 and using the Bradford, PA research weather station # 360868 (not Bradford airport station), the **ANF *P. carolinus* season appears to extend from 719 mGDD-1200 mGDD with the best nights between 815-1100 mGDD.** It needs pointed out that in 2011, it was June 27 before 880 mGDD were reached, whereas in 2012, a much "earlier summer", 880mGDD degrees were reached almost 2 weeks earlier on June 15. Also note that though the minimum degree days may be reached in early June, the *P. carolinus* will not display until suitable night time temperatures and conditions are present. Example, in 2012, 719 mGDDs were reached by May 31, however it was June 10 (mGDD 817) before nighttime conditions were warm enough for flight. With increasing years of records, these parameters will become even more accurate. The following website is a very easy and free way to quickly check the weekly (updated each Saturday) accumulated degree days for ANF. Use the March 1 start date.
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/degree_days/grodgree.txt
Please see http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/degree_days/gdd.shtml for a more complete explanation of modified corn growing degrees days (mGDD).

2. A less technical method of predicting when *P. carolinus* is likely to be flying in high numbers is by noticing which local vegetation is beginning to bloom and fruit at the same time. Informally, I noted some of the most common flowering plants in the Kellettville area during our surveys. Some of these may prove to be accurate "calendar plants" for predicting peak flight of the fireflies. Many of these species are not native and are, in fact, invasive, but they are abundant and should be familiar to most people. In no particular order, the blooming of purple flowering raspberries (*Rubus odoratus*), crown vetch (*Coronilla varia*), elderberry (*Sambucus canadensis*), common milkweed (*Asclepias syriaca*) daylilies (*Hemerocallis fulva*), and Deptford pinks (*Dianthus armeria*) are good indicators, as is the ripening of wild red raspberries (*Rubus idaeus*) and domestic blueberries *(Vaccinium sp.*), and the mating of Japanese beetles (*Popillia japonica*) all occurred near the peak flight of *P. carolinus.*

3. It is an incredible and fun thought, but theoretically, if one knew where each pocket of the synchronous *P. carolinus* fireflies existed, in the unusually early spring of 2012, one could have begun at the southernmost range of *P. carolinus* in the north Georgia Appalachians May 1 and followed the *Light Show* up through the mountains of TN, NC in late May and on up through W VA and VA in early June and arrive in the ANF by mid-June, and end *the Light Show* tour in NY in early July (see map p. 16).

Firefly viewing: Possibilities and suggestions

ANF has a high species diversity (15+ species) of fireflies (pp. 6, 17-23). Ten of these species produce glows and flashes, which can easily be noticed by visitors. Of all the firefly species we encountered, we suspect 2 species will have the broadest appeal to most people, the "WOW!" factor: *Photinus carolinus, the synchronous firefly,* and a species in the *Photuris versicolor* complex, which we called the "Chinese Lanterns", because of their beautiful glowing light displays (description p. 22). We hope that, because of the widespread nature of *P. carolinus* throughout the forest, managing huge crowds will not become necessary by the ANF. Observing the magnificent display of the "low, slow, 1-2 sec glowing" Chinese Lantern *Photuris,* whose peak season ran (in 2012) slightly earlier by a few days than *P. carolinus,* however might require some management. Although this species is widespread in the more open and margin areas of the ANF (especially near water), the best spot we found for observation was on the Kellettville Bridge by the ACE campground from 11-12 pm. The only way this will continue is if this area continues to have little to no auto traffic and no permanent lighting. Ideally, observers must dark-adapt their eyes for 5 minutes to get the best show looking up or down the Tionesta River. If cars are driving past, the entire spectacle will be greatly diminished. In future years, the timing of the "Chinese lantern" peak and *P. carolinus* peak will be better understood by local observers. These two "WOW!" species peaked in large numbers simultaneously in 2012, but may not necessarily have such large populations every year nor peak together every year.

We made a special effort to note firefly activity in and around the smaller oil and gas well sites and newer tank storage areas. Firefly activity was apparent around most of the sites as long as there were no security lights present. When the bright, unshielded lights were present, no fireflies were noted in these lit areas. A simple solution could be to shield the lights with simple downward shades to prevent the stray light from penetrating the surrounding forest. Better still, if regulations permit, use motion detector activated lights with shades.

Newly disturbed land is not usually conducive to firefly activity, especially for the more vulnerable species with flightless females; they will have an especially hard time recolonizing. However, the margin areas created by openings, where habitats come together, can be very rich in species diversity, especially once the initial land disturbance has recovered and if areas nearby still have healthy populations. The firefly diversity of the ANF benefits greatly from the combination of the many habitats ranging from forests to swampy areas to rivers to open meadows.

