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Firefly (Coleoptera: Lampyridae) Flight Periods, Sex Ratios, and Habitat Frequencies in a United States Mid-Atlantic Freshwater Tidal Marsh, Low Forest, and their Ecotone

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ABSTRACT

As part of a long-term arthropod study, we operated six Malaise traps in Dyke Marsh Wildlife Preserve (DMWP), Virginia from April 1998 through December 1999 and obtained 727 adult lampyrid beetles in six genera. They were present in samples from early April through early October. The abundances of five of the genera varied among a low forest, freshwater tidal marsh, and the forest-marsh ecotone during at least 1 yr of the study. In genera with over 10 trapped specimens, four showed a male sex bias in combined samples from both years. Malaise traps can be used efficiently to survey and monitor certain lampyrid species in DMWP and similar places. To understand the lampyrid biodiversity and phenology of the Preserve more fully, it would be worthwhile to survey the entire Preserve for at least 10 yr.

Key words: beetles, deciduous forest, fireflies, Lampyridae, phenology, sex ratios, tidal freshwater marsh.

INTRODUCTION

Although fireflies (Coleoptera: Lampyridae) are common in many terrestrial environments throughout the world where they have several main roles in food webs, there are only a few published studies of lampyrid communities in particular habitats (e.g., Levesque & Levesque, 1997; Zaragoza-Caballero et al., 2003). Lampyrid larvae, which often live in moist areas, consume fallen fruit (e.g., *Sambucus* sp., *Vitis* sp.); are predators of annelids (Hirundinea, Oligochaeta), arthropods (e.g., flies [Bibionidae, Mycetophilidae], damselflies [Coenagrionidae], bugs [Membracidae], moths [Noctuidae, Notodontidae], and spiders [Salticidae]), and mollusks (Ancylidae, Philomycidae, Zonitidae); and are scavengers of dead insects (Keiper & Solomon, 1972; Buschman, 1984a, b). On the other hand, many organisms consume lampyrids including ants (Formicidae), antlions (Myrmeliontidae), bats (Chiroptera), birds (Anatidae, Caprimulgidae, Fringillidae, Hirundinidae, Icteridae, Nyctibiidae, Odontophoridae, Parulidae, Tyrannidae, Vireonidae), centipedes (Chilopoda), crustaceans (Armadillidiidae, Cambaridae), fish (Cyprinidae), flies (Phoridae, Tachinidae), frogs and toads (Bufonidae, Hylidae, Ranidae), fungi, harvestmen (Sclerosomatidae), lizards (Iguanidae), other lampyrids (some *Photuris* spp.), mantids (Mantodea), mites (Acari), nematodes (Nematoda), snails (Gastropoda), spiders (Argiopidae, Araneidae, Lycosidae), true bugs (Belostomatidae, Reduviidae), and wasps (Crabronidae) (Lloyd, 1973; Lewis & Monchamp, 1994; EMB, pers. obs.).

Our study concerns lampyrids in a freshwater tidal marsh and adjacent floodplain forest of Dyke Marsh Wildlife Preserve (DMWP) in the Mid-Atlantic region of the United States. Our general aim in this study is to increase knowledge about the biology of lampyrids in view of conserving them. Specifically, we address the

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following questions by analyzing Malaise-trap samples. Which lampyrid taxa occur in DMWP? What are their flight periods? What are their abundances and sex ratios in three main Preserve habitats — floodplain forest, freshwater tidal marsh, and the ecotone between them? Are Malaise traps useful for surveying and monitoring lampyrids? Overall goals of our long-term DMWP research include discovering which arthropods occur in the Preserve and understanding its food web.

MATERIALS AND METHODS

As part of a long-term arthropod study, we collected lampyrids from April 1998 through December 1999 using six Townes-style Malaise traps (Townes, 1972) in Dyke Marsh Wildlife Preserve (DMWP), part of the George Washington Memorial Parkway, a national park in northern Virginia (Johnston, 2000). The Preserve includes 153.8 ha of land on the western shore of the Potomac River and part of the river in Fairfax County, Virginia. Elevation is 0–3.25 m asl (B. Helwig, pers. comm.). The Preserve, which contains the largest remaining freshwater tidal marsh in the Washington, DC, area, has experienced marked degradation in recent decades due to air pollution, alien invasive organisms, shoreline erosion due to boat wakes and storms, and water pollution (Johnston, 2000; Engelhardt, 2004; EMB, pers. obs.).

