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Impact of artificial light on the distribution of the common European glow-worm, *Lampyris noctiluca* (Coleoptera: Lampyridae)

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ABSTRACT The influence of artificial light on fireflies is often discussed. Specialists agree that the normal mating behaviour of fireflies is disturbed by artificial night lighting. The effects of artificial light on the behaviour of the common European glow-worm, *Lampyris noctiluca*, are not well understood. Males of *L. noctiluca*, which can fly but do not glow, are attracted to glowing, flightless, larviform adult females, and are easily caught by simple light-emitting diode (LED) traps. LED traps were placed in illuminated and dark areas (under and between street lights, respectively) in a residential quarter of the village of Biberstein in Switzerland. On nights when the street lights were on, the LED traps attracted males only in dark places, while traps under the street lights stayed empty. In contrast, on nights when the street lights were switched off, males were trapped both between and under the lights. This indicates that artificial night light interferes with the ability of males to locate females, or that males avoid illuminated areas. Night lighting, however, had no apparent influence on the spatial distribution of glowing females during the last six summers (2004–2009). Females displayed both under the lamps and in the dark areas bordering the path surveyed. As females normally do not move from their display sites, those displaying under street lamps may die without mating. Artificial night lighting may, therefore, cut 'cheese holes' in the mating landscape of glow-worms.

Keywords: Artificial light, light pollution, mating behaviour, glow-worm, *Lampyris noctiluca*

INTRODUCTION

Artificial night light, which has become common in populated areas, may have negative impacts on fireflies. The mating activity of fireflies that are active at twilight is triggered by diminishing light intensity and can be delayed by artificial light, which may also decrease the efficiency of firefly bioluminescent emissions as mating signals (Lloyd 2006). Firefly specialists agree that light pollution may be one

of the reasons for a decline in firefly populations around the world, but few studies are available to support this hypothesis. A laboratory study of *Luciola aquatilis* in Thailand noted that artificial light conditions prolonged courtship and dorsal mounting behavior, thus lengthening mating time (Thancharoen et al. 2009). No field studies have been published on the influence of artificial light on firefly behaviour.

The common European glowworm, *Lampyris noctiluca*, which is the subject of this study, is a widespread species with a range extending from Portugal and Britain in the west, across Europe and Asia to China in the east (Tyler 2002). During summertime in Switzerland, and especially in June and July, the flightless larviform adult females begin to glow soon after dusk. They often display on low vegetation in open spaces, for example along waysides, forest edges and grasslands. With their bioluminescent signal, the females attract males, which fly in obstacle-free zones in search of a mate (Ineichen 2004). Soon after mating, females stop glowing. The same individual females of *L. noctiluca* have been found glowing night after night under street lamps and in other illuminated sites for up to 17 nights (Ursula Moor, pers. comm. in 2009). The objective of this study was to determine the effect of artificial night light on the ability *L. noctiluca* females to attract males, using simulated female glows emitted by LED (light-emitting diode) traps.

Figure 1 Map of the residential area in Biberstein, Switzerland where *Lampyris noctiluca* was sampled. LED traps targeting males were placed along 210 m of a pedestrian lane illuminated at night with street lamps. Yellow spots mark each trap. Red circles show the locations of lamps. A small creek (not visible in the map) flows on the right side of the lane and empties into a pond indicated by the white arrow. The red box marks the area where the distribution of females was examined in 2007.

METHODS

The study was conducted along a 210 m section of a pedestrian lane (midpoint of lane 47°24'59"N, 8°05'07"E; Fig. 1) flanked by a creek, in the residential quarter of the village of Biberstein in Switzerland. Vegetation bordering the path largely comprised grasses and small shrubs in a more or less open space.

The positioning of five high pressure sodium street lamps along the lane resulted in alternating illuminated and dark areas beneath and between the lamps, respectively, which were used to investigate the effects of illuminance on the glow-worm. Male glow-worms were sampled using LED traps on 14 fair-weather nights between 14 June and 7 July 2010. For three of the sampling nights (28 June, 1 and 4 July), the street lamps were switched off. The LED traps, which are designed to simulate female glow behavior, have been established to be an effective method of sampling *L. noctiluca* males (Ineichen 2004; J. Tyler, pers. comm. in 2007). One LED trap was placed beneath each of the five street lamps (five illuminated areas), between the street lamps and at both ends of the lane (six dark areas) as shown in Fig. 2. The traps were operated between 10.00–11.15 pm, at the end of civil twilight, which occurred between 10.06–10.09 pm during the study period (sunsets took place between 9.26–9.29 pm). Trapped males were collected and put in a box and released at the end of each nightly sample. Illuminance at each trap site was measured using a luxmeter (Voltacraft® MS-1300).

Figure 2 A LED trap (lower left) in an illuminated area beneath a street lamp. Another trap (not visible) is placed in the dark area between this and the next street lamp in the distance.

The mean number of males caught per night was calculated for each trap, from the total catch over the 11 days when the lamps were turned on and, separately, for the three days when the lamps were switched off. Means per trap were standardised for differences between periods when lamps were on and periods when lamps were off by dividing them by the overall mean for all traps when lamps were on and off, respectively. Differences between standardised mean catches on lit and unlit nights were compared within traps placed under and between street lamps, and were tested for significance using paired t-tests. The results were examined in relation to the spatial distribution of glowing females in this area in 2007, using data provided by Ursula Moor.