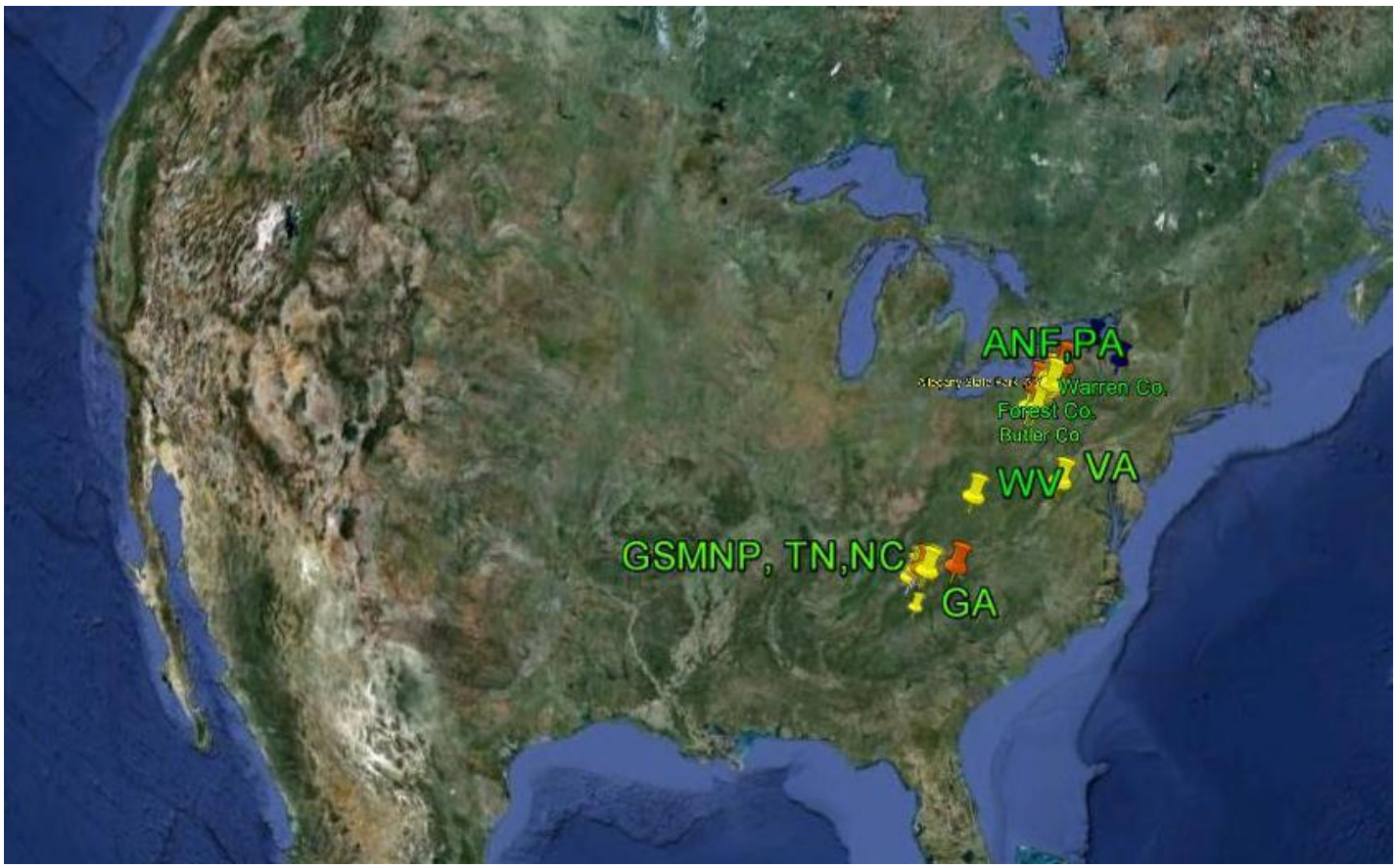
The question we were most often asked during and after our studies in the ANF is this: "Why are we suddenly seeing these fireflies in the ANF?" There is no one simple answer, but I (Lynn Faust's opinion only) would like to propose an explanation based on 20 years of experience and witnessing a similar situation in the Great Smoky Mountains National Park. The answer could be a combination of a number of factors:

1. People are not outside in the dark as much anymore. They are inside in their air conditioned, well lit, comfortable homes watching TV and using their phones and computers. Even when camping, the use of bright lanterns, big flashlights or a roaring campfire will prevent full appreciation and often even awareness of the *Light Show.*

2. The *Light Show* is a seasonal, short-lived phenomenon, impressive or noticeable only on the 5-10 peak nights each year (the dates of which will vary each year) and only in the specific habitat where it occurs. In other words, one can come a week too early or a week too late or camp ½ mile away where density is much less and never see the *Light Show.*

3. Not only did Dr. Lloyd document *P. carolinus* just south of here (Butler Co., PA) over 50 years ago, but I have personally received an increasing number of unverified reports of possibly synchronous displays for the past 4 years stretching from Ohio to Pennsylvania and as far north as Buffalo and Ithaca, New York. Is this a function of increasing numbers or the ease with which we can communicate questions over the internet? A few travelers, historians and naturalists from the 1800s also reported similar sightings. My personal belief is that this species has been widespread in the forests surrounding the Appalachians and present in suitable habitats long before historic times, yet this species is most likely in more fragmented, isolated populations these days.

