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SHORT COMMUNICATION

Lampyrids Recovered from Emergence Traps in the Great Smoky Mountains National Park

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Introduction

Photinus carolinus Green is a popular firefly that attracts thousands of visitors each year to the Great Smoky Mountains National Park (GSMNP) (Faust, 2009). This firefly is famous for its synchronous flash display in late May and June. The adult flash behavior of this firefly was described by Lloyd (1966) and the synchronous flash behavior was further detailed by Copeland and Moiseff (1995) and Faust (2009, 2010). The biology and natural history of this insect was reported by Faust (2010). This firefly is dependent on larval feeding for its nutrition (adults are nonfeeding), but we know little about the seldom seen larval stage. Rearing has repeatedly proved difficult. For instance, though Buschman (1977) was able to record field and some laboratory observations on field collected larvae, only 2 of the original 59 *Photinus consimilis* Green complex larvae (closely related to *P. carolinus)* were successfully reared to adulthood (unpubl. obs.). These larvae were found in marshy habitat feeding on small annelids (Buschman, 1977). Some 40 yr later the biology and natural history of larval *Photinus* spp. remains poorly understood. This study was done to determine if the fireflies were emerging from the soil/leaf litter in the firefly habitat. This information on larval habitat will be important for understanding the conservation, survival and/or maintenance of fireflies like *P. carolinus.* It could also support the hypothesis that they are feeding on earthworms and/or other organisms in the soil and leaf litter.

Methods and Materials

We used cone emergence traps to study Lampyrid emergence in a wooded habitat where *P. carolinus* adults occur in large numbers. The emergence traps (91 cm in diameter) (Fig. 1A) were constructed from black aluminum window screen (18 × 14 mesh) and were similar to those described by Raney and Eikenbary (1969). The screen was supported by 4 wood strips (ca. 2 × 2 × 76 cm). A circular wooden platform (2 cm thick × 15.5 cm in diameter) was stapled inside the screen cone. The platform had an opening (5.5 cm) through which insects could pass into the collecting jar. The top of the platform was machined to accept the inverted ½ pint canning jar (237 ml). The jar included a secondary screen cone that helped confine insects in the jar. A total of 40 traps were installed along a 230 m transect just off a forest trail where the firefly density was very high historically. Selection of trap sites included the following criteria: relatively flat (so jars would stay on the trap), as much leaf litter as possible, free of obstacles like roots, rocks or large plants and out of sight from the walking trail. This maturing forest (75 yr from clear cutting) with a relatively open understory had trees up to 60 cm diameter (at breast height). The trees are dominated by the pioneer species, tulip poplar (*Liriodendron tulipifera* L.), with some smaller maple, oak, rhododendron, beech and hemlock trees. The substrate was broken metamorphic sandstone with a number of small springs that came to the surface in the area. Based on the predictions of the mGDD model (Faust and Weston, 2009) the fireflies were scheduled to emerge in early May. The traps were installed beginning May 1, with data collection beginning 10 May 2012 when all 40 traps were installed. They were checked daily until 2 June which was past the peak of the flight. All trap sites were checked for earthworms at conclusion of the study. Other insects found in the traps were also recorded to document the suite of other organisms in the habitat that could serve as potential prey or predators/parasites.

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Fig. 1. A) LLB holding jar from the emergence trap installed in the forest and leaning on a hammer used to pack the edge of the traps. B) *P. carolinus* male resting in the opening in the platform, inside the trap, but not in the jar. C) *P. macdermotti* male hiding in the crack between the jar (now removed) and the wall of the groove that held the jar. D) *P. carolinus* male hiding in the crack between the jar (now removed) and the wall of the groove that held the jar. E) Adult stone flies (Plecoptera: *Acroneuria carolinensis*). F) Water in a hole 30 cm deep and 30 cm from a trap that had stone flies. G) The "gray fly" (Diptera: Heleomyzidae). H) The "yellow fly" (Diptera: Lauxaniidae, *Homoneura incerta* (Mallach)). Photos A, C, and E by LFF; and B, D, G and F by LLB.

Results and Discussion

The Lampyrids were recorded on all collection dates but the non-Lampyrids had a few missing dates. The first flashing *P. carolinus* males were observed in Elkmont May 3, the first female May 11. This was the earliest recorded emergence of *P. carolinus* in Elkmont in the 21 yr of records by LFF. The peak male flight occurred 20–27 May. In the study area, immediately around the traps, the first flashing male *P. carolinus* were observed 11 May, after the traps were installed and data was being collected.