We placed two traps in each of three habitats — low forest, freshwater tidal marsh, and the ecotone between them as described by Barrows et al. (2004, Fig. 1). The six traps were in a broad transect that ran east to west. The ecotone (defined as 10 m on each side of the forest-marsh edge) ran about 200 m approximately NNE to SSW in our sampling area. We oriented each trap so that its longitudinal axis ran east-west, and its collecting head faced due east. The forest traps were about 50 m west of the ecotone, and the marsh traps averaged about 60 m east of the ecotone. The mid-point location of the traps in each habitat was 38.77194°N 77.05083°W (forest), 38.77139°N 77.05056°W (ecotone), and 38.77172°N 77.04990°W (marsh).

Each trap was 1.2 m wide, 1.7 m long, 1.0 m high at its back, and 2.0 m high at its front (Barrows et al., 2004, Fig. 2; Barrows & Kjar, 2008) and was made of crab-cage wire, a supporting metal frame, and a collecting head. We spray-painted trap gauze and supporting frames black in an attempt to decrease their visibility to lampyrids and human park visitors. The crab-cage wire encircled the base of each trap and prevented Snapping Turtles (*Chelydra serpentina*) and objects such as driftwood from tearing trap gauze. Each trap was mounted on a floating platform, 1.2 by 1.8 m, that rose up to 1 m above the ground when the tide entered the Preserve's marsh. Vertical metal poles kept traps in place as they moved up and down. Forest traps did not float because their sites did not flood during our study period, but can flood as high as 2.6 m. Lampyrids flew or crawled into a trap's collecting head where they were preserved in 95% ethanol. All traps ran during our entire 21-mo sampling period, except the marsh traps. We removed them from late December 1998 through late March 1999 because possible flooding during that time could have destroyed them. We emptied traps every 3–24 days, and we collected samples less frequently during the cold months when daily arthropod captures were low compared to warm months (Table 1).

We used the key in Downie & Arnett (1996) and obtained help from James E. Lloyd for specimen identification. Because of limitations of the key and the need to observe light flashes of *Photuris* spp. to make species identifications, we could not identify specimens of this genus to the species level. To test for possible differences in the number of lampyrids among habitats, we used repeated-measures analysis of variance (rmANOVA) and the Scheffé test (SPSS, Inc. 2006). To test for possible biased sex ratios in samples, we used Preacher's (2007) online Chi-square test program. Voucher specimens are in the Georgetown University Arthropod Collection.

Table 1. Lampyrid sampling intervals in Dyke Marsh Wildlife Preserve, Virginia, 1998–1999.

Sample interval	1998	1999
1	12–19 April	11–25 April
2	19–28 April	25 April – 8 May
3	28 April – 10 May	8–23 May
4	10–17 May	23 May – 6 June
5	17–28 May	6–20 June
6	28 May – 6 June	20 June – 2 July
7	6–14 June	2–18 July
8	14–24 June	18–23 July
9	24 June – 7 July	23 July – 8 Aug.
10	7–19 July	8–15 Aug.
11	19–30 July	15–29 Aug.
12	30 July – 9 Aug.	29 Aug. – 12 Sept.
13	9–12 Aug.	12–26 Sept.
14	12–28 Aug.	26 Sept. – 11 Oct.
15	28 Aug. – 11 Sept.	11–24 Oct.
16	11–26 Sept.	24 Oct. – 8 Nov.
17	26 Sept. – 11 Oct.	8–21 Nov.
18	11–26 Oct.	21 Nov. – 5 Dec.

RESULTS AND DISCUSSION

Lampyrid taxa

The Malaise traps captured 727 lampyrids during our 2-yr study. The samples contained *Ellychnia corrusca* (Linnaeus), *Lucidota atra* (Fabricius), *Photinus pyralis* (Linnaeus), *Pyractomena lucifera* Melsheimer, and *Pyropyga decipiens* (Harris), as well as at least three *Photuris* spp. that we could not identify by keying. There were 446 lampyrids in the 1998 samples and 281 in the 1999 samples (Table 2). All genera except *Pyractomena* were less common in 1999 compared to 1998. The observed yearly differences in lampyrid abundances might be the result of natural fluctuations in their population sizes due to weather and other factors. Based on information in Ulke (1902) and Downie & Arnett (1996), there may be as many as 32 lampyrid species in the combined area of Maryland, Virginia, and Washington, DC. This suggests that there may be more lampyrid species in DMWP than our traps captured and that hand collecting, use of other types of traps in addition to Malaise traps, and examination of living specimens may uncover more species and genera in DMWP.

In contrast to our study, a lampyrid survey in a *Rubus* 'Boyne' monoculture and adjacent forest dominated by *Pinus strobus* in southern Quebec, Canada, obtained six genera and eight species (Levesque & Levesque, 1997). A lampyrid survey in a tropical dry forest in the Sierra de Huautla Biosphere Reserve, Morelos, Mexico, found eight genera and 19 species (Zaragoza et al., 2003).