The synchronous firefly *Photinus carolinus is* found in specific habitats and isolated populations that extend over 550 miles from north GA mountains to southern NY.



The *Photinus* Fireflies

Photinus- This is the genus containing the synchronous firefly *Photinus carolinus*. Members range from 6-14 mm depending on species (6 were found in ANF). All species recorded here have flighted males and females. Males have 2 lanterns, females one. *Photinus* are the most common prey for the *femme fatale Photuris* fireflies. *P. carolinus* (upper left), *P. obscurellus* (upper rt), *P. pyralis* (mid left), *P. macdermotti* (mid), *P. marginellus* (mid rt), *P. indictus* (bottom).

All *Photinus* have lanterns and flash except *Photinus indictus* (left and right). Though it has pale areas where its lanterns should be, this species is diurnal and non-flashing.

Photuris "Chinese Lanterns", "Single Flash" and "Fast Fives"

Photuris: These fireflies often prey on fellow fireflies to obtain defensive chemicals for their eggs (above rt). At times they battle spiders for the captured firefly prey (kleptoparastism) (see below). These are larger (10-17 mm), swifter, longer legged, "humpbacked" predators that often have a black "arrow" on their head shield (pronotums). Males and females both have two lanterns. The females are the hunters. *Photuris* species are very difficult to tell apart because they all look very similar and also because each species can mimic many other firefly patterns. There is much ongoing scientific investigation into correctly determining species. We separated our ANF species by distinct flash patterns, though all appeared to belong to the *Photuris versicolor* complex. The "WOW!" level *Photuris* we called "Chinese Lanterns" is a member of this genus. The experience of sitting in the dark in the middle of the Kellettville bridge by the campground between 11-12, viewing a peak night display of Chinese lanterns, drifting ghostlike among the river front and island vegetation, is a natural phenomenon that will not be forgotten.

Pyractomena

***P. angulata* (up left)** **Size comparison of *P. angulata* and *P. marginalis* (center)** ***P. marginalis* (up right)**
With 2 orange mites (mid left) **Pale *P. linearis* (mid right)**

Pyractomena- These fireflies are seldom found in huge groupings like some *Photinus* and *Photuris spp*, but instead are usually encountered singly or in small groups. *P. angulata* is a very recognizable June species with a showy flickering orange flash seen in the woods and open areas, hence its name "the candle firefly". *Pyractomena linearis* and *marginalis* are most often found near water and swampy situations and exhibit amber flashes. Females have 4 small lanterns on 2 segments. We suspect a possible 3 additional species that fly at other times of the year (*P. borealis**, *P. dispersa* and *P. lucifera*). *reported earlier by volunteers.

Fireflies lay eggs just before their death (left), larva hatch out in ~ 3 weeks (mid) and they pupate (pink shrimp-like, right) for 2-3 weeks the following season just before emerging as adults. These 3 future 2013-14 Light Show stars (mid), *P. carolinus* larvae hatched July 20 from eggs laid June 30.

The Diurnal Daytime Non Flashing Fireflies: *Ellychnia, Lucidota, Pyropyga*

***Ellychnia corrusca* complex (above)** known as "winter fireflies" or "daytime fireflies", these hardy non flashing fireflies overwinter as adults on the south sides of large trees. This species can be found flying slowly through the forest or small openings in low numbers almost every month of the year. The *E. corrusca* complex, in need of revision, separates its species by size. We found great size variation but will call all of them *Ellychnia corrusca complex* following current trends. *Ellychnia* can be recognized by the 2 pale "parentheses" on their pronotums (head shields).

***Lucidota* (above)** The 2 *Lucidota* species are frequently encountered slowly flying during the day in the forest and along trails. They are day active and have no lanterns, presumable using pheromones to find their mates. In the ANF there is a melanistic (all black) form of *L. atra (above right)* (7-12mm) in addition to the normal form with yellow and red on its pronotums (head shield). The much smaller (6 mm) *L. punctata (above center)* is found in similar habitats. They both have enormous flattened antennae.

