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Lunar illuminated fraction is a poor proxy for moonlight exposure

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Introduction

San-Jose et al. recently demonstrated that the colouration of barn owls impacts their hunting success under moonlit conditions, and therefore affects their reproductive success[1]. They found that near full moon conditions, the youngest nestlings with white fathers were fed more and were likelier to survive than those with redder fathers. While the study is interesting, the percentage of the moon that is illuminated (lunar illuminated fraction) is unfortunately a poor proxy for moonlight exposure. We suggest lunar illluminated fraction should in general never be used in biological studies, as alternative variables such as horizontal illuminance better represent moonlight exposure, and therefore offer a greater chance of detecting effects of moonlight. Here, we provide a brief explanation of how moonlight varies with season and time of night, and stress the need for greater collaboration between biologists and astronomers or physicists in such studies in the future.

Due to the moon's rotation around the Earth, it rises later each night than it did the night before. This means that for most nights each month, the moon is not in the sky for the entire night. When the moon is in the sky, the amount of light it provides depends strongly on how high it has risen (Table 1). Figure 1 shows how different moonlight exposure can be on nights with similar illuminated fractions (~80% for both May 24 and June 3). The predicted horizontal illuminance (amount of light falling on a horizontal surface) [2] on the ground (bottom) for clear skies near the study area of San-Jose et al. is higher on May 24, because the waxing spring moon rises higher in the sky than the waning moon (top). The timing of maximal moonlight also shifts before and after the full moon.

Lunar illuminated fraction has been used in other studies that also would have benefited from a more complete picture of moonlight. For example, Fallows et al. examined attempts of white sharks to capture seals at sunrise on "full moon" (>90% illuminated) and "new moon" nights [3]. This implies they grouped days in which the moon had already set into their "full moon" dataset. York et al. examined the time at which birds started singing relative to the end of nautical twilight. They found it was earlier when the moon was above the horizon and at least 65% full [4], but their results may have been stronger had they used an illumination model. As a final example, Portugal et al. recently showed that the body temperature of wild barnacle geese was higher on clear moonlit nights when the moon was closer than normal to Earth [5]. However, if the cause of the physiological change is exposure to moonlight, then differences in elevation angle and total time in the sky during night should have an even stronger effect than the relative size of the moon.

Unfortunately, even horizontal illuminance may not be the right parameter for understanding the impact of moonlight on animal physiology and behaviour[6]. For example, an owl attacking with the moon at its back may be nearly invisible to its prey, whereas owls flying into moonlight will appear brightest to prey. In the laboratory experiment of San-Jose et al., simulated moonlight came from the side. However, they did not report in which direction they oriented their luxmeter. Their value of simulated moonlight (250 mlux) is far brighter than the horizontal illuminance typically experienced in Switzerland [7], but may be reasonable for vertical illuminance when the full moon is closer to the horizon (note that San-Jose told us by email after publication that they measured vertical illuminance, meaning their setup was on the bright side, but not unreasonable). Furthermore, the undefined simulated new moon condition of <1 mlux does not provide sufficient information for replication, and is likely below outdoor exposures due to starlight, airglow, and light pollution in open settings [8, 9]. We hope this discussion motivates those conducting future lab experiments simulating moonlight to engage in collaboration with physicists or astronomers, both in designing the setup, and later in writing the methods, in order to ensure replication is possible.

We realise that otherwise highly trained biologists and ecologists may not be versed in astronomy, nor have knowledge of how lunar cycles operate. This letter is therefore not meant primarily to criticise San-Jose et al., whose work we find “illuminating”. Rather, our hope is that this letter will encourage biologists to consider more than just the phase of the moon in future studies. It would clearly be beneficial if the open source community were to further develop a web application or R or Python script to produce lunar illumination tables (in the meantime researchers who need lunar illumination tables are welcome to contact us). We also recommend that when doing experiments involving nighttime light levels and exposures, biologists collaborate with astronomers or others with relevant physical expertise.

References

[1] San-Jose, L. M. *et al.* Differential fitness effects of moonlight on plumage colour morphs in barn owls. *Nat Ecol Evol* **3**, 1331–1340 (2019).

[2] Janiczek, P. & DeYoung, J. A. Computer programs for sun and moon illuminance with contingent tables and diagrams. Tech. Rep., Naval Observatory Washington DC (1987).

[3] Fallows, C., Fallows, M. & Hammerschlag, N. Effects of lunar phase on predator-prey interactions between white shark (carcharodon carcharias) and cape fur seals (arctocephalus pusillus pusillus). *Environ Biol Fish* **99**, 805–812, 10.1007/s10641-016-0515-8 (2016).

[4] York, J. E., Young, A. J. & Radford, A. N. Singing in the moonlight: dawn song performance of a diurnal bird varies with lunar phase. *Biol Lett* **10**, 20130970 (2014).

[5] Portugal, S. J., White, C. R., Frappell, P. B., Green, J. A. & Butler, P. J. Impacts of "supermoon" events on the physiology of a wild bird. *Ecol Evol* (2019).
[6] Jechow, A., Kyba, C. & Hölker, F. Beyond all-sky: Assessing ecological light pollution using multi-spectral full-sphere fisheye lens imaging. *J Imaging* **5**, 46 (2019).
[7] Kyba, C., Mohar, A. & Posch, T. How bright is moonlight? *Astron Geophys* **58**, 31–32 (2017).
[8] Hänel, A. *et al.* Measuring night sky brightness: methods and challenges. *J Quant Spectrosc Ra* (2017).
[9] Falchi, F. *et al.* The new world atlas of artificial night sky brightness. *Sci Adv* **2**, e1600377 (2016).

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Author contributions statement

C.C.M.K. produced the figure and wrote the first draft, J.C. developed the sky brightness model and edited the manuscript, T.S. ran the model and edited the manuscript.

Additional information

Competing interests The author(s) declare no competing interests.

Phase	Rise	Max	Set	Highest	Lowest
New	06:00	12:00	18:00	Summer	Winter
1st quarter	12:00	18:00	00:00	Spring	Fall
Full	18:00	00:00	06:00	Fall	Summer
3rd quarter	00:00	06:00	12:00	Winter	Spring

Table 1: A mnemonic table for approximate times at which the moon rises, sets, and reaches maximum elevation in the sky. Also shown is how the elevation of the moons varies throughout the seasons.

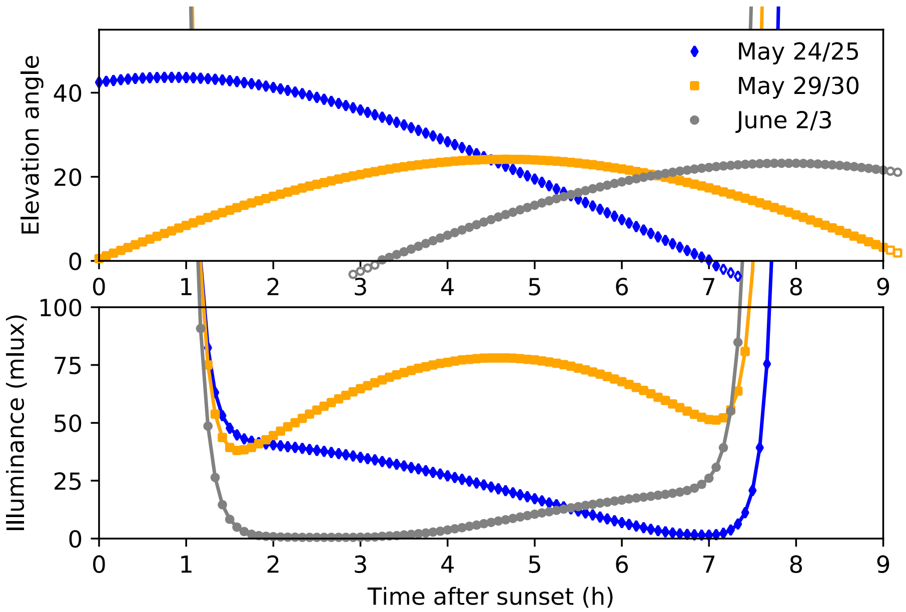

Figure 1: Height of the moon in the sky (top) and model estimated horizontal illuminance of moonlight (bottom) for three different nights in 2018. The moon was 79% illuminated at midnight on May 25, 100% illuminated on May 30, and 83% illuminated on June 3.