RESULTS

A total of 73 males were trapped throughout the 11 nights with illumination and all were exclusively in the dark areas (between lamps). Sampling on the three nights with no illumination yielded 58 males in total from traps both under and between lamps. One third of the combined total for all nights were captured between 10.30–10.45 pm. Standardised mean catches under lamps on lit and unlit nights differed significantly (paired t-test, $T = -0.56$, $P = 0.005$), with all catches occurring only on unlit nights (Fig. 3). In non-illuminated areas between lamps, standardised mean catches on lit and unlit nights were also significantly different (paired t-test, $T = 5.14$, $P < 0.005$), with catches on lit nights exceeding catches on unlit nights (Fig. 3). On lit nights, illuminance beneath street lamps ranged from 46–64 lux, and at dark areas measured between 0.1–0.4 lux. During the three nights with no illumination, maximum illuminance was 0.4 lux.

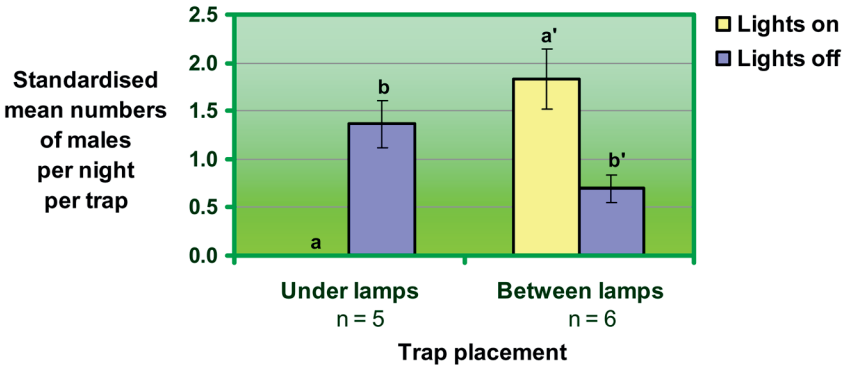

Figure 3 Standardised mean numbers (± S.E.) of *L. noctiluca* males captured per night per trap under and between street lamps when lamps were switched on or switched off. Means with the same letter within trap placement categories were not significantly different (paired t-test, $P \leq 0.005$).

Records of the distribution of females in that area in 2007 (data courtesy of Ursula Moor) revealed some clustering around the pond and along some stretches of the path next to the stream (Fig. 4). However this clustering appeared independent of the street lamps, i.e., females were just as often found displaying near street lamps as in the dark areas between lamps. Further, in our own study, we counted a total of 31 females displaying within 5 m of the street lamps and 76 females in the dark areas outside the 5 m radius of the cones of light, although actual numbers in dark areas may be higher than what was counted because females stop glowing soon after mating, which in dark areas could take place earlier.

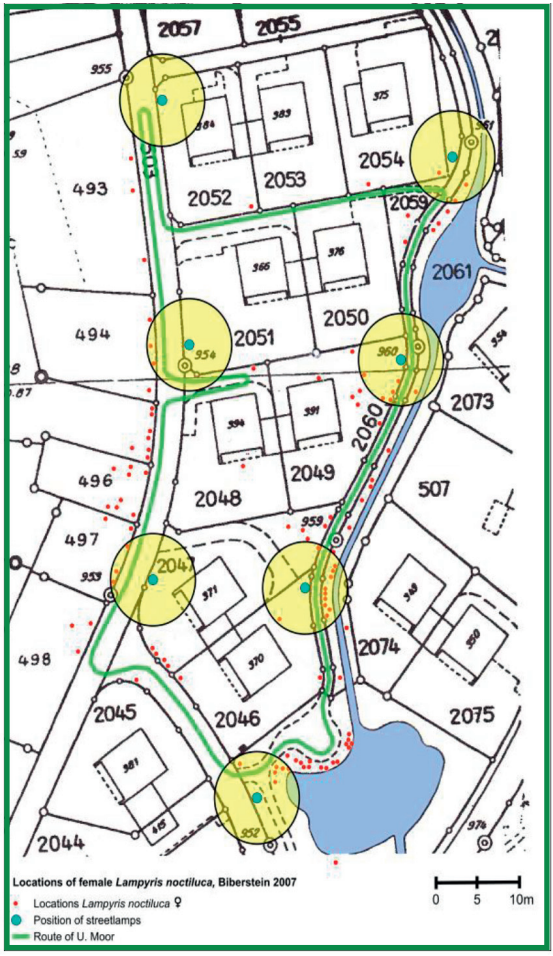

Figure 4 Distribution of *L. noctiluca* females along the streets and pedestrian pathway of a residential area of Birbenstein, Switzerland in the summer of 2007. Distribution map kindly provided by Ursula Moor.

DISCUSSION

The results clearly indicate that artificial night light interferes with the ability of *L. noctiluca* males to locate females, or that the males avoid illuminated areas. This is evident from the absence of any males in traps under lamps but their presence between lamps on nights when the lamps were switched on, which contrasted sharply with their presence in traps both under and between lamps on nights when the lamps were switched off. Within the cones of light produced by the lamps, illuminance was as much as 550 times greater than in areas only a few meters away.

The high number of females displaying in illuminated areas suggests that female glow-worms do not base their selection of display sites on whether or not that area

is artificially illuminated at night. In their final instar, they select their pupating and displaying sites during the day, preferring vegetation that borders on open spaces (personal observations). The vegetation provides refuge in the day and a perch from which they can display and attract males after dusk. However, as adult females rarely move from their original selected site (Ursula Moor, pers. comm.), it is likely that females displaying beneath street lamps die without having mated.

Artificial night light is, therefore, anticipated to carve "cheese holes" in the mating landscape of glow-worms. Whether these sinks where females die under street lamps without mating endanger the local population remains to be seen and warrants further study. Although in some areas artificial night light may lead to the extinction of common glow-worms, in the well-planned residential quarter of Biberstein the population of *L. noctiluca* does not appear to be negatively affected at this time.

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