Pyropyga dicipiens (left) These are tiny (5-6mm), day active, lanternless fireflies that can be found in tall grass and weeds. Along with the smallest *Lucidota* and the smallest *Ellychnia*, these "tiny fireflies" can be mind-numbingly difficult to tell apart, especially once out of their typical habitat and flight mode, even with the aid of microscopes and dissecting equipment. Many of these "tiny lanternless fireflies" have switched from one genus to the next over the past century and continue to challenge scientists (see similar ***Pyropyga*** and ***Lucidota*** right).

Firefly species of the ANF

Genus species	Common name, if any	Male primary flash pattern X= flash, sec=seconds of dark between flashes. general average at 68°F	Habitat	Season and best time to view display in local time	Modified Corn Growing Degree-mGDD day range of survey observations of prime display	Relative abundance in ideal habitat A=Abundant M= moderate S- usually solitary or low numbers NS-not seen but historically present	"Wow factor" for human observer on peak nights. 1=diurnal &m no flash 2-4 pretty 5= Wow	Comment
Photinus carolinus (*P. consimilis-ardens* complex)	Synchronous firefly	XXXXXX lasting~3 sec; Followed by 9-12 sec of dark; then repeat flash train XXXXXX	Forest, flying in groups 3-7 feet off the ground	Mid June-early July 10:45-midnight	817-1100	A	WOW! 5	All flash in flash-trains of average 6 flashes, flash at same time, go dark at same time
Photinus indictus	No lantern Photinus	none	Open areas, fields	June	909-1083	M	1	Diurnal, no functioning lantern, though it has pale end segments and abdomen
Photinus obscurellus (P. ardens group) Following Lloyd 69 and Luk et al 2011		XX or XXX repeated every ~5 sec	Swampy wet open areas	June-?, 10:15-midnight	909-1200	M	3	Gathered in groups in low, damp or swampy areas, flash in trains of 2-3 flashes.
Photinus macdermotti	Father Mac's firefly	X 2 sec X 4 sec X 2 sec X	Forest Dusk-first dark	June-July, 8: 50-9:30pm	909-1083	M-A	4	Paired flashes every 4 seconds flying low in forest
Photinus marginellus	Little Gray	X 4 sec x	Forest, margins dusk	June, 8:30-9:30	1083-1200	M	2	Grey wing covers (elytrae)
Photinus pyralis	Big Dipper	X 6 sec X	Open fields, flies low with dipping "J" flash,	Late June-July 8:30-9:30	1000+	A	4	Most widespread Eastern US firefly
Photinus scintellans***		X 2-3 sec X 2-3	Open and margin areas, begin just as dark falls, quick flash, flying low in grass	June		NS	3	Not seen during survey but found south and east of ANF. Pale bodied, possibly later season. Flightless females.
Photinus ignitus*		X 5-6 sec X	A quick flash in open areas at dusk			NS		Not seen during survey but historically present in CMNH records. Possibly later season.

Genus species **Please NOTE:** ***Photuris* ID is very tough and uncertain at the species level!**	**Common name, if any**	**Male primary flash pattern X= flash, sec=seconds of dark between flashes. general average at 68°F**	**Habitat**	**Season and best time to view display in local time**	**Modified Corn Growing Degree-mGDD day range of survey observations of prime display**	**Relative abundance in ideal habitat A=Abundant M= moderate S- usually solitary or low numbers NS-not seen but historically present**	**"Wow factor" for human observer on peak nights. 1=diurnal &m no flash 2-4 pretty 5= Wow**	**Comment**
***Photuris versicolor* complex** may be the same species as the next 2 flash patterns. Possibly *P. caerulucens* (or *lucicrescens* with atypical behavior and flashes)	*Chinese Lanterns**	1-2 sec low, slow glows every 3-4 seconds	Near water, margins trees and out in open.	June-early July, dusk 9:20-midnight 11 best	909-1100	A	WOW! 5	Flying glows, low, slow at dusk and move higher later in evening
***Photuris versicolor* as in Barber 1951.** may be the same species as the above and below	Fast Fives*	xxxxx 1-2 sec xxxxx	Tree tops, late at night, 11-12	June	909-1100	M	3	Flashtrains of ~5 rapid, strobelike pulses lasting <1 sec, late night in treetops
***Photuris versicolor* complex** may be the same species as the above 2 species	Single tree flashers*	X 2-3 sec X	Trees along margin areas	Late May June 10-12	909-1200+	A	4	In same trees as Fast Fives, but from dusk to late
Photuris hebes? may be the same species as above but appear to be smaller and faster flashing.	Christmas Lights*	Twinkling single flashes every 1-2 sec. Often flash rhythmically 5-10 times then go dark for undetermined amount of time before restarting	Flying slowly about boughs of trees, 10-all night	June-early July, 10:15 pm with some all night	909-1200+	A	WOW! 5	Fill trees with Christmas like lights, flash all night, abundant in nearby Butler Co
Photuris quadrifulgens ** *versicolor* complex	4 flashers*	xxxx 4 sec xxxx	Open fields flying 3-10' high after dark	Late May or early June	<800			Flash a train of 4 flashes at ½ sec intervals in open fields
Pyropyga decipiens *Large color/size variation noted.*	Tiny daytime firefly*	_	Low and perched in open fields	June	909-1100+	M	1	Diurnal, no lantern, usually perched on grass and weeds
Lucidota atra Color/size variation	Black Lucy		Forest and open	June-July	909-1100+	M	1	Flying slowly, low along trails
Lucidota punctata	Tiny Lucy*		forest	June-July	982-1100+	S	1	Flying low or perched on low vegetation in forest
***Ellychnia corrusca* complex** *which currently includes E. autumnalis, E. lacustris. Large color/size variation noted*	Daytime or winter firefly		Forest and open	April-June	Year around, highest #s in spring	M	1	Adults may be found year round

