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How many bioluminescent insects would be needed to produce the same level of light pollution as London?

Sophie Willett
The Centre for Interdisciplinary Science, University of Leicester
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Abstract
This paper determines how many light emitting *Pyrophorus noctilucus* would be required to produce the same level of light, and so the same amount of light pollution, as London. It was determined that if one *P. noctilucos* emitted 0.00153 lumens, it would take 2.940×10^{11} of them to produce the 449×10^{6} lumen emitted by London. This number of bugs equates to an area of approximately 1.911×10^{8} m^2 which is 8 times smaller than the size of London.

Introduction
Light pollution is the veil visible over cities and towns due to outdoor night-time lighting. The atmosphere causes light from urban areas to scatter and produce the distinct halo of light which is commonly visible even from great distances [1]. The scattering occurs from the ground light interacting with aerosols and other molecules within the atmosphere. Light pollution affects the ability for astronomers to observe the sky, with light from distant objects in space, such as the glow of a galaxy, lost in the glare of the cities sky [1]. Today, the city with the largest brightness and producing the largest light pollution within the UK is London.

The production of light causing light pollution is solely man-made. In nature, bioluminescence is a key mechanism for many species to survive, whether that be for protection or mating. The brightest of the luminous organism on Earth is the *Pyrophorus noctilucus* [2]. Unlike common belief, this is not a firefly but a species of click beetle. The calculations done in this paper have assumed the two luminous organs of the *P. noctilucus* are circular, emitting uniformly and constantly, and the insect itself being modelled as a rectangle.

Theory and application
As a city, London was recorded to have a total brightness of 449 million lumens by the Suomi NPP and DMSP satellites [3]. This is almost 4 times that emitted by Northern Island alone and a sixth of the total brightness of the UK. It should be recognised that there is discrepancy in brightness values between the satellite recorded value and absolute value due to factors such as atmospheric scattering and satellite orbital distance.

It can be determined as to whether *P. noctilucus* could replicate the measured brightness by comparing the brightness of the light they themselves are able to emit. *P. noctilucus* can vary the brightness of their light, unlike fireflies who flash on and off as a signal. The *P. noctilucus* has two prothoracic light organs on their backs, each almost circular in size, the largest measured had a diameter of 0.147 cm [2]. For this paper, it is assumed the largest of these insects are used, the area of these organs is 0.01697 cm^2 and light only emitting vertically. This was calculated using equation 1:

$$Area = \pi r^2 \qquad (1)$$

One organ has a brightness of 0.045 lumen cm^{-2} [2]. This means that one *P. noctilucus*, with its two organs, has a brightness of 1.527×10^{-3} lumen:

$$Brightness\ (1\ organ) = 0.045\ lumen\ cm^{-2} \times 0.01697\ cm^2 = 7.637 \times 10^{-4}\ lumen \qquad (2)$$

$$Brightness\ (2\ organs) = 1.527 \times 10^{-3}\ lumen \qquad (3)$$

$$\frac{London\ brightness}{cucuyo\ brightness} = number\ of\ P.noctilucus\ required \quad (4)$$

$$\frac{449 \times 10^{6}\ lumen}{2(7.6373 \times 10^{-4})\ lumen} = 2.940 \times 10^{11} \quad (5)$$

Therefore, the number of *P. noctilucus* it would take to produce the same amount of light emitted by London would be 2.940×10^{11}.

This is a staggering number of insects required. The *P. noctilucus* can vary in size however a common length is 4.4 cm [4]. From analysing photographs, it has been determined that the width is approximately a third of the *P.noctilucus'* length. Hence, one *P. noctilucus* has a body area of 6.5×10^{-4} m^2. Multiplying this by the number of *P. noctilucus* needed to replicate the brightness of London, the size of this group is equal to 1.911×10^{8} m^2 or 191.1 km^2.

This can be compared to sizes of cities. Leicester city is approximately 7.33×10^{7}m^2 in size, meaning the Leicester would fit within the area of *P. noctilucus* at least twice [5]. London as a city is approximately 1.572×10^{9}m^2 and so is significantly greater than the area of *P. Noctilucus* [6].

Conclusion

To conclude, this paper used measurements and statistical data to determine the luminosity of the *P. noctilucus*, giving 1.527×10^{-3} lumen for each insect. Although it would take 2.940×10^{11} individual *P. noctilucus* to recreate the brightness of London and produce the same amount of light pollution, this would only require the area approximately 8 times smaller than the size of the city itself. It should be noted that a lot of the values used are averages from the small amount of information available on this species and the assumption that there is little difference between true and measured brightness of London is made. Therefore, there is definite room for error when solving this hypothetical question.

References

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