Ecological Entomology (1982) 7, 443–446

Prey attraction by luminous larvae of the fungus gnat *Orfelia fultoni*

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ABSTRACT. 1. Bioluminescence in predacious larvae of the fungus gnat *Orfelia fultoni* attracts potential prey.

2. Transparent traps placed over larvae caught more arthropods than opaque traps put over neighbouring conspecifics.

3. Small Diptera are particularly vulnerable to light lures, while apterous soil arthropods are seemingly unaffected.

Key words. Bioluminescence, prey-attraction, Mycetophilidae.

Introduction

For nearly a century the bioluminescence of certain animals has been presumed to attract prey (Meyrick, 1886; reviewed by Buck, 1978). Until now, however, evidence of such attraction has been circumstantial, ambiguous or obtained under artificial conditions (note the qualitatively different phenomenon of aggressive mimicry of luminous sexual signals in *Photuris* fireflies: Lloyd, 1975). Small electric lights simulating the colour and intensity of commonly encountered marine photophores lure some crustacea and small fish (Nicol, 1959). Beebe & Vander Pyl (1944) saw copepods swim towards the ventral lights of lanternfish (Myctophidae) in aquaria. The fish would turn and snap up approaching crustaceans. Placement of light organs in the ceratoid anglers, such as on a rectractable rod (illicium) dangling in front of the mouth or within the mouth are suggestive of lights as lures (Bertelsen, 1951; Herring & Morin, 1978). The supposition that the lights of certain larval fungus gnats (Mycetophilidae: Diptera) serve as lures has apparently been based on its plausibility as an explanation for the co-occurrence of the phyletically unusual traits of carnivory and luminescence.

I here report on arthropods collected in the field using traps baited with the glows of *in situ* luminous predators, larvae of the fungus gnat, *Orfelia fultoni* (Fisher). These data demonstrate that bioluminescence can increase the density of potential prey in the vicinity of a light emitter.

O.fultoni, an inhabitant of North America's Appalachian mountains, is the sole luminous fly in the New World (Lloyd, 1978; see, however, citations in Peck & Russell, 1976). Larvae inhabit small cavities in soil, mosses, dead wood, or crevices between stones, and weave a sprawling web attached by adhesive spindles to the substrate (Fulton, 1939). Vermiform larvae glide along the strands and eat captured arthropods. In the final instar, larvae measure *c.* 1.5 cm in length and construct a web up to 5 cm across. Light organs located in the head and tail of all instars emit a relatively constant blue light throughout the night (Fulton, 1941).

Methods

In order to determine the attractiveness of *O.fultoni*'s light, traps to capture potential prey were constructed that either transmitted

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or obscured larval bioluminescence. Transparent and blackened plastic petri dishes, 16.1 × 50 mm, were covered with Tack Trap®, a sticky compound capable of holding even large insects. Clear dishes were placed over 145 late-instar *O.fultoni* larvae and their webs. To the human eye, the lights were little affected by the trap. Dishes painted flat black were put over 139 neighbouring larvae. Other dishes (102 clear, 104 black) were set in an area where *O.fultoni* occurs, but not over larvae. These latter traps tested for any preference arthropods might have for one of the dish colours. Traps were put out on fourteen nights and picked up the following mornings. Statistical tests are by contingency table chi square, which compare the ratio of captures on blackened and clear dishes placed over flies and over bare ground. The numbers of insects in the treatment with the largest trapping surface are adjusted downward to make them comparable with the results of the treatment with the smaller surface area (see Table 1). Most captures were of small, fragile arthropods, usually damaged by removal from the trap. Many specimens were therefore identified only to family.

Results and Discussion

The number of arthropods trapped on clear dishes over *O.fultoni* is significantly greater

TABLE 1. Arthropods captured in transparent and blackened traps placed over *O.fultoni* larvae or on neighbouring substrate.