Genus species	**Common name if any**	**Male primary flash pattern X= flash, sec=seconds of dark between flashes. general average at 68°F**	**Habitat**	**Season and best time to view display in local time**	**Modified Corn Growing Degree-mGDD day range of survey observations of prime display**	**Relative abundance in ideal habitat A=Abundant M= moderate S- usually solitary or low numbers**	**"Wow factor" for human observer on peak nights. 1=diurnal,no flash 2-4 pretty 5= Wow**	**Comment**
Pyractomena borealis**	Earliest treetop flasher*	X ~ 2-3 sec X	Flying slowly about the often leafless early spring treetops	Late April-early June, after dark until midnight	420	NS	3	Not seen, but probable. One of the earliest flashing species, large 14-20mm
Pyractomena angulata	Candle firefly	Orange Flicker up high every 2-4 seconds	Forest and margin areas	June-early July, 10:30-1 am	909-1100	S	4	Distinctive orange flickering flash lasting ~ .5 sec
***Pyractomena linearis* complex**		Possible glows, flashes and flickers-our data inconclusive	Swampy open	June-?	909-1100+?	S	3	grey wing covers (elytrae) Often found with *P. obscurellus,*
Pyractomena marginalis		single orange-yellow flash every ~ 5 sec	Swampy or areas near water	June-?	909-1200+?	S	2-3	Dark wing covers
Pyractomena dispersa***		Brief orange flicker ~ 4 sec;	Found in swampy, cattail areas	Most likely early season species	Early <800 (from TN records)	NS		*Not seen but probable. P. dispersa* is early season (May-June)
Pyractomena lucifera***		Single amber flash ~ 5-6 sec	Found in swampy, cattail areas	Later season species	and >1200 late season (from TN records)	NS		*Not seen but probable. P. lucifera* is later season(late June-July)

*Simple names we gave the most common fireflies

**Not seen during survey dates but reported by volunteers, seen previously by first author in neighboring county or in Carnegie Museum of Natural History collection records and/or widely reported in literature and highly probable.

*** Not present during our survey times, but likely ANF species

Changing Populations, Habitats and Perceptions:

Spreading populations? We were asked repeatedly, "Why are we suddenly just noticing these fireflies?" In the past 20 years throughout the Great Smoky Mountains National Park, I have likewise informally noticed what appears to be a "spreading" of *Photinus carolinus*. Areas that had no evidence of this species in the early 1990s now have very robust populations. My 69 year old husband remembers as a child (in the 1950s) walking a mile up the road from his Smokies' cabin, part of an old logging town, with his parents to view the *Light Show* because the fireflies were not near (the then) more open areas around the cabins, where the previously timbered forest was still in early succession. Instead the fireflies displayed in the older forest up the road. The forest "up the road" had been one of the first logged in the late 1800s and early 1900s and by the 1950s and 1960s was further along in maturity than some of the more recently logged areas of the Great Smoky Mountains National Park. Now in 2012, big trees surround the abandoned cabins and so do the synchronous fireflies.

Logging history. The logging history of the GSMNP and the ANF are very similar; both forests were heavily logged up until about 70 years ago. The ANF and the GSMNP were both established the same decade (1930s). Logging still occurs in the ANF, but much of the ANF now has maturing secondary forests approaching 40-70 years. In spite of the widespread, large-scale logging a century ago, clearly remnant populations of have *P. carolinus* survived in pockets throughout the Appalachians. Now, as forests across the eastern U.S. approach a half-century or more of maturity, and with the underbrush of succession forests diminishing, the prime habitat for *P. carolinus* is again spreading and it is possible the fireflies are increasing in numbers in these areas. One surprise we encountered was the low numbers of *P. carolinus* in the actual old growth forest of Hearts Content State Park. Instead these "rebel" fireflies actively displayed out over the tall grassy area adjoining this forest! Similarly, in an old growth forest of the Smokies near a picnic area, the highest numbers are found within the picnic area itself instead of the majestic virgin remnant adjoining this picnic grounds. Please note however, that these relatively small open areas are always surrounded by forest. *Photinus carolinus* is a forest species.