We collected a total of 4 *P. carolinus* from the 40 emergence traps, two males (22 & 26 May) and two females (26 & 30 May) (Fig. 1B). Despite the low sample number, this data suggests that the sex ratio could be close to 50:50, although females are observed much less frequently in the field than are males. The area under each 91 cm diameter trap was 0.66 m^2. Therefore the 40 traps covered a total of 26 m^2. We collected two male *P. carolinus* in the traps, so the area per male firefly comes to 13 m^2. The square root of 13 m^2 gives us the distance between fireflies, which is 3.6 m (11.8 ft). This means that an observer would see a firefly every 3.6 m (11.8 ft). This density represents the season long emergence density and may not be the field density that an observer would see at any specific time. This emergence density of *P. carolinus* seems to be lower than the field density that an observer perceives, because the observer is usually viewing the fireflies from the side over varying terrain and is probably experiencing an optical illusion–the fireflies appear to be closer together than they really are because there is little depth perception in the dark (Copeland and Moiseff, 1995). The field density of flashing *P. carolinus* also appears to be greater because of the multiple flashes in the flash pattern and the tendency for displaying males to join flashing males in higher density areas. This emergence density, one per 3.6 m (11.8 ft), provides important preliminary data on *P. carolinus* population density at high population sites. This low number of fireflies collected in the emergence traps suggests that future studies comparing emergence in differing habitats may require several hundred traps to obtain enough insects to be analyzed with confidence.

Wing (1988) reported collecting more than 300 flightless *P. collustrans* females from a 360 m^2 area, for a density of 0.83 females per m^2. The *P. carolinus* density of 0.15 fireflies per m^2 is comparable, but lower than the density of *P. collustrans.* These values are also comparable to those for the herbivorous western corn root worm (WCRW), *Diabrotica virgifera vergifera* LeConte, also a beetle that lives in the soil. Gray *et al.* (1992) report recovering 1.25, 1.85 and 0.1 adult WCRW per trap over three years in 55 to 60 emergence traps (0.26 m^2 per trap), so there were 4.8, 7.2 and 0.38 WCRW per m^2. *Photinus* larvae are predators so their populations would be expected to be lower than the herbivore rootworm populations.

Since leaf litter depth was a major criterion for site selection, the depths of leaf litter in the traps did not appear to correlate with *P. carolinus* catches. The three traps that produced *P. carolinus* had 3 ($n = 2$), 4, and 2 cm of litter. The mean leaf litter depth ranged from 1.3 to 8.25 cm with 14 traps having 4 or more cm of litter and 26 traps having at least 2.5 cm of litter.

We found six *P. carolinus* males on the traps (not in the traps), on 16, 23 ($n = 2$), and 24 ($n = 3$) May (Fig. 1D). These captures along with emergence captures correlate well with the *P. carolinus* flashing activity in this area. We collected a total of five male *Lucidota punctata* LeConte in the traps on 2 June and one male *P. macdermotti* Lloyd on, not in, the trap (Fig. 1C). A total of 16 individuals from 3 Lampyrid species were collected in or on the 40 emergence traps; 9 in the traps, and 7 on the traps.

A number of other insects were recorded from these emergence traps; some flies were collected as potential parasites of the lampyrids or the earthworms (later determined to be not likely parasites), others because their eggs and larvae could possibly be prey for the predaceous larvae of *P. carolinus* and still others were just interesting. There were a total of 53 "Gray flies" (Diptera: Heleomyzidae) collected from 21 traps (Fig. 1G), a total of 23 "yellow flies" (Diptera: Lauxaniidae, *Homoneura incerta* (Mallach)) collected from 16 traps (Fig. 1H), seven Bibionids (Diptera: Bibionidae) and a fly (Diptera: Rhagionidae, *Rhagio hirtus* (Loew)). There were also several Lampyrid look-a-likes, Coleoptera: Tenebrionidae, *Arthromacra sp.* and Coleoptera: Cantharidae, *Cantharis* sp. Surprisingly, several known aquatic insects were also caught in the traps: four adult stone flies (Plecoptera: Perlidae, *Acroneuria carolinensis* (Banks)) were caught in two traps (Fig. 1E) and an adult caddis fly (Tricoptera) was found in another trap. The presence of aquatic insects requires an explanation. The two traps that had the stone flies had deep cavities in the ground that were filled with leaf litter and were probably connected to below surface water channels leading to nearby springs (3–5 m away) (Fig. 1F). The area was littered with jumbles of large boulders covered with leaf litter forming an apparent firm surface. Other insects collected included: wood roaches (Blattaria: Blattidae) ($n = 13$), Diptera ($n = 42$) (Fig. 1F), Coleoptera ($n = 31$), Hymenoptera ($n = 12$), Lepidoptera ($n = 12$) and various other insects and small invertebrates ($n = 16$)—(a few representative Coleoptera and Diptera were mounted for preservation in the GSMNP park museum).

