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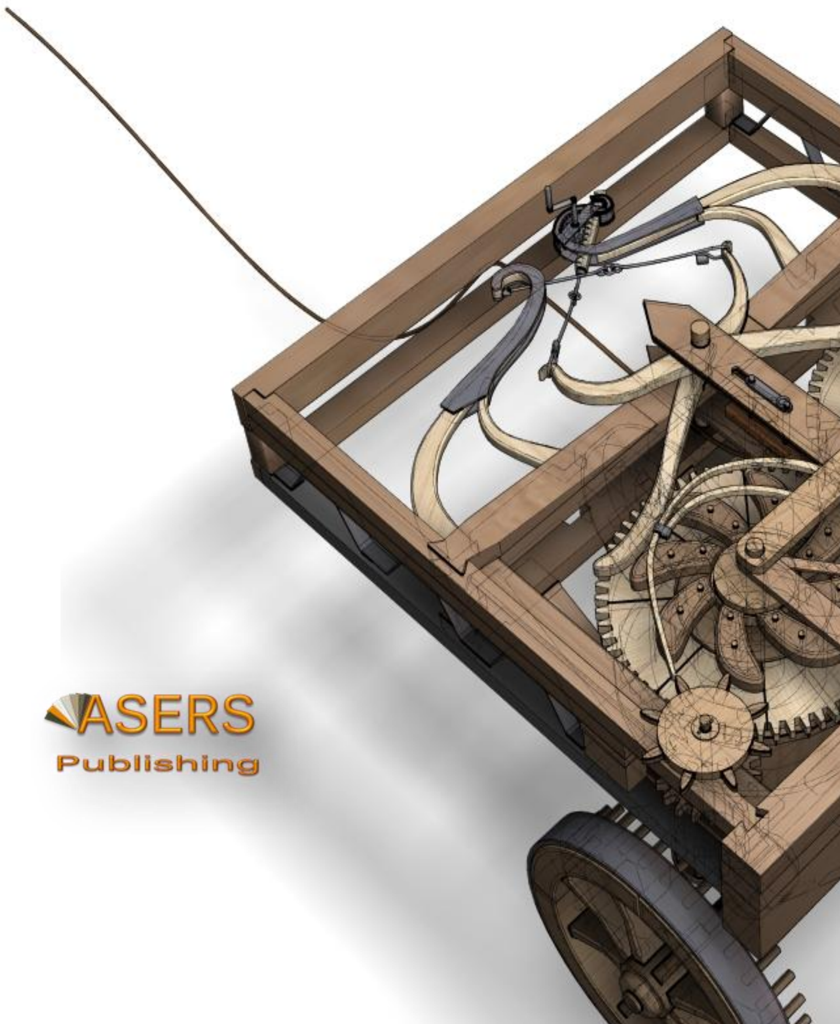

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Understanding Human Perception of Artificial Light at Night and Preferred Lighting Conditions in Parks and Protected Areas: A Pilot Study

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Abstract: Naturally dark environments are increasingly threatened by artificial light at night (ALAN), even in parks and protected areas (PPAs). This study explores visitor preferences for lighting spectra and intensity in front-country, PPA-like settings to better understand how to balance human lighting needs with the protection of ecological and cultural resources. An onsite survey was conducted at a university arboretum in the United States (n = 167). Participants were asked to select preferred lighting conditions (color and intensity) using bollard fixtures with adjustable amber and white LEDs. Statistical analyses examined spectra and intensity preferences as well as demographic influences (gender, youth environment, nighttime recreation experience). Results indicate a significant preference for amber light (67%) over white light (33%). On average, participants preferred amber light at lower intensities (2.87 lux) compared to white light (5.18 lux). Prior nighttime recreation experience was associated with lower preferred light intensity and stronger selection of amber light. Participants from rural and suburban backgrounds were more likely to choose amber, while urban-raised participants showed no clear preference and tended toward higher intensities when selecting white light. This pilot study is one of the first to experimentally examine visitor lighting preferences in relation to both spectra and intensity in a PPA-like setting. Findings challenge assumptions based on industry standards, which often recommend higher light levels, and provide context-sensitive guidance for PPA lighting management. The sample consisted largely of university students, limiting age diversity and generalizability. Future research across broader populations and within actual PPAs is needed to validate results. Findings suggest that lower-intensity amber lighting can meet visitor needs while minimizing ecological impacts, offering managers evidence-based strategies for sustainable lighting design in PPAs. By aligning visitor preferences with conservation goals, PPA managers can protect naturally dark skies while maintaining visitor safety and experience, supporting the rise of noctourism - nighttime recreation and tourism that values darkness as a resource - and reinforcing the cultural and ecological significance of darkness as a shared resource.

Keywords: artificial light at night; light pollution; parks; protected areas; visitor experience; visitor preference.

JEL Classification: Q52; Q56; Q57.

Introduction

Throughout human history, the stars of the night sky have been a muse for sonnets and songs, a foundation of religions and cultures, and a natural map guiding exploration. Yet, rising levels of artificial lighting have dulled the visibility and beauty of the night. Artificial light at night (ALAN) - such as streetlights, building illumination, and outdoor lighting - is a form of anthropogenic light that alters natural night light cycles (Klinkenborg, 2008). When nighttime lighting is excessive, misdirected, or spills into unintended areas, it becomes light pollution (Gallaway *et al.* 2010; Bennie *et al.* 2015). Common manifestations include skyglow, light trespass, and glare (Bullough *et al.* 2008). Light pollution continues to grow globally and increasingly encroaches upon natural and cultural resource areas, including national parks and wilderness areas (Kyba *et al.* 2023). Even within parks and protected areas (PPAs), lighting is often installed to facilitate nighttime visitor use for navigation and safety.