Changing forests. The forests we see now (mature or not) in no way resemble the forests of old. Our American chestnuts and many elms have been gone for decades and new forests have taken their place. The Eastern hemlocks have all died in much of the Eastern US this past decade, with a number of other important species threatened. As a result, the composition ratio of tree species is completely different from the 1800s, yet, thus far, this species has adapted and continues to exist in these ever changing Appalachian forests.

Changing temperatures. In addition to habitat changes, seasonal events regularly occur, like in the record breaking "early spring" of 2012 when our GA, TN and NC *Photinus carolinus* appeared and disappeared 3-4 weeks earlier than ever before documented. The ANF firefly season seemed likewise "early". Will changing and evolving forest composition or warming or cooling trends help or harm the spread of *P. carolinus* and the other firefly species in the ANF? No one knows.

Charismatic insects. The ANF has an amazing species-rich firefly (lightning bug) community. Around the world, fireflies are recognized and appreciated by young and old alike as magical and non-threatening, universally associated with happiness, love, life, and oddly, death. Fireflies are one of the few "charismatic" insects that are not perceived as pests. They tend to draw people back into nature with their mesmerizing and peaceful male courtship flash displays. They can serve as both indicator species of the health of an environment and an intangible asset to bring awareness to the web of life, bring friends and family together for an evening of beauty, and introduce children to the world of nature in a fun, safe, fascinating way.

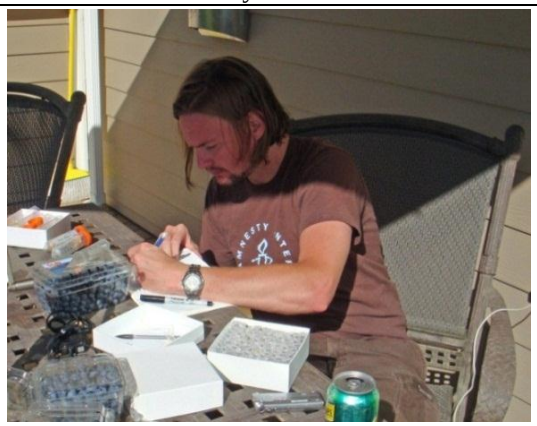
FIRE team

The 5 member FIRE team arrived with many years of collective firefly field and lab experience (p. 24). As stated earlier, we had all spent from 1-20 field and lab seasons working with the Great Smoky Mountains National Park and northern Georgia *Photinus carolinus* populations. Individual areas of expertise combined to create a versatile, efficient and knowledgeable team. Ample curiosity, skepticism, lively debates and enthusiasm in the field and lab provided for an extremely productive, enlightening and enjoyable survey for all involved. It should be noted that the majority of survey work was done on a professional, yet volunteer basis by FIRE team participants who collectively donated over 500 hours in the field, lab and in preparation of this report. In cooperation with the U.S. Forest Service, Department of Agriculture, Allegheny National Forest, under the Secure Rural Schools Act, P.L.110-343 and Forest Service Agreement 12-DG-11091900-011, the FIRE team was encouraged and enabled to assemble and work in the ANF of Forest and Warren counties.

Dr. Raphael De Cock of University of Antwerp, Belgium conducts worldwide comparative firefly surveys in Europe, Asia and the Americas. Though specializing in the behavior and ecology of fireflies, larval biology and the use of warning signals, he is interested in all aspects of firefly biology. He has most likely observed as many different species in the wild as anyone currently in the field, which gives him invaluable perspective in his work and makes him a highly sought after team member. Dr. Kathrin-Stanger Hall of University of GA conducted the DNA collections, gathered flash data and performed the lab analysis once she returned to UGA. She continues her work on better understanding flash evolution and the phylogenies of fireflies. PhD candidate (UGA) Sarah Sander included the ANF in her season-long (March-July) firefly survey of the Eastern US where emphasis is on variations in light emission spectra between the species and genera. PhD student Zachary Marion of the University of TN is focused on chemical protection and how the complex mixtures of firefly defensive chemicals vary within and among different species and locations. FIRE team leader Lynn Faust has spent the past 20 years conducting research individually and as a member of research teams (from TN to Borneo) primarily, but not limited to, *Photinus carolinus* in the GSMNP. In recent years, in addition to giving many talks and writing publications on firefly life histories, she served as a “firefly consultant” for the Discovery Channel’s upcoming 7 part nature series (due out in 2013) *Wild Planet: America*.