This study confirms that *P. carolinus* larvae live in/on the soil and are associated with leaf litter where the earthworms are known to be common. Earthworms were collected in the leaf litter and soil under each and every one of the 40 emergence traps. This supports our current understanding that earthworms could be important food for *P. carolinus* larvae. *P. carolinus* larvae were also reared from eggs collected from this 2012 brood and were fed pieces of earthworm. They reached mature larvae within the next year, but failed to pupate to the adult stage suggesting something is still missing from their diet and/or rearing protocol. There were several additional potential prey items identified in this study, such as eggs and larvae of insects that were collected in the emergence traps, on which larvae could be feeding.

There is an invasive species of annelid that has established itself in portions of the GSMNP (Snyder *et al.,* 2011). Since annelids are one of the few food items that *Photinus* larvae are known to eat, it will be important to monitor the potential impact of these invasive annelids on the native annelids, soil community and structure in the prime synchronous firefly habitat.

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Literature Cited

Buschman, L. L. 1977. Biology and Bioluminescence of selected Fireflies in three Genera: *Pyractomena*, *Photinus*, and *Photuris* (Coleoptera: Lampyridae). Ph.D. Dissertation, Department of Entomology and Nematology, Univ. Florida, Gainesville, Fla. 203 pp.(Also available at URL: http://ufdc.ufl.edu/UF00099131/00001/pdf?td=buschman. Last accessed 10/24/2013.)

Copeland, J., and A. Moiseff. 1995. The occurrence of synchrony in the North American firefly *Photinus carolinus* (Coleoptera: Lampyridae). Journal of Insect Behavior 8(3):381–394.

Faust, L. F. 2009. Synchronous firefly, *Photinus carolinus* (Coleoptera: Lampyridae), of the Great Smoky Mountains National Park. *In* B. Napompeth (ed.). Diversity and Conservation of fireflies, pp. 126–140. Proceedings of the International Symposium on Diversity and Conservation of fireflies, held at Queen Sirikit Botanic Garden, Chiang Mai, Thailand, 26–30 August 2008.

Faust, L. F. 2010. Natural history and flash repertoire of the synchronous firefly *Photinus carolinus* (Coleoptera: Lampyridae) in the Great Smoky Mountains National Park. Florida Entomologist 93(2):208–217.

Faust, L. F., and P. A. Weston. 2009. Degree-Day prediction of adult emergence of *Photinus carolinus* (Coleoptera: Lampyridae). Environmental Entomology 38(5):1505–1512.

Gray, M. E., A. S. Felsot, K. L. Steffey, and L. Levine. 1992. Planting time application of soil insecticides and western corn rootworm (Coleoptera: Chrysomelidae) emergence: implications for long-term management programs. Journal of Economic Entomology 85(2):544–553.

Lloyd, J. E. 1966. Studies on the flash communication system in *Photinus* fireflies. Museum of Zoology, University of Michigan 130:1–95.

Raney, H. G., and R. D. Eikenbary. 1969. A simplified trap for collecting adult pecan weevils. Journal of Economic Entomology 62:722–723.

Snyder, B. A., M. A., Jr., Callaham, and P. F. Hendrix. 2011. Spatial variability of an invasive earthworm (*Amynthas agrestis*) population and potential impacts on soil characteristics and millipedes in the Great Smoky Mountains National Park, USA. Biological Invasions 13:349–358. (doi:10.1007/s10530-010-9826-4)

Wing, S. R. 1988. *Photinus collustrans*: Reproductive ecology of flightless female fireflies (Coleoptera: Lampyridae). Ph.D. Dissertation, Department of Entomology and Nematology, Univ. Florida, Gainesville, Fla. 107 pp.