Shedding Light on Campus: Improving Student Safety and Energy Efficiency through Light Pollution Analysis

Kaitlyn Briggs, Hibah Ganie, Owen Crosby, Arianna Huang, and Dr. Lisa Stratton

Introduction

- Previous work conducted by UCSB students, Lux Ray and Justin Park, highlighted the negative impact that lights can have on wildlife in natural areas around UCSB.
- This study continues that work, but focuses on how excessive light negatively impacts humans through reduced safety due to glare, disturbances in circadian rhythms, and diminished opportunities for stargazing.
- Our circadian rhythm is impacted by exposure to lights during the night, which impedes on our natural sleep cycle.[5] Lower academic performance is associated with disrupted sleep and light exposure.[8]
- Light glare reduces visibility of surrounding areas and objects, which decreases safety.[4,6] There have been many cases of excessive lights increasing crime as victims cannot see criminals in the shadows (Fig. 10).
- Lights without covers, such as "Johnny Balls" contribute to light pollution and reduce visibility of the night sky.[1] Shields can reduce light pollution, light trespass, over illumination, and glare for students in their residence and during night-time campus activity.
- LEDs use significantly less energy than incandescent bulbs, resulting in LEDs lowering electricity costs. The duration of LEDs outlives incandescents along with customizable color temperature to emit warmer light and reduce physiological effects on our circadian rhythm.[2]

Methods

- Identified problematic lights around 12 campus residential areas and took field measurements of light intensity and color temperature. Visual examples of problematic lights shown in Figures 1 & 2.
- Generated an ArcGIS Online map to visualize color temperature gradient measured by kelvin and the amount of light overlap measured by lux intensity. Buffers were used to find the amount of light overlap.
- Quantified sky light pollution with the Unihedron Sky Quality Meter at 6 zones around residential and natural area zones mapped out in ArcGIS Online.
- Created 6 versions of attention-grabbing info flyers with a QR code for a student engagement survey about specific problematic lighting around their residences. Flyers were posted around campus, displayed on digital screens in residential lobbies and dining commons, and sent out through residential email list servers
- Calculated average annual cost of outdoor lighting with provided estimates of the quantity of 3 main light types on campus and a rate of $0.15 per kilowatt-hour.
- Utilized cut sheets sourced from UCSB's Long Range Development Plan to assess different types of shields that could be used to reduce light trespass into residential rooms and into the night sky.

Figure 1. Campus Standard with glare and shining into dorm rooms

Figure 2. Campus Standard taped by students to block light shining into dorm windows.

Results

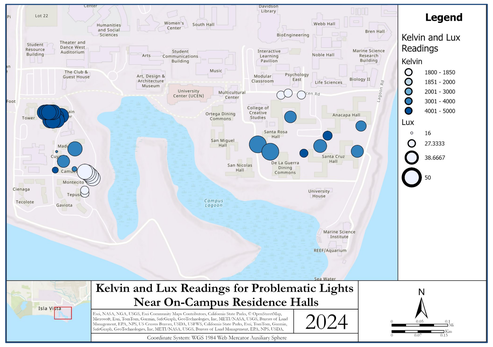

Figure 3. Lights with values higher than 4000K are problematic due to impact on circadian rhythm. Lights with lux (brightness) values that overlap with a neighbor light are problematic as that indicates excessive light intensity.

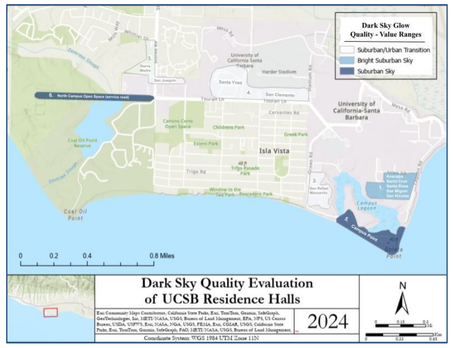

Figure 4. ArcGIS Map depicts the dark sky quality readings for 6 zones around campus. Darker colors indicate a darker sky, while light colors indicate higher rate of light pollution.