2012 Allegheny Forest Firefly Survey FIRE team

The FIRE team hails from around the world: Team leader Lynn Faust from Tennessee, Dr. Raphael De Cock of Antwerp, Belgium, German-born Dr. Kathrin Stanger-Hall from University of GA, and PhD candidate Sarah Sander of UGA and PhD student Zach Marion of the University of Tennessee.



Clockwise from top left- FIRE team; Sarah, Raphael and Lynn in Kellettville lab; Lynn sweep netting in Buzzard Swamp; Zach vouchering specimens; Sarah and Kathrin setting up light traps at Beaver Meadows, Sarah conducting light emission studies.

Local Volunteers

Without the local volunteers organized, overseen and instructed by Cathy Pedler, our surveys would have lost much scope and depth. Her original 2011 field observations were responsible for encouraging this survey to become a reality. In 2012, firsthand volunteer observer reports began in April and continued into July, far past the time we left June 27. These reports have been extremely helpful in bracketing seasonality and location, especially of the 2 "Wow!" species. These volunteers wrote detailed reports of their sightings and offered maps and suggestions of additional sites for us to investigate, which was extremely helpful since none of us were from this area. Local volunteers provided well over a 100 volunteer field survey hours at 9 sites. In turn, they instructed and encouraged other interested friends and neighbors and we received additional field reports (from as far as Alleghany State Park in NY) from these "second generation" volunteers.

As evidenced by the very helpful local volunteers, quite a few experienced and interested firefly spotters now exist in the ANF area. The more people know about their local firefly fauna, the more will be appreciated, noticed and documented. So, in 2012 there were many more people looking and knowing what to look for than in 2011 or earlier. And with their continued efforts the body of knowledge about the ANF fireflies will steadily increase, and more visitors to the ANF will benefit.

Survey Methods and Identification

The FIRE team used multiple approaches to assure the maximum opportunity to document as many firefly species as possible in the study area in June. Since there were 5 of us, we were able to cover much territory at any given site. We not only documented adult fireflies, but also eggs, larvae and pupae. We reared these immatures whenever possible (see photos of larvae from 2012 brood, p. 19, 29). Daytime surveys were conducted with sweep nets and close visual inspection of vegetation in likely places. Vouchers were collected and inspected in more detail later at the lab. Night time surveys, usually lasting from 7 pm-past midnight at the chosen site, were conducted by observation, voice recordings and netting individuals exhibiting specific flashing patterns and later inspecting individuals under a microscope and using comparative literature. Light traps of several types were additionally used. These included UV lights, female species-specific mimic LED lights run by programmable diodes, and using caged receptive females as lures in areas of high male density to attract males. Voice recordings of flash patterns and behavior, always taken with date, ambient temperature and time were later transcribed and timed later with stop watches. Other flash data was timed directly in the field with stopwatches. Additionally, we drove over 500 miles on forest service roads during the day and night employing quick superficial surveys, especially to determine the full extent of the occurrence of *Photinus carolinus* within the ANF. After finishing for the night a detailed, usually 4+ hour survey of an area (for instance, Beaver Meadows, Buzzard Swamp, Heart's Content, Kelly Pines, Tionesta River snow-mobile trails, Minister Creek, The Branch or Salmon Creek etc.) we would proceed to drive very slowly on the dark Forest Service roads. Every ¼ to ½ mile, we extinguished our lights, got out and observed flash activity. With this quick sampling technique, we could cover much ground, see how widespread the species was and select especially promising looking sites for more detailed surveys in coming nights. Unfortunately, the unexpected cold nights the final 4 nights of our survey prevented us from planned surveys up in the north end of ANF around Allegheny Reservoir, but fortunately, we received good reports of sightings from our local volunteers.