Light pollution poses risks for both ecological and experiential dimensions of PPAs. Many protected areas are particularly sensitive due to their ecological value and the opportunities they provide for solitude and stargazing - experiences that depend on natural darkness (Albers & Duriscoe, 2001; Duriscoe, 2001). High levels of ALAN near or within these areas threaten not only ecological systems but also cultural and aesthetic resources (Aubrecht *et al.* 2010). Plants and animals have evolved with consistent day–night cycles, often using light as a cue in critical life-history strategies such as reproduction, migration, and foraging (Seymoure *et al.* 2025; Moore *et al.* 2006; Sanders *et al.* 2021). Disruption of these cues through artificial illumination alters photoperiodism, phenology, and circadian rhythms (Longcore & Rich, 2004; Gaston *et al.* 2012; Crump *et al.* 2021; Cronin *et al.* 2014). Consequently, ALAN has widespread ecological effects (Bará & Falchi, 2023). However, lighting is also for people, serving important social functions of comfort, safety, and recreation. Understanding how humans perceive and value lighting in PPAs is essential for finding a balance between necessary illumination and conservation of natural nightscapes.

1. Research Background

1.1. Protected Areas and Human Experience

As urban and ex-urban growth boundaries continue to increase, managers of PPAs that are charged with protecting ecological and cultural resources, including the natural night environment and night sky, are becoming more concerned not only with resource protection but also visitor experiences at night (Beeco *et al.* 2011). Increasingly, artificial light is leading to the degradation of natural darkness and the quality of experiences for nighttime visitors to parks (Smith & Hallo, 2019). Correct to the following: Natural darkness is an important consideration for nature-based noctourism. Noctourism can be defined as nature-based tourism activities at night in which natural darkness is critical to the experience (Beeco et al., 2025). Dark sky tourism (a subcomponent of nature-based noctourism) is an important driver of visitation for people who are motivated to view dark, star-filled night skies (Kulesza *et al.* 2013; Mitchell & Gallaway, 2019), and nighttime recreation experiences are important to visitors' overall park experiences (Smith & Hallo, 2019). Nighttime recreation in PPAs provides unique and valuable experiences for visitors, and natural night sky conditions are essential qualities of wilderness (*i.e.*, untrammeled, natural, undeveloped opportunities for solitude) (Beeco *et al.* 2011; Beeco *et al.* 2015). Many parks also provide special programs focused on biological resources, such as fireflies and bat flight programs or events, where natural darkness is vital for both enhancing these experiences and preserving these natural resources (Henry *et al.* 2022). However, artificial light can detract from the visitor experience. That is perhaps why visitors report overwhelming support for management actions to protect night sky quality (Beeco *et al.* 2023). Of the seven different management actions presented to visitors at state and national parks in Utah, U.S. for protecting night sky quality, all seven management actions had over 75% support (Beeco *et al.* 2023).

The literature of human responses to lighting at night has many conflicting findings with respect to social constructs and preference; however, research findings specific to parks and protected areas are beginning to reveal a more consistent trend (Beeco *et al.* 2025). While earlier research on the visitor experience at night revealed that lighting could distract from a visitor's experience (Smith & Hallo, 2019), this finding was generally broad, and little is known specifically about lighting's impacts on people. Recent experimental light manipulation studies have found that light pollution can negatively impact mood, arousal, and scenic evaluations (Benfield *et al.* 2018). Some studies have found lightscapes to have no impact on perceptions of safety (Smith & Hallo, 2019; Benfield *et al.* 2018; Calleri *et al.* 2019). Little is known about the lighting characteristics (*i.e.*, spectra and intensity) that would be considered acceptable to nighttime visitors in PPAs. Fristrup *et al.* (2024) determined that visitors in Grand Teton National Park assessed red lighting as more protective of the environment and expressed higher ratings for visual comfort and safety. Brightness, spectra, and fixture type are three critical elements of lighting design to consider. Regarding light brightness, previous research in urban settings has explored the effects of light fixture intensity on participants, finding that participants preferred lower intensity, warm white fixtures to higher intensity, neutral white fixtures (Davidovic *et al.* 2019). Additionally, in urban setting, Lis *et al.* (2024) found that evenly lit spaces are preferred in nighttime green space environments. In terms of light spectra, the amount of light pollution emitted by light fixtures is related, in part, to the spectral characteristics of lamps (Falchi *et al.* 2011). Falchi (2011) found lamps with high blue content had a significant impact on human health and visual perception (Falchi *et al.* 2011). Spectral composition of lighting type and characteristics of lighting can inform the conversion of current lighting infrastructure to be more efficient in parks and other natural areas (Davidovic *et al.* 2019; Elvidge *et al.* 2010).

1.2. A Sister Study

The study reported in this manuscript is part of a larger study and master's thesis (Crump, 2023). The findings in two other published analysis are worth highlighting here. The first paper used the same sample and lighting fixture type, though different methodology. Overall, there were seven light stations installed along grass-field edge habitats and trailed forest areas in a university that managed arboretum. The first six stations were used in prior analysis (Himschoot *et al.* 2024) and deployed in a random rotating configuration of two different light colors, warm white (3000K Correlated Color Temperature (CCT)) and amber (695 nm direct amber), and with varying intensities. Eight experimental lighting conditions were used: amber 0.5 lux, amber 1.0 lux, amber 5.0 lux, amber 10.0 lux, warm white 0.5 lux, warm white 1.0 lux, warm white 5.0 lux, and warm white 10.0 lux. A survey was conducted at each light station which included feelings about the light condition, and a series of tasks designed to explore participant's ability to perceive their environment was also undertaken. Himschoot *et al.* (2024) found that study participants were 36% more likely to report greater feelings of safety in warm white light than amber light and 82% more likely to report greater feelings of safety at intensity levels 5 lux or higher.

The second study used three different samples, including Grand Teton National Park, Acadia National Park, and the arboretum data we used here (Beeco *et al.* 2025). The study found that visitors to protected areas are generally willing to sacrifice human preference and feelings of safety for more conservation focused lighting. However, the findings were not as strong for the arboretum sample as compared to the two national park samples.

In the analysis presented in this study, only Station 7 data are analyzed. While more details are presented below in the Material and Methods section, generally, at Station 7 visitors were asked to select which light color and level of light they preferred based upon the question "Imagine that you are tasked with selecting lighting that strikes a balance of conditions that are good for both humans and wildlife. What would be the most ideal nighttime lighting condition?" Asking participants to "strike the balance" is a much different question than simply asking for a preference or feelings of safety.

1.3. Study Purpose and Research Questions

There is a precedent for providing light at night in human occupied spaces including developed areas of PPAs, but it remains unknown about what amount and color of light is necessary in these spaces (Smith & Hallo, 2019). With the rise of LED technology, ALAN use has increased per capita, however, this technology is easily controllable, thus able to be retrofitted to have a lower lighting impact on the environment. Industry standards addressing outdoor lighting are generally developed for the built environment providing prescriptive illuminance recommendations based on application, level of use, and assumed ambient background conditions. These areas likely do not share environmental context or missions similar to PPAs for protecting natural and cultural resources including the night sky, therefore may not be appropriately applied to PPAs. Further, contrast is an important factor in lighting design, and PPAs are likely to have darker ambient conditions which may allow lower levels of light for necessary contrast. There is currently no standard level of light that is required in PPAs, and work is needed that can act as a guide for determining context sensitive light levels in PPAs. It is important to understand ALAN lighting preferences for those who visit PPAs at night to make acceptable and necessary changes in lighting infrastructure as well as educate the public (by example and education programing) about the importance of proper outdooring lighting. Policy and management of nighttime lighting conditions should maximize the benefits of artificial lighting while limiting the costs (Gaston *et al.* 2015), and upgrades to the lighting systems used by PPAs can help meet the agencies' mandates to protect naturally dark skies and the night environment as a social and ecological resource.

This study sought to advance understanding of outdoor lighting preferences in relation to spectra and intensity in a PPA setting by addressing the following research questions: (1) What spectra of light do participants prefer in the context of creating the most ideal nighttime lighting condition? (2) What intensity of light do participants prefer in the context of creating the most ideal nighttime lighting condition? (3) Do any demographic characteristics (*i.e.*, gender, youth environment, previous nighttime outdoor recreation experience) influence lighting preference?

2. Methods

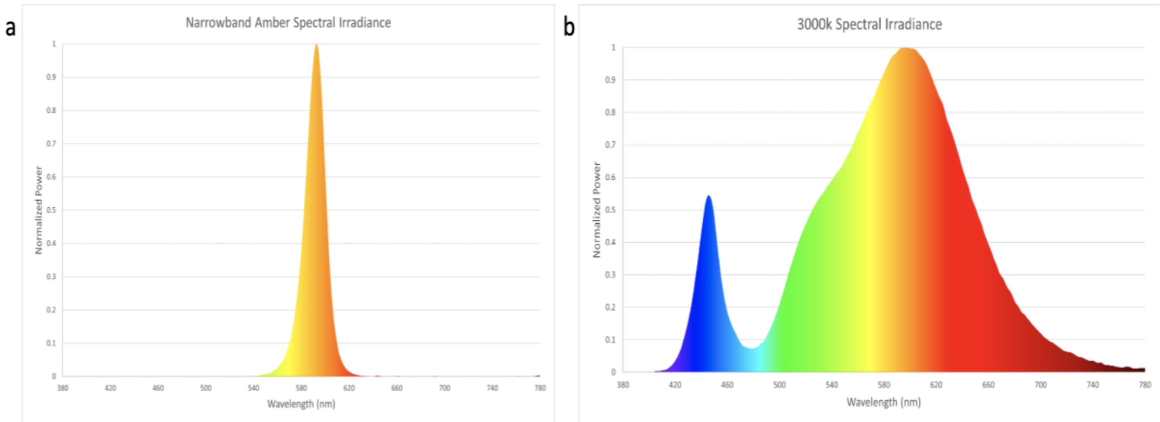
This study took place at an arboretum (Figure 1) of a large rural university in Pennsylvania, U.S. in the fall of 2021, spring of 2022, and fall of 2022. While this arboretum is a more developed setting than some PPAs, the rural nature of the university makes the quality of the night sky and the amount of light pollution visible at night from the study site comparable to many PPAs. The arboretum covers 340 acres of land, including fields and woodlands that are used for research and recreation. This study location is also similar to front country areas in iconic U.S. PPA settings, as well as other NPS units such as national arboreta, historic sites, and urban-facing park units, where visitor experiences often involve a blend of natural and developed landscapes. This study site allowed for two primary advantages over conducting the study on state or federal lands. First, the sample of university students is more diverse across most demographic categories than visitors to PPAs, excepting age which skews lower. This sample also allows generalizing to certain demographics of non-PPAs users, something that survey work on state and federal lands lacks. Second, the experimental design took significant time for participants to complete (approximately 40 minutes). A study this long would likely place an unreasonable burden upon recreationists in a PPA.

Figure 1. Map of the study site and lighting stations

2.1 Lighting Design

A pathway lighting fixture that would be suitable for PPAs was selected for this experiment. Pathway lighting is a prevalent application across PPAs which provide visitor access at night, thus bollards, short pole lighting fixtures, were selected to meet these needs. In an effort to protect the natural night as a social, cultural, and ecological resource across protected areas several criteria were used to select an appropriate bollard. These criteria included fixtures producing zero-uplight, controlled light distribution with backlight control, dimming controls, and both broadband and narrowband color options. The Kim Pavilion™ bollard met each of these criteria with options that produced no uplight, used Type 3 light distribution with no backlight via an optional house side shield, used dimmable LED drivers, and provided 3000K Correlated Color Temperature (CCT) and 695 nm direct amber LED engines (Figure 2). We selected the 14-watt 3000k LED engine and 22-watt direct amber engine for the experiment. The higher wattage of the direct amber bollard was necessary to ensure both light engines could produce a near-equal light output range as perceived by a photopic adapted observer.

Figure 2. Spectral profiles for the **a.** 695 nm direct amber LED engines and **b.** 3000K



Each bollard was fitted with a custom dimmer and voltage meter display allowing survey participants to control light output in the field, and researchers to record voltage. Light output was measured in average horizontal illuminance in lux (lx), the SI unit for illuminance and the standard metric for pathway lighting design. It should be noted that the term "intensity" is used in the survey instrument to ensure participants understood what they were selecting. Average lux was calculated using an evenly spaced grid of illuminance measurements across a 20 ft. x 10 ft. space representative of the expected area of illumination for a light along a pathway. All measurements were made with a Konika-Minolta T-10a illuminance meter. Prior to deployment we measured average illuminance and voltage output across a range of dimmer settings, and during the Himschoot *et al.* (2024) survey we collected illuminance and voltage measures, allowing us to derive average illuminance from user inputs in the field based on the reported voltage output during the experiment (see equations 1 and 2 in section 2.5 Field Design). While the Himschoot *et al.* (2024) study used matched preset lux levels for each color treatment, this study allowed users to set intensity using a continuous dial, based on preference. Due to the higher efficacy of the 3000K light engine, the maximum selectable intensity of this bollard was higher than direct amber.

2.2 Field Design

Seven individual lighting stations were installed in both the edge habitat and in the trailed segments of the forest in the Arboretum (Figure 1). Participants were guided by a researcher through the first six stations in groups before individually completing Station 7. This analysis focuses only on Station 7.

At Station 7, participants were asked to identify the spectra (amber or white) of light and level of intensity they preferred in a specific context. Participants were posed the following question: "Imagine that you are tasked with selecting lighting that strikes a balance of conditions that are good for both humans and wildlife. What would be the most ideal nighttime lighting condition?". Participants were instructed to select which spectra and intensity they preferred on a bollard lighting fixture (see below for details). Participants completed lighting selection at Station 7 individually (rather than in a group) to eliminate potential bias from viewing other participants' selections.

2.3 Survey Methods

The survey data was collected using convenience sampling. Recruitment flyers for the study were distributed to general education courses in multiple departments, including but not limited to Recreation, Park and Tourism Management; Geography; Education; English, and Wildlife and Fisheries Science. Faculty and staff distributed the recruitment flyers via email and class announcements. A survey was developed in Qualtrics for quantitative data collection using tablet computers.

The survey activities and instruments were divided into two primary sections. This paper focuses only on Section Two of the study. Section One of the surveys focused on participants' ability to navigate and complete tasks at a set of six specially designed activity stations that tested their perception of light. Results of Section One can be found in Himschoot et al (2024). After completing Section One, Section Two of the survey collected information about participants' preferences of light color and intensity, participant demographics, and participants' values, management preferences, and previous experiences in relation to outdoor recreation areas at night.

The study was approved by the Pennsylvania State University's Institutional Review Board (STUDY00017949) as well as the U.S. Office and Management and Budget (OMB 1024-0224) The Pennsylvania State University's Institutional Review Board determined this work to be exempt from formal IRB review. Participation in this study was voluntary, and all participants were informed their data were going to be used by "NPS Managers and Planning staff in future initiatives related to the visitor use and resource management related to night skies," and reported, "in aggregates … no individually identifiable responses will be reported," to obtain informed consent.

Each participant was given a Samsung Galaxy A7 Tablet with screen light control through the mobile app Twilight. Twilight allowed tablet screens to be viewed in red light to minimize obstruction to respondents' night vision. Before beginning the survey, informed verbal consent was obtained from all the participants. Consent was documented through each participant hitting "agree" at the beginning of the survey. The study took around 40 minutes to complete and was guided by a research technician. A total of 167 responses were collected over the course of 16 months with a sampling period of five months.

2.4 Data Analysis

All statistical analyses were performed in R version 4.2.2 (R Core Team, 2021) Data was cleaned and voltage values recorded at Station 7 were converted to average illuminance values (lx) using Equation 1 for the participants who selected direct amber as their color preference and Equation 2 for those who selected white as their color preference. These equations, derived from lab and field measurements of average lux and voltage output, allowed for rapid calculation of average illuminance along a continuous range of voltages recorded during the survey. Equations were provided by the National Park Service's Natural Sounds and Night Skies Division.

(1) Illuminance = -(0.1078voltage2) + (2.5085voltage) – 2.2725

(2) Illuminance = 2.9483voltage – 2.5415 (2)

The survey data were confirmed to be normally distributed to enable the use of parametric tests. This also included viewing the demographic information of study participants (Table 1). The basis of this study is exploratory analysis due to the lack of literature that would conventionally guide hypothesis testing with a similar data set. With this, all statistical tests were performed to inform the guiding research questions of what spectra and intensity of lighting participants prefer as well as if any participant characteristics influenced their lighting preference.

To explore participant selection of spectra, a χ^2 goodness of fit test was conducted for the choice in spectra (amber or white) (Figure 3). The relationship between spectra and intensity was explored by performing a one-sample t-test testing for significance in intensity in relation to the spectra (Figure 3).

To understand if participant characteristics influence choice in spectra and intensity, select demographics of survey respondents were examined (Table 1). Spectra choice and participant characteristics were modeled (nighttime recreation experience, youth upbringing environment, gender) using one-way ANOVA. Two-way ANOVA testing between spectra choice and participant characteristics as explanatory variables and intensity were conducted after running the initial ANOVA test (Figure 4).

3. Research Results

Survey participants (n=167) were evenly distributed in relation to gender. Because the sample came from a university campus, most participants were college-aged (24% were between the ages of 18 and 19 and 60%

were between the ages of 20 and 24). The majority of participants had a suburban youth environment, were residents of the United States, and had engaged in a prior nighttime recreation experience (Table 1).

Table 1. Descriptive results of the sample

Group	n	Percent Sample
Gender		
Male	82	49.10%
Female	82	49.10%
Youth Environment		
Rural (population <5000)	38	22.75%
Suburban (population between 5000 and 50000)	92	55.08%
Urban (population >50000)	33	19.76%
Country of Residence		
U.S. Resident	148	88.62%
Non- U.S. Resident	15	8.98%
Prior Nighttime Recreation Experience		
Yes	131	78.44%
No	33	19.76%

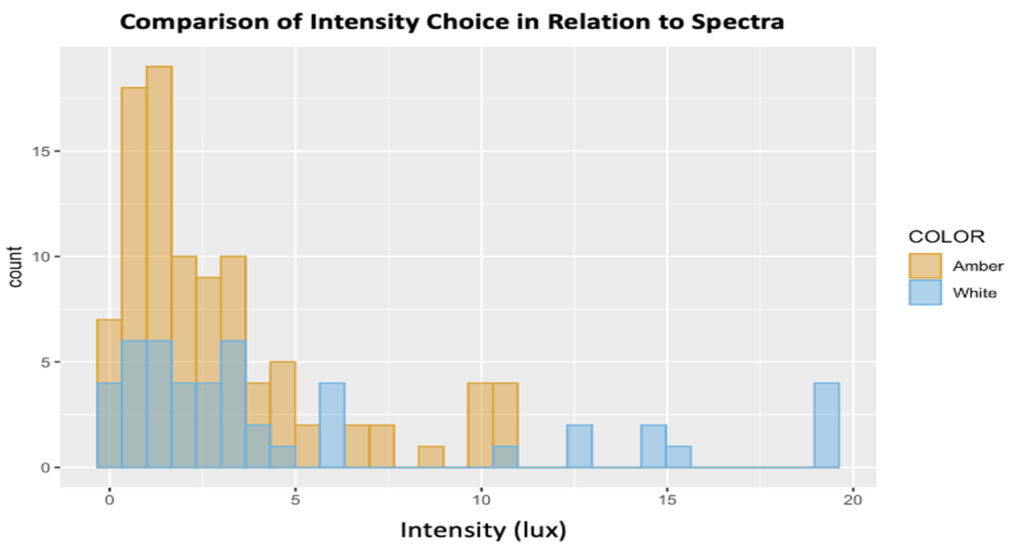
3.1 What Spectra of Light Do Participants Prefer in the Context of Creating the Most Ideal Nighttime Lighting Condition?

In examining participant preference of spectra, the majority of participants selected amber light (n=97 out of 144 [67%]). The Chi-square goodness-of-fit test showed that the distribution of the number of participants who chose amber or white in this study was not consistent with the expected distribution of a 50:50 distribution ($\chi^2 = 17.361$; df = 1; p = <0.001). This means that the color choice of amber (n=97) is significantly different than the color choice of white (n=47 out of 144 [33%]) at Station 7.

3.2 What Intensity of Light Do Participants Prefer in the Context of Creating the Most Ideal Nighttime Lighting Condition?

In looking at the interaction between the choice of light intensity in relation to spectra, there is a significant difference in mean intensity between amber (mean = 2.87) and white (mean = 5.18) (t (-2.5318); df = 56.246; p=0.01417) (Figure 3). These results suggest that amber light is the preferred color of light with 2.87 lux being the average level of intensity preferred. For comparison, 0.2 lux is the average illuminance of a natural full moon.

Figure 3. Participant choice of spectra and intensity (lux)



Interestingly, participants who selected white light preferred it at a higher intensity (mean = 5.18) than those who selected amber light (mean = 2.87). Figure 3 displays the variation in lux values per color choice.

3.3. Do Any Demographic Characteristics - Gender, Youth Environment, Previous Nighttime Outdoor Recreation Experience - Influence Lighting Preference?

Regarding color selection in relation to participant demographics, those who had previous experience with nighttime outdoor recreation were more likely to select the amber light than the white (Table 2). Looking at light intensity selection, those who had prior outdoor nighttime recreation experience and selected amber light had the lowest mean intensity selection of 2.48 lux (Table 2). Both males and females were more likely to select amber light than white light (Table 2). Those who were raised in rural or suburban environments were more likely to select amber light; however, in looking at those raised in urban areas, there was no clear preference of white or amber light (Table 2). Those who were raised in urban environments and selected white light selected the highest mean intensity at 5.93 lux (Table 2).

Table 2. Descriptive statistics for ANOVA testing.

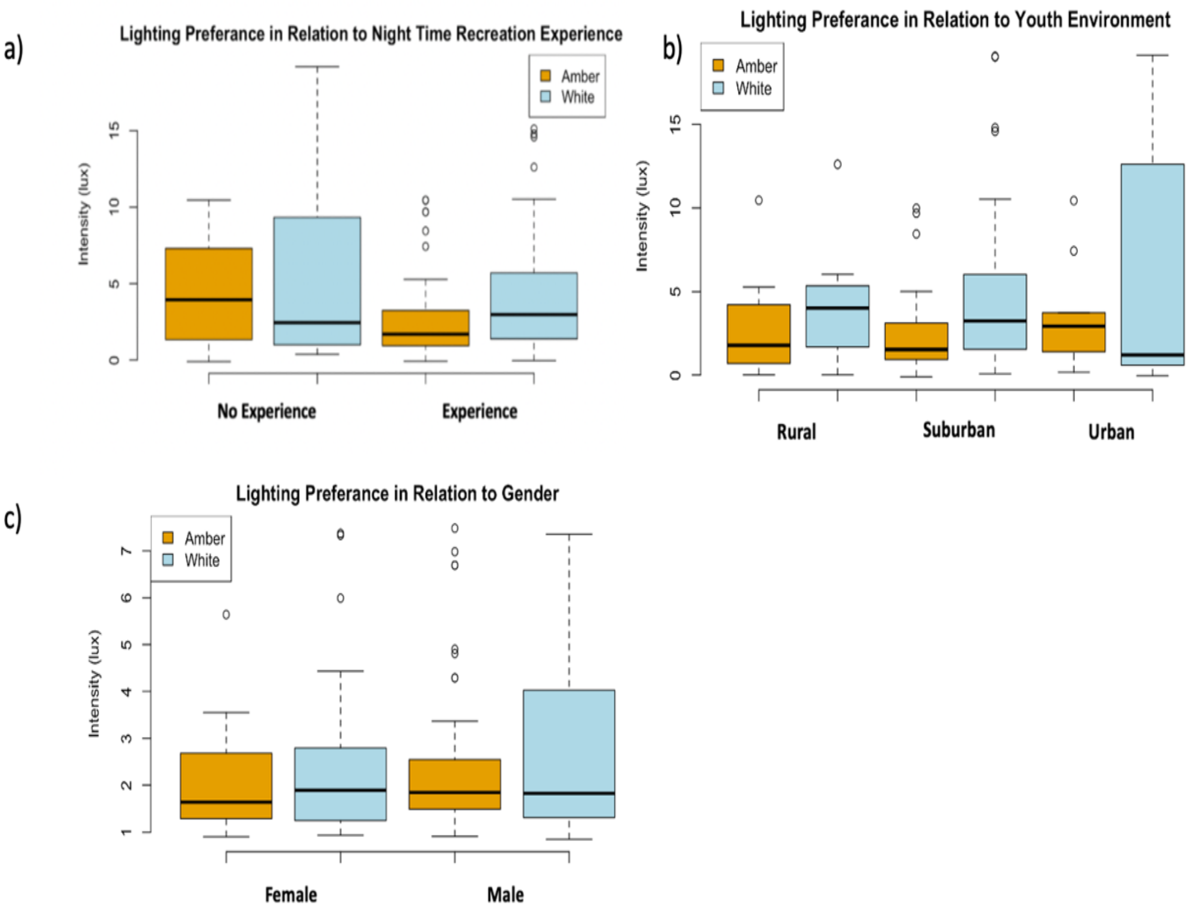
Color	Prior Nighttime Outdoor Recreation Experience	n	Mean	Std. Deviation
Amber	Yes	80	2.48	2.37
	No	17	2.72	3.86
White	Yes	35	4.96	5.55
	No	12	5.78	7.09
Color	**Gender**	**n**	**Mean**	**Std. Deviation**
Amber	Male	49	2.97	2.76
	Female	48	2.78	2.86
White	Male	23	5.60	6.32
	Female	24	4.77	5.59
Color	**Youth Environment**	**n**	**Mean**	**Std. Deviation**
Amber	Rural	22	2.95	3.05
	Suburban	57	2.48	2.49
	Urban	17	4.08	3.35
White	Rural	7	4.38	4.17
	Suburban	26	4.98	5.68
	Urban	14	5.93	7.25

Table 3. (a) ANOVA table comparing intensity (lux) across spectra choice and prior nighttime recreation experience. (b) ANOVA table comparing intensity (lux) across spectra choice and gender. (c) ANOVA table comparing intensity (lux) across spectra choice and youth environment.

(a)	df	Sum of squares	Mean square	F	p
Color	1	68.90	68.90	4.22	0.042*
Nighttime Recreation	1	50.79	50.76	3.11	0.040*
Color*Recreation	1	10.82	10.82	0.66	0.417
Error	141	2298.00	16.30		
(b)	**df**	**Sum of squares**	**Mean square**	**F**	**p**
Color	1	168.80	168.80	10.04	0.02*
Gender	1	8.37	8.37	0.98	0.48
Color*Gender	1	3.25	3.24	0.19	0.66
Error	140	2353.71	16.81		
(c)	**df**	**Sum of squares**	**Mean square**	**F**	**p**
Color	1	391.90	89.35	5.29	0.023*
Youth Environment	3	38.25	12.83	5.29	0.52
Color*Youth Environment	2	5.76	2.88	0.76	0.84
Error	137	2325.3	16.90		

Two-way ANOVA testing confirmed that there is a significant relationship between color selection and intensity (Table 3a,b,c). In looking at intensity in relation to color and gender or youth environment, there was no statistical significance in relationship to the gender or youth environment (Table 3b,c). However, when conducting an ANOVA test for intensity selection, color selection, and prior nighttime recreation experience a significant relationship was found (Table 3a, Figure 4) (Amber-Experience n=80, Amber-No Experience n=17, White-Experience n=35, White-No Experience n=12).

Figure 4. (a) Intensity (lux) in relationship to color choice and nighttime recreation experience (b) Intensity (lux) in relationship to color choice and youth environment (c) Intensity (lux) in relationship to color choice and gender



4. Discussions

In this study participant preferences for various spectra and intensity of artificial lighting at night in a park and protected area-like setting was investigated. Results can inform researchers to better understand human preferences of artificial light at night in outdoor recreation settings to better manage lighting in PPAs.

Gaston *et al.* (2017) identified minimum required levels of lighting in general as a current gap in the literature and as an area needing to be addressed. Because of the dearth of industry or park standards for lighting requirements that are specific to the unique purposes and missions of PPAs, park managers are left to determine lighting levels and design on their own. Through this experimental study, which asked participants to identify the intensity and spectra of light considered appropriate for a park-like setting for pathway lighting, the level of light necessary for PPAs is better understood. Study results show statistical significance in the selection of spectra by participants. Significantly, more participants selected amber (n=97) than white (n=47). Results were inconsistent with Smith and Hallo's (2019) study where park visitors preferred white light for pathway lighting; however, in the previous study, visitors did prefer warmer lighting for purposes other than pathway lighting. However, visitors in Grand Teton National Park expressed higher ratings for visual comfort and safety under red streetlight lighting than white streetlight lighting (Fristrup *et al.* 2024). Possible causes of differences in results could be due to sampling population, sampling size, demographic variables, or a difference in spectra used in the study. Smith and Hallo (2019) used 4200K for white light whereas this study used 3000K for white light which is equivalent to their warmer lighting (3000K) which was preferred at comfort stations and amphitheatres. Fristrup et al (2024) utilized blended red-white lamps consisted of 30 narrowband LED with a peak wavelength 623 nm and two 3000 K white LEDs (Fristrup *et al.* 2024). Introducing white light into the fixtures improves color rendering (Fristrup *et al.* 2024). Further, differences in results could be related to a more general societal understanding about the effects of light pollution and a better understanding of how the color of lights impact both wildlife and stargazing. There is growing literature, signage, and promotion of wildlife and stargazing friendly lighting colors and practices, such as turning off lights during bird migration or encouragement of using the red-light function of headlamps to preserve night vision, in recent years (Elgert *et al.* 2020; Peña-García & Sędziwy, 2019; Schulte-Römer *et al.* 2019).

Beyond color alone, results show a significant difference in intensity preference (how bright participants wanted the light) between those who chose amber light and white light. Participants who chose amber light selected a much lower average intensity of 2.87 lux compared to those who chose white light selected an average intensity at 5.17 lux. While 2.87 lux is still much higher than any naturally occurring light (*i.e.*, a full moon), this lighting level is consistent with the lowest recommendations from the most recent ANSI/IES RP-43 standard for pedestrian walking surfaces for Lighting Zone 1 (2 lux) (IES, 2022). Smith and Hallo (2019) found the preferred lighting intensity for path lighting of visitors to be 1.4 lux, but this value is only comparable to those who selected white as their preferred hue in this study. Results suggest that with amber light, park visitors would find a lighting intensity of 2.87 lux to be acceptable for outdoor nighttime recreation for pathway lighting. As with any recommendation, there will be outliers. Within this study, participants who chose amber did so in the intensity range of 0.10 to 10.46. This all should be taken into consideration for managerial action.

This study also sought to determine if any visitor characteristics or demographics influenced lighting intensity and spectra choice. Across participant characteristics of gender, youth environment, and previous nighttime recreation experience, there was no statistically significant relationship between spectra choice and any of the characteristics. However, there was a statistically significant relationship between intensity with the explanatory variables of previous nighttime recreation experience and spectra choice. Interestingly, those without previous nighttime recreation who selected amber as their spectra had a higher mean intensity (lux) than those who selected amber with previous recreation or those who selected white for their spectra. While a higher intensity of light is not preferred for resource protection, selection of amber by those without nighttime recreation is an encouraging result. Those without nighttime recreation experience may have selected a higher intensity for reasons of perceived increase in safety (Peña-García & Sędziwy, 2019). Some studies have found that individuals often associate brighter lights with feelings of safety, however, too bright of light can be counterproductive in increasing the visibility of their surroundings due to glare and contrast with shadows (Stone, 2017). The lack of results from testing participant characteristics, like visitor demographics in PPAs, regarding spectra and intensity selection is encouraging. However, given that this study drew from a relatively homogeneous, student-based sample, findings should be interpreted with caution. While adequate for exploratory research, this sample may not fully represent the broader diversity of park visitors. Expanding future work to include a wider range of demographic and experiential backgrounds would strengthen understanding of how lighting preferences vary across visitor populations.

Perhaps most interesting, is the differences in results between the analysis presented here and the findings of the sister study by Himschoot *et al.* (2024). Himschoot *et al.* (2024) found that study participants were 36% more likely to report greater feelings of safety in warm white light than amber light and 82% more likely to report greater feelings of safety at intensity levels 5 lux or higher. Yet, when asked “Imagine that you are tasked with selecting lighting that strikes a balance of conditions that are good for both humans and wildlife. What would be the most ideal nighttime lighting condition?” the findings presented here suggest participants selected a preference for low-level amber lighting. These differences could be due to methodological differences – including that the first 6 stations had fixed settings while Station 7 had an interval setting. However, the difference could also be due to the question participants were posed at Station 7 – specifically asking for a balance between humans (presumably their preference) and wildlife. Although a specific educational intervention was not used here, this finding aligns with a prior study that found participants who valued biodiversity rated lower lighting levels more favourably when they were provided with information about the impact of lighting (Boomsma and Steg, 2014). Further, the findings here actually do align with the other sister study by Beeco *et al.* (2025) that found participants at the arboretum were willing to trade-off their own preferences and feelings of safety for lighting that focused on wildlife and natural night conservation needs. These finding all suggests that asking participants to balance the benefits of lighting for humans against the environmental impacts is an important component of making research informed design selection for lighting.

Limitations, Conclusions, and Further Research

The mean age of participants in this study was 20 years old, and the results of color and intensity preference may change when sampling a more diverse age range. In the Smith and Hallo (2019) study in Acadia National Park, the average participant age was 41.4 years old with a range of 18 to 63 years of age whereas this study had a range of 18 to 58 years of age with an average of 20. Smith and Hallo (2019) did test different light colors, but younger visitors may be more accepting of different lighting colors than the average park visitor. There have been reports of fewer young people and increasing numbers of older people visiting national parks over the past few years (Keen & Dorrell, 2012). At its face, age is an important consider of lighting due to declining visual abilities and is certainly a limitation of this study – suggesting replication in a different environment is needed.

The sampling for this study took place on a large U.S. university campus with a mostly student-based sample. While there are disadvantages to this, such as a younger sample size described above, there are also many advantages. Most importantly, this is a sample made up of both experienced and inexperienced visitors to PPAs (*i.e.*, university arboretum). While similar studies inside of parks are important, this study informs lighting preference from participants who may be less familiar with PPAs than studies taking place in actual PPAs. Sampling human preference about parks from non-park visitors is a valuable effort, especially on a topic ubiquitous to all 21st century humans – artificial light at night.

Additional study is needed to better understand the socio-ecological impact of lighting in protected areas. Future studies should focus on sampling in PPAs, examining both wildlife and human responses to lighting simultaneously, examining a wider variety of colors/intensities, examining lighting fixtures beyond bollards alone, and examining how information or education may influence human responses to lighting.

This study revealed visitors' preferences of lighting spectra and intensity in a park-like setting. The objectives of this study were twofold. The first objective was to develop a reference point for lighting preferences across both intensity and spectra that can be consulted when retrofitting and updating park lighting, especially for bollard style lighting. The second objective was to better understand how visitor demographics influence lighting preference for nighttime outdoor recreation. Taking into consideration the intensity and color choice of participants, managers could both lower the brightness of park lights while also implementing warmer colors of lighting into a park's light design. Further, since previous nighttime recreation experience was the only significant demographic predictor of intensity and spectra, education may play a critical role in visitor acceptance of non-traditional light regimes in PPAs. This paper is not suggesting any specific lighting values or threshold for general PPAs or specific parks. Rather we present these findings as reference points in an area of study (and management) that has a dearth of information.

General principles for responsible and sustainable lighting guidance issued by the DarkSky International, Illuminating Engineering Society, Design Lighting Consortium, and the U.S. National Park Service all suggests that using light only when needed, using the correct amount of light, and using warmer spectra of lighting are all advisable when lighting the human environment while limiting the detrimental impacts of light to the environment (Beeco *et al.* 2023). This study supports these recommendations and begins to quantify the 'right amount of light' for pathway applicants in parks - suggesting a lower level of light should be considered. Further, the broader support for amber lighting over white lighting is also encouraging because most research to date suggests that warmer color lights have less influence on wildlife and insects. However, lighting will always be very context specific.

The night sky is an important cultural and ecological asset with important benefits to humans and wildlife (Gallaway *et al.* 2010; Mace *et al.* 2004) and is protected by the laws and policies of the many PPAs, including U.S. NPS. The literature related to ALAN and light pollution is heavily saturated with studies on the impacts of lights on wildlife but rarely takes into consideration visitor needs or preferences of lighting when making suggestions for change in PPAs. Natural dark skies are increasingly recognized as an important cultural and experiential resource in national parks (Smith & Hallo, 2019; Manning *et al.* 2016). With this in mind, it is critical to keep the visitor at the forefront of managerial decisions alongside considerations of wildlife and the environment, as lighting is after all for humans. This study suggests that a better balance in lightscape management within parks and protected areas, that prioritizes wildlife friendly lighting regarding spectra while considering lighting needs of visitors in relation to intensity, can be found.

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Credit Authorship Contribution Statement

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B. Derrick Taff: Conceptualization, Investigation, Methodology, Project administration, Writing – review and editing, Funding acquisition.
J. Adam Beeco: Conceptualization, Investigation, Methodology, Project administration, Writing – review and editing.
Jeremy White: Conceptualization, Investigation, Methodology, Validation, Writing – review and editing, Visualization.
Stephanie Buckley: Conceptualization, Investigation, Methodology, Writing – review and editing.
Steve Lawson: Conceptualization, Investigation, Methodology, Validation, Writing – review and editing.
Peter Newman: Conceptualization, Investigation, Methodology, Project administration, Writing – review and editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they have not used generative AI and AI-assisted technologies during the preparation of this work.

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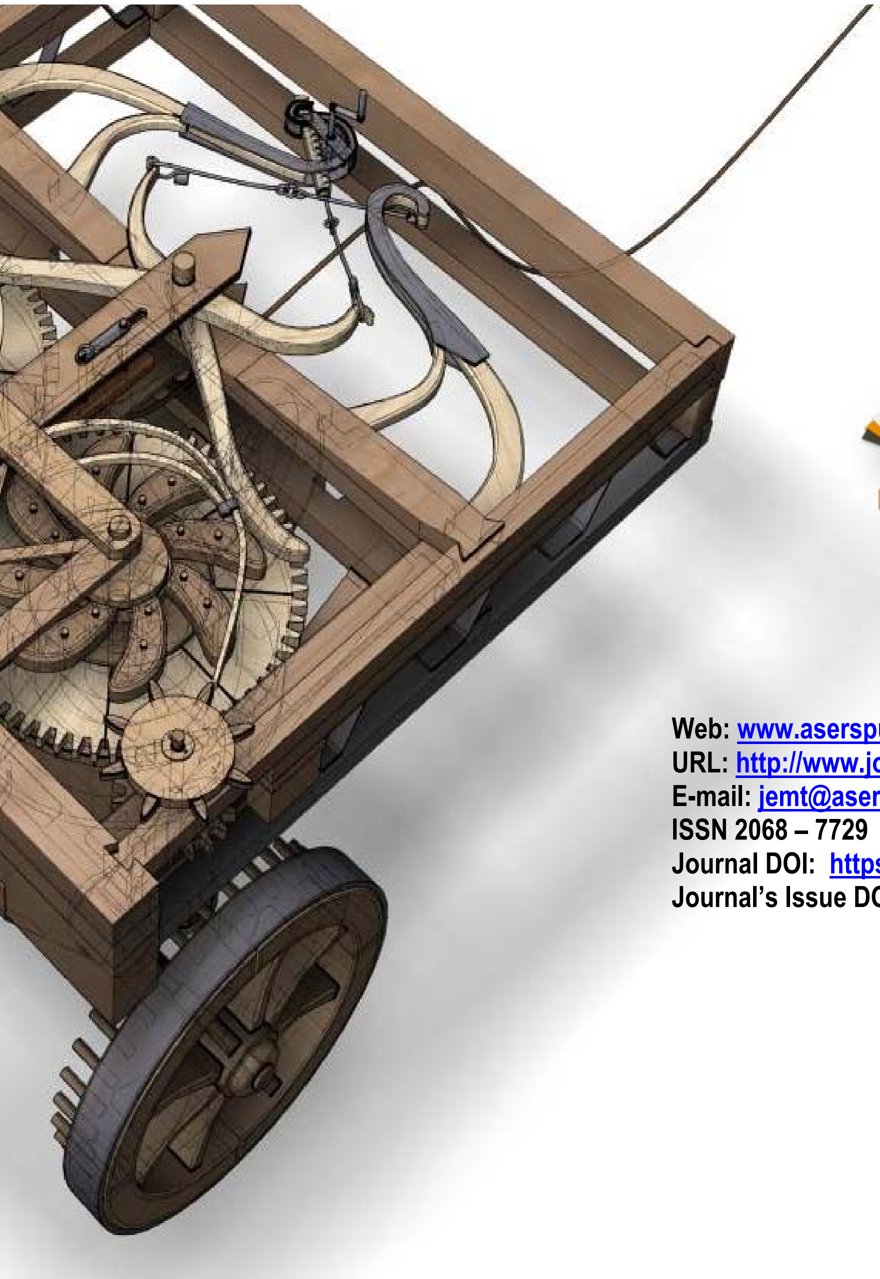

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