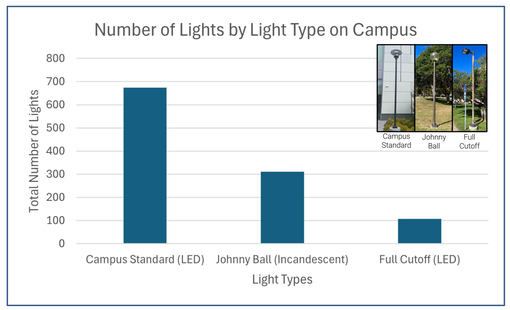

Figure 5. Bar graph shows the number of 3 main light fixtures on campus, categorized into LED or incandescent bulbs. There are more than double the amount of Campus Standards as Johnny Balls.

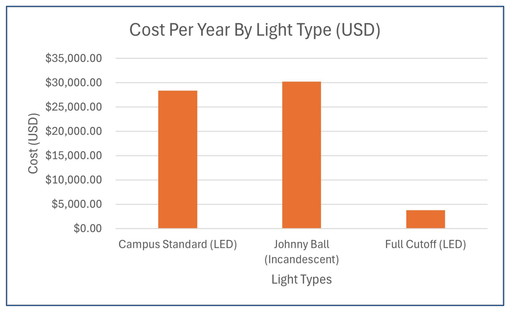

Figure 6. Bar graph shows the total cost per year in USD for each light type. Total cost is proportional to overall energy use by wattage for LED or incandescent and the rate of $0.15 per kilowatt-hour.

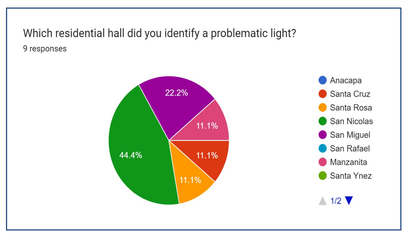

Figure 7. Pie chart showing the proportion of which residential halls the students are reporting on the survey. (n = 9 responses)

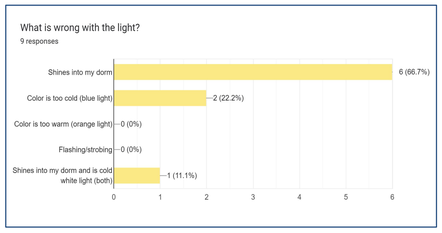

Figure 8. Bar graph showing proportion of survey answers for what is wrong with the light. (n = 9 responses)

There were **35 problematic lights** measured by the team around the residential areas of campus with upwards of 35 identified as being problematic for factors not limited to kelvin and lux values. Our findings reveal 14 of the 35 measured lights were **greater than 4000K** and 18 of the 35 measured lights had lux values that resulted in **excessive light overlap** (Fig. 3).

For the Dark Sky Quality results, zone 1 was classified as a **bright suburban sky**; zone 2, 3, 4 were classified as **suburban/urban transition**; zone 5 & 6 were classified as **suburban sky** (Fig. 4). At zones 5 and 6, only **hints of zodiacal light** are seen on the best nights in autumn and spring[9]. Brighter zones 3 and 4 result in light pollution making the **entire sky light gray.**

The cost per year (USD) for individual fixtures was calculated at Campus Standard (65W): $42.09; Full Cutoff LED (55W): $35.62; Johnny Balls (150W): $97.13. The **total cost** for all 674 Campus Standards was **$28,369.17** and for all 107 Full Cuttoff LEDs was **$3,810.83,** while the 311 Johnny Balls cost **$30,208.21** per year (Fig. 5 & 6).

From the **6 versions of info flyers** distributed across campus from January and continuing today, there were **9 student responses** recorded within the first two months. There was a majority of reports from San Nicolas at 44.4% (Fig. 7) and the most frequently reported issue was the **light shining into the student's dorm** from 7 of 9 responses (Fig. 8).