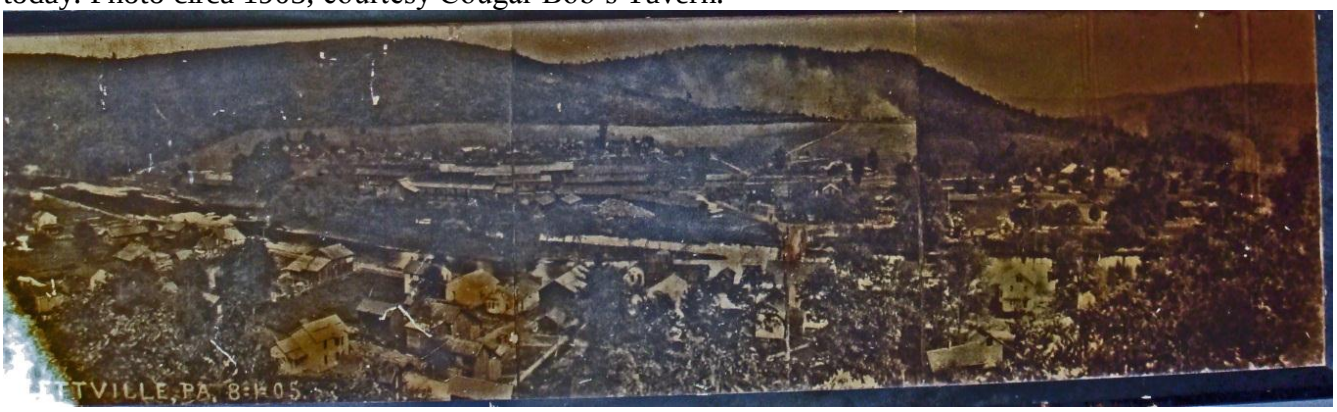
Our laboratory consisted of 2 dissecting microscopes, a number of lower tech magnifiers and lights, all needed dissection instruments and collection vials, preserving fluids, coolers and a freezer (p. 26). We used 6 computers, 4 cameras, two 30-gallon containers of firefly literature and numerous online papers. The day spent at the Carnegie Museum of Natural History helped prepare us for likely species we might encounter. In addition to data entry and vouchering each specimen collected by the different team members, over 40 typed pages of field notes and flash data were recorded from voice recordings and field notes and over 1500 (pre-edit) digital photographs taken to assure proper memory of individual specimens. Identifications were made from a combination of using our collective experience, flash pattern documentation and recognition before capturing vouchers, comparisons to already identified vouchers from our private collections, referring daily to the published literature, much lively discussion, dissections, DNA analysis and close morphological examinations through our dissecting scopes and. We welcome any debate and discussion now and in the future on our species' identifications.

The Past and the Future

This tiny 2mm larva (below) hatched after 3 weeks from eggs laid by a *P. carolinus* female collected June 26, 2012 along FR 536. Along with others of the 2012 year brood, this larva represents future years of magnificant flash displays in the Allegheny National Forest.

Another glowing, but seldom seen firefly larva (below) (probably *Lucidota atra* 11mm) from Heart's Content. Maintaining healthy larval habitats and populations are every bit as important as preserving adult firefly habitat. Much remains to be learned about larval requirements of all the firefly species.

Forest and alluvial vegetation with prime firefly habitat have now replaced the once bustling tannery town of Kellettville, PA. Note, island visible in center is just upstream of the Kellettville bridge and ACE campground today. Photo circa 1905, courtesy Cougar Bob's Tavern.



Additional Sightings

Although tangential to our focus, one of our team members (ZH Marion) is also a knowledgeable herpetologist and noted the occurrence of several reptiles, amphibians and other creatures. Specifically, the following species were observed:

Reptiles:

Garter snake (*Nerodia sipedon*)
Northern water snake (*Thamnophis sirtalis*)
Painted Turtle (*Chrysemys picta*)

Amphibians

American toad (*Bufo/Anaxyrus americanus* depending on the taxonomist)
Bullfrog (*Rana catesbiena / Lithobates catesbienus*)
Green frog (*Rana/Lithobates claimitans*)
Northern leopard frog (*Rana/Lithobates pipiens*)
Eastern newt (larval, eft, and adult stages; *Notophthalmus viridescens*)
Dusky salamander (*Desmognathus fuscus*)
Red-backed salamander (*Plethodon cinereus*)
Slimy salamander (*Plethodon glutinosus*)
Spring salamander (*Gyrinophilus porphyriticus*)

Other wildlife encountered:

Birds

Ruffed grouse (*Bonasa umbellus*)
Common pheasant (*Phasianus colchicus*)
Wild Turkey (*Meleagris gallopavo*)
Red-tailed Hawk (*Buteo jamaicensis*)
Bald Eagle (*Haliaeetus* leucocephalus)

Mammals

White-tailed deer (*Odocoileus virginianus*)
North American porcupine (*Erethizon dorsatum*)
North American beaver (*Castor canadensis*)
Cotton-tailed rabbit (*Sylvilagus sp.*)
Groundhog *(Marmota monax*)

Spiders

Raft spider (*Dolomedes vittatus*)
Fishing spider (*Dolomedes sp.*)

Helpful References

The following papers were used as references during our survey. Many scientific papers are now accessible to anyone online as free downloadable PDFs or for a small fee from Amazon or the journal or author's University lab website. Googling the title or using Google Scholar is also productive for the interested individual.

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