Flight Periods

In DMWP, lampyrid flight seasons varied among taxa (Table 2, Figs. 1–2). Collectively, lampyrids were captured from 19 April through 11 October, with peak abundance in July. Zaragoza et al. (2003) found a similar seasonal abundance distribution. Their lampyrids primarily flew during the rainy season in Huautla, which is approximately from June through September and roughly corresponds to the warm season of May through early October when lampyrids primarily flew in DMWP.

Abundances

As a group, DMWP lampyrids did not show abundance differences among habitats in either year (Table 2). *Lucidota atra* and *Photinus pyralis* were most common in the forest in 1998, and *Photuris* spp.

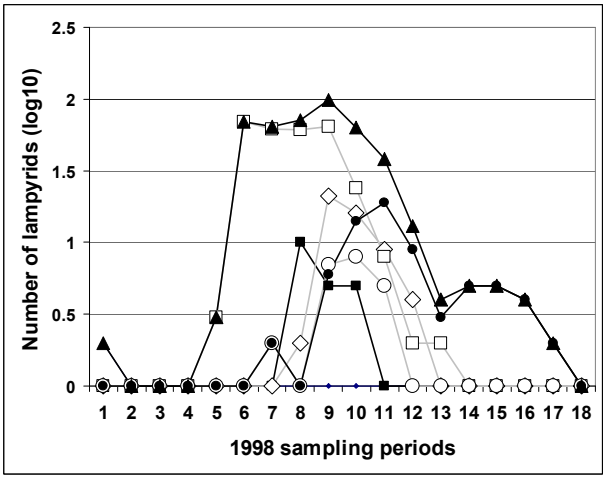

Fig. 1. Lampyrid abundance during the 1998 flight period, Dyke Marsh Wildlife Preserve, Virginia. See Table 1 for sampling periods. The black diamond represents *Ellychnia corrusca*; black square, *Lucidota atra*; open diamond, *Photinus pyralis*; open square, *Photuris* spp.; open circle, *Pyractomena lucifera*; black circle, *Pyropyga decipiens*; black triangle, all lampyrids.

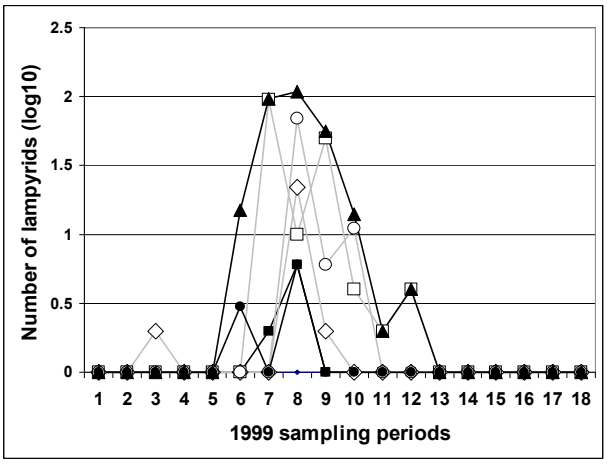

Fig. 2. Lampyrid abundance during the 1999 flight period, Dyke Marsh Wildlife Preserve, Virginia. See Table 1 for sampling periods and Fig. 1 for taxon symbols.

and *Pyractomena lucifera* were most common in the ecotone in both years. Kjar & Barrows (2004) reported *Photinus* sp. and *Photuris* sp. larvae from pitfall samples of the DMWP forest. Little is known about the biology of most *Pyractomena* spp., but Buschman (1984b) noted that larvae of *Pyractomena lucifera* are aquatic and crawl on moist plants near water. This information and the abundance of *P. lucifera* in the DMWP ecotone suggest the hypothesis that adult *P. lucifera* in DMWP tend to stay in and near their

Table 2. Lampyrid abundance in three habitats based on Malaise-trap samples from Dyke Marsh Wildlife Preserve, Virginia, 1998–1999.

Taxon	Number of lampyrids[1]									Flight period, 1998–1999
	1998				1999				1998–1999	
	E	F	M	Total	E	F	M	Total	Total	
Ellychnia corrusca	0	0	1	1	0	0	0	0	1	12–19 April
Lucidota atra	1a	16b	0a	17	0	6	0	6	23	14 June – 19 July
Photinus pyralis	5a	42b	0a	47	1a	20a	2a	23	70	14 June – 9 Aug.
Photuris spp.	185a	55b	46b	286	129a	5b	28b	162	448	10 May – 12 Aug.
Pyractomena lucifera	32a	0b	4b	36	70a	0b	13c	83	119	6 June – 19 July
Pyropyga decipiens	17a	6a	36a	59	4a	0a	3a	7	66	14 June – 11 Oct.
All lampyrids	240a	119a	87a	446	204a	31a	46a	281	727	19 Apr. – 11 Oct.