Discussion

- Our field measurements and direct responses from student surveys show there is a sufficient amount of problematic lights that need to be addressed by the campus lighting staff to improve the health and safety of students in the residential halls.
- The Bortle Scale,[9] used to characterize dark skies, ranges from 22.0 (Excellent Dark Sky) to <18.0 (City Sky). Readings for heavily populated cities like Buenos Aires, Argentina were 16.09 (Inner City sky), while the NamibRand Nature Reserve in Namibia was 22.05 (excellent dark sky)[8]. UCSB's dark sky readings ranged higher, towards a intermediate-darker sky. Zones with excessive light pollution and minimal visibility of the night sky must be addressed with replacing or adding shields to fixtures that have vertical light trespass.
- LEDs cost less and last longer than incandescents and thus should be the preferred bulb. Switching incandescents to LEDs would save $17,117.98 per year.
- Aforementioned studies reveal increased lighting does not necessarily decrease crime as light glare can impede a victim's vision of objects in the shadows (Fig. 10).[4, 6]
- There were limited student responses to the survey, next steps would include more active, in-person engagement such as night tours or tabling outside the library to speak face-to-face and directly hear their concerns.
- Off-campus residential zones had full beam spread overlap, so single fixture measurements were not feasible. Future readings would focus overall light trespass into rooms rather than specific problematic fixtures.
- Our findings will be reported to the lighting staff to take our suggestions into consideration to reduce light pollution, increase campus safety, and improve student health and academic performance.
- We will recommend shields to campus lighting staff to be purchased and installed on all problematic lighting fixtures. We will identify unnecessary lights that could be removed to save energy costs and reduce light overlap.

Figure 9. Aerial view of campus light shining into the night sky. Top photo San Nicolas Slope. Bottom photo Manzanita Village. Photo credit Jeremiah Bender

Figure 10. Visual representation of light glare impeding vision. A person in the shadows of both pictures - top photo unable to see with glare; bottom photo visible by blocking the glare. Photo credit Ken Walczak

References

1. Chepesiuk, R. (2009). Missing the Dark: Health Effects of Light Pollution. *Environmental Health Perspectives*, *117*(1), A20–A27. https://doi.org/10.1289/ehp.117-a20
2. *Choose the right LED lighting*. (2024). Sustainability Victoria. https://www.sustainability.vic.gov.au/energy-efficiency-and-reducing-emissions/save-energy-in-the-home/
3. *DarkSky International*. (2024). DarkSky International. https://darksky.org/
4. DarkSky Staff. (2023). *Outdoor lighting at night doesn't do what you think it does to reduce crime and increase safety*. DarkSky International. https://darksky.org/resources/what-is-light-pollution/
5. Dumont, M., & Beaulieu, C. (2007). Light exposure in the natural environment: Relevance to mood and sleep disorders. *Sleep Medicine*, *8*(6), 557–565. https://doi.org/10.1016/j.sleep.2006.11.008
6. Kitsinelis, S., & Zissis, G. (2012). A Short Review on Lighting and Security. *Journal of Applied Security Research*, *7*(3), 341–353. https://doi.org/10.1080/19361610.2012.686096
7. *Maps & Data—Globe At Night*. (2023). https://globeatnight.org/maps-data/
8. Phillips, A. J. K., Clerx, W. M., O'Brien, C. S., Sano, A., Barger, L. K., Picard, R. W., Lockley, S. W., Klerman, E. B., & Czeisler, C. A. (2017). Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Scientific Reports*, *7*(1), 3216. https://doi.org/10.1038/s41598-017-03171-4
9. Unihedron Sky Quality Meter (2007) http://www.unihedron.com/projects/darksky/

Acknowledgements

This project was funded by The Green Initiative Fund. Many thanks to Dr. Lisa Stratton for guidance on this project. Thank you to Mark Rousseau and Jordan Sager for providing essential data for our work. A big thanks to our summer team, Lux Ray and Justin Park, for conducting foundational research that made this project possible. Thank you for support from the Cheadle Center for Biodiversity and Ecological Restoration at UCSB.