	Clear, no larva*	Black, no larva	Clear, over larva	Black, over larva†
Diptera	22	30.4	61.1	28
Tipulidae	4	1	3.9	2
Mycetophilidae	0	1	1.9	0
O.fultoni (male)	0	0	2.9	0
O.fultoni (female)	0	0	0	1
Chironomidae	0	1	4.9	0
Sciaridae	0	0	1	2
Cecidomyiidae	13	24.5	34	17
Dolichopodidae	0	0	1	1
Phoridae	1	1	7.8	1
Unidentified	4	1.9	3.9	4
Collembola	42	57.8	76.6	72
Sminthuridae	17	33.3	22.5	16
Isotomidae/Entomobryidae	25	24.5	54.3	56
Coleoptera	2	0	6.8	1
Ptiliidae	2	0	3.9	0
Elateridae	0	0	1	1
Phausis reticulata (Lampyridae)	0	0	1.9	0
Potential predators	1	2.9	14.6	6
Araneida	1	1	9.7	6
Phalangida	0	0	3.9	0
Neuroptera larvae	0	0	1	0
Hymenoptera	0	2	0	0
Miscellaneous	7	3.9	18.4	12
Mecoptera larvae	1	1	0	2
Gryllacrididae‡	1	0	7.8	6
Acari	2	1	2.9	2
Psocoptera	0	0	1	0
Cicadellidae	2	1	2.9	1
Lepidoptera	0	0	1	0
Diplopoda§	0	0	1	0
Unidentified	1	1	1.9	1
All arthropods	74	94	170.7	118

*Trapping area is 0.98 that of black traps not over larvae.
†Trapping area is 0.97 that of clear traps over larvae.
‡Almost certainly too large to be killed and eaten by *O.fultoni* larvae.
§Probably too large to be considered prey.

than those taken on black dishes ($\chi^2 = 9.1$, $P < 0.005$, see Table 1). Most of this difference is due to the greater number of Diptera captured in traps that transmit larval lights ($\chi^2 = 8.2$, $P < 0.005$; not including adult *O.fultoni*).

A more conservative comparison between flies taken on dark and clear dishes can be made after discarding tripulids, because of a possible preference for clear dishes in the absence of larvae, and deleting phorids, some species of which are parasitoids and could visit larvae as entomophages (the known parasitoids of luminous mycetophelids are Hymenoptera; Hudson, 1892; Fulton, 1941). Even with these subtractions, transparent larvae-covering dishes catch significantly more flies than the opaque ($\chi^2 = 8.0$, $P < 0.005$).

It had been thought that small flightless soil arthropods, particularly Collembola, comprise the bulk of *O.fultini*'s diet (Fulton, 1941). If so, it is not due to their attraction to larval glows. There is no difference in the numbers of Collembola captured in dark and lightened traps ($\chi^2 = 1.8$, $P > 0.10$). This disparity in susceptibility between Diptera and Collembola may be related to the function of the 'phototropisms' *O.fultoni* exploits. A popular explanation for the attraction of insects to lights supposes that close, dim lights can be mistaken for heavenly bodies. When celestial objects are held at a constant position relative to the insect for the purpose of moving in a straight line such an error can result in spiralling toward the dim, close light (Lloyd, 1977). A vagile winged insect might use celestial lights in navigation, and so fall victim to a 'star-mimicking' predator (at least one moth has been found to use stars in orientation; Sotthibandhu & Baker, 1979). Relatively sedentary arthropods such as Collembola might (i) be less likely to use celestial orientation clues, and (ii) by intimately sharing a habitat with a luminous predator evolve to ignore or avoid its lights (note, however, that Collembola are attracted to the glows of luminous mushrooms; Sivinski, 1982). When all winged insects are considered, more are taken in clear traps over larvae than in darkened traps ($\chi^2 = 11.1$, $P < 0.001$). There is no corresponding difference, however, in the summed apterous arthropods ($\chi^2 = 1.8$, $P > 0.10$).

Mycetophilid larval lights and webs may also serve purposes other than prey attraction and capture. One luminous web spinning Japanese species, *Keroplatus nipponicus,* apparently eats only fungal spores (Kato, 1953). Webs may alert residents of a predator's approach or restrain them from reaching the larvae. Poisons found in the webs of some nonluminous and luminous taxa might also discourage attack (Fulton, 1939; see Mansbridge, 1933). The apparatus of luminous luring could be a secondarily evolved elaboration of what was initially an aposematic signal and a fortress (see Sivinski, 1981). Relatively large predators, particularly the salamander *Plethodon jordani*, are common in *O.fultoni* habitats. A station-inhabiting, light-emitting insect must be either unpalatable or nimble to survive under such circumstances.

Acknowledgments

This work was supported in part by a Grant-in-Aid from the Highlands Biological Station, Highlands, N.C. Comments by J. E. Lloyd, T. J. Walker, S. Wing and P. Sivinski improved the paper. B. Hollien professionally prepared the manuscript. Florida Agricultural Journal Series No. 3225.

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Accepted 24 April 1982