[1]E = ecotone traps; F = forest traps; M = marsh traps. Within year and taxon, trap site totals (N = 2 traps) followed by different letters indicate that their respective sites have significantly different abundances from each other ($P \leq 0.05$), and totals followed by different letters indicate that their respective sites have significantly different abundances from one another ($P \leq 0.05$, rmANOVA, Scheffé test). The 1998 and 1999 sample for *E. corrusca* and the 1999 sample for *L. atra* are too small for Scheffé analysis.

larval habitat. Of the eight lampyrid species found in their trapping study, Levesque & Levesque (1997) obtained six or more specimens of *E. corrusca*, *L. atra*, and *Pyropyga decipiens*. They did not perform statistical analyses of species distributions among habitats; however, their raw data suggest the hypotheses that *E. corrusca* is more common in the boundary and forest than in the *Rubus* monoculture, and *L. atra* does not show a habitat preference. In our study, *L. atra* was most common in the forest. Furthermore, those researchers found that *P. decipiens* occurred only in the most open area (the *Rubus* monoculture), whereas in our study, this species was not statistically more abundant in open areas. Possible reasons for the differences in taxon distributions of these two studies include habitat-preference differences among populations within species and differences in sample sizes.

Sex Ratios

In 2-yr samples, adult sex ratios for *L. atra*, *Photinus pyralis*, *Photuris* spp., and *Pyropyga decipiens* are male biased (Table 3). *Photinus pyralis* shows a male bias in the forest; *Photuris* spp., ecotone and forest; and *P. decipiens*, forest and marsh. *Pyractomena lucifera* shows a female bias in the ecotone. These biases may be due to an actual preponderance of one sex in particular habitats, or, if a species or genus has an actual 1:1 adult sex ratio, a greater tendency for the traps to catch females or males depending on the taxon. Females of some *Photinus* species are brachypterous and do not fly, so Malaise traps might catch them only rarely, if at all.

Monitoring with Malaise Traps

Malaise traps may be the most effective trap type for collecting adult lampyrids of some species. For non-flashing species, pheromone traps (apparently not yet developed) may be highly successful. Lampyrids infrequently come to lights suggesting that light traps would be a poor means for collecting these beetles. In our study area, adult lampyrids of most species are usually hidden from dawn through dusk so it is difficult to collect them diurnally. It is also difficult to net lampyrids in the dark when they are flying and hand-collect them from foliage and other objects because they are usually hard to find.

We found that Malaise traps can obtain a large lampyrid sample, adequate for comparing species and genus abundances and adult sex ratios of some taxa

Table 3. Sex ratios of lampyrids by habitat based on Malaise-trap samples from Dyke Marsh Preserve, Virginia, 1998–1999.

Taxon	Habitat[1]							
	Ecotone		Forest		Marsh		All sites	
	N	% female	N	% female	N	% female	N	% female
Ellychnia corrusca	–	–	–	–	1[2]	100	1[2]	0
Lucidota atra	1[2]	0	22	14	–	–	23	17**
Photinus pyralis	6	33	62	5***	2[2]	100	70	10***
Photuris spp.	314	26***	60	22***	74	58	448	31***
Pyractomena lucifera	102	61*	–	–	17	41	119	58
Pyropyga decipiens	21	57	6	0*	39	26*	66	33**
All lampyrids	444	36***	150	13***	133	47	727	34***

[1] *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$ (Chi-square test).
[2] This sample is too small for Chi-square analysis.

among habitats and years. The traps can operate all day and readily obtain lampyrids with short daily flight times, short annual flight times, or both. Therefore, the traps are useful for determining the conservation status of readily-trapped taxa based on their sample population sizes. In a preserve of over 40.5 ha (100 acres) such as DMWP, six Malaise traps may not have significant adverse effects on lampyrid populations.

For many *Photuris* species, it is necessary to examine male light flashes to identify them to species (Downie & Arnett, 1996), but this is not possible with killing-type Malaise traps. To monitor the relative population sizes of such species, one could take censuses along transects or at random points when lampyrids flash, collect the males in traps that do not kill them and then observe their flash patterns, or both. A fast, inexpensive method for identifying large numbers of lampyrids by examining their nucleotide sequences would be a boon for lampyrid surveys.

Conclusions

Overall, we found that lampyrid genera often have different abundances in different DMWP habitats and female- or male-biased adult sex ratios based on Malaise-trap samples. Our study obtained baseline data to be used in monitoring and managing lampyrids in DMWP. Many lines of future research are needed to solve more mysteries about lampyrids, including a complete survey of species and their life histories and a long-term study of population fluctuations in different DMWP habitats in view of global climate change and its effects on biodiversity.

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