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Research article

Support for management actions to protect night sky quality: Insights from visitors to state and national park units in the U.S.

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ABSTRACT

Light pollution is a global phenomenon where anthropogenic light sources continue to grow unabated, affecting both social and ecological systems. This is leaving parks and protected areas as some of the last vestiges of naturally dark environments for protecting views of the night sky. Yet, even parks and protected areas have outdoor lighting. Alternative lighting practices are needed to reduce or prevent light pollution from within parks. However, making parks darker may not be desirable for some visitors if they believe it will reduce navigability, safety, or restrict how they recreate (e.g., requiring the use of red-light flashlights after dark and before dawn). How visitors will respond to alternative lighting practices that park managers can implement is still unknown. We used an on-site intercept survey at nine state and national park units in Utah, U.S., to investigate nighttime visitors' support or opposition to management actions to protect night sky quality and their interest in learning about topics related to night skies. Further, this study also segmented visitors into two groups: those 'dependent' on the dark sky as a resource and those whose activities did not depend on a dark sky. Defining what a 'dark sky dependent' visitor is, which has yet to be done in the literature, is a fundamental step to furthering night sky research and management efforts. Across nine parks and protected areas, 62% of nighttime visitors participated in dark sky dependent activities. Findings indicate broad support for management actions designed to improve night sky quality, with between 74% and 89% of all visitors supporting seven different management actions. There was stronger support from dark sky dependent visitors for some elements of alternative lighting practices, but there was still strong support for those who do not participate in dark sky dependent outdoor recreation. Additionally, between 57% and 75% of visitors were interested in learning more about topics related to night skies. This research indicates most visitors would welcome actions to preserve the quality of the rapidly dwindling naturally dark experiences offered by parks and protected areas.

1. Introduction

Light pollution is a global issue that occurs as anthropogenic light sources increase the amount of light that exists in an area at night. Skyglow, the most common component of light pollution, is caused by atmospheric scattering of light from ground-based sources (direct or reflected). Eighty percent of people worldwide experience light polluted night skies where they live. In industrialized regions like most parts of United States and Europe, conditions grow more severe with 99% of all people living under light polluted night skies (Falchi et al., 2016). Light pollution is expected to get worse as the world population grows and as urban areas expand (Albers and Duriscoe, 2001; Kyba et al., 2017). A recent study found the average night sky in Europe and North America became almost 10% brighter each year between 2011 and 2022 (Kyba et al., 2023).

A growing body of research is demonstrating light pollution is

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responsible for disruption of human and animal circadian rhythms (Cao et al., 2023; Touzot et al., 2023; Benke and Benke, 2013), marine ecosystems (Marangoni et al., 2022), migratory patterns (Korpach et al., 2022; Burt et al., 2023), and alterations to plant seasonal cycles (Meng et al., 2022), as well as changes in reproductive cycles of insects (Firebaugh and Haynes, 2016) and other wildlife (Sanders et al., 2020). These are just a few of the effects of light pollution on wildlife that are being studied. Light pollution also affects humans' ability to experience the night sky (Beeco et al., 2013; Benfield et al., 2018; Manning et al., 2018) as well as human health (Cho et al., 2015). In addition to the negative impacts to humans and wildlife, light pollution is also an inefficient use of energy (Gallaway et al., 2010). Light pollution is now affecting even some of the most remote places on Earth, such as parks and protected areas (Falchi et al., 2016).

For land management agencies there are two primary management strategies for protecting natural night skies and preventing the loss of darkness: 1) managing on-site lighting and 2) working with adjacent communities to prevent light pollution. This research focuses on on-site lighting because that is the factor park and protected area managers have the most control over. Land management agencies would benefit from information that provides insights into better ways to balance protection of resources such as natural darkness with visitor experience considerations such as safety, wayfinding, and recreation (Turina, 2018).

Therefore, the purpose of this study is to better understand nighttime visitors[3] and their perceptions of management actions to protect night sky quality across multiple U.S. park units. Our specific research questions are:

(1) What activities do nighttime recreationists participate in, and what percentage of nighttime recreationists participate in activities that are dark sky dependent?
(2) What level of support do nighttime recreationists have for management actions to protect night sky quality?
(3) Are nighttime recreationists interested in learning more about night sky related topics, including how to improve night sky viewing?
(4) Are there differences in the degree to which visitors support management actions to protect night sky quality and interest in learning about night skies between dark sky dependent recreationists and other recreationists who do not depend on a dark sky?

1.1. Alternative lighting practices

Several organizations involved in the protection of dark skies have issued principles and guidelines to reduce light pollution. These organizations use varied language to describe their principles. The nomenclature related to sustainable lighting and alternative lighting practices is not uniform. Wildlife-friendly, night sky-friendly, and dark-sky friendly lighting (or similar) are not terms of art, but rather convey a general sense of purpose. What is common among these alternative approaches to lighting are the practices. The most notable organizations to author such practices include the International Dark-Sky Association (IDA) and the Illuminating Engineering Society (IES)—which have created the "Five Principles" –the Design Lights Consortium has also authored the "Seven Strategies," and the U.S. National Park Service has created sustainable lighting practices (Table 1) (Design Lights Consortium, 2022; Hartley and Liebel, 2020; U.S. National Park Service, 2023a). These recommended lighting practices are very similar, and collectively describe feasible management actions that can be taken by park and protected area managers to improve existing lighting or to be included in new lighting projects. However, no study to date in English that the authors are aware of has investigated visitor support or opposition to specific park management actions to preserve night sky quality based on these principles for responsible and sustainable lighting.

1.2. Visitor perceptions and experiences at night

Few studies have focused on visitors' experiences in parks and protected areas at night or their perceptions of management actions to help preserve night sky quality. Perhaps the first published study on the visitor experience at night in a park (with a focus other than camping) was an observational study of visitors, finding their activities to be primarily legitimate rather than destructive, and noting that visitors seemed to be motivated simply by a desire to be out at night (Kuekes, 1989). More recent research has examined the experience of guided night hikers, finding participants were motivated by the opportunity to have a new or different experience. Unique soundscapes (what visitors could hear) and night skies were foundational to the experience, and nighttime visitors felt a higher level of solitude relative to daytime experiences (Beeco et al., 2011). In Acadia National Park, interviews with park visitors and qualitative analysis revealed dark skies were important for imagination and personal imaginings (Derrien and Stokowski, 2020). Additionally, in a laboratory simulation of national parks, higher levels of light pollution were found to negatively affect mood and scenic evaluations of the parks (Benfield et al., 2018).

Most visitors to three different U.S. National Park Service units thought the parks should be preserved for dark sky viewing (Mace and McDaniel, 2013; Manning et al., 2016). However, few studies have investigated environmental education around night skies related topics and visitor perceptions of specific actions parks should or should not take to help preserve dark skies. A 2009 visitor survey in Bryce Canyon National Park found 56% of visitors learned about night skies or astronomy during their visit, and that 59% wanted to learn more about this topic on a future visit (Holmes et al., 2010). In Bryce Canyon National Park and Cedar Breaks National Monument, visitors that attended a night skies interpretive program experienced more benefits compared to day visitors, such as inspiring creativity, creating a curiosity in science, and feeling connected with nature (Mace and McDaniel, 2013). These visitors were also more likely than day visitors to believe parks should be preserved for dark skies, and that areas around parks should contribute to this effort (Mace and McDaniel, 2013).

Two studies that we are aware of have investigated preferences or support for management actions to reduce light pollution in park or protected area settings (Silver and Hickey, 2020; Smith and Hallo, 2019). One study found community members near a dark sky preserve in Ontario, Canada were highly supportive of actions to reduce light pollution, including regulating residential, street, and commercial lighting (Silver and Hickey, 2020). In Acadia National Park, a qualitative and descriptive study found that when presented with different options of lighting, which varied in color and brightness, nighttime visitors' preferences varied by park location/purpose (Smith and Hallo, 2019). For instance, visitors wanted much brighter lights at a restroom area compared to a pathway, but preferred white lights on the pathway (compared to yellow lights at the restroom area and amphitheater). Visitors also indicated they wanted night lighting to maintain natural brightness/darkness and wanted the minimum amount of light needed for the task that would still support safety (Smith and Hallo, 2019). Collectively, these studies indicate visitors may be open to alternative lighting practices to help protect night sky quality, but more research is needed to better understand support for specific management actions across multiple parks and protected areas.

[3] Throughout this paper, we use the terms "recreationist" and "visitor" interchangeably. Although someone could be visiting for a purpose other than recreation (e.g., work), the vast majority of visitors to these parks are there for recreation.

Table 1
General principles for responsible and sustainable lighting.

Category	IDA[a] and IES[b] Five Principles for Responsible Outdoor Lighting	Design Lights Consortium Seven Strategies to Minimize Negative Impacts of Outdoor Light at Night	U.S. National Park Service's Sustainable Lighting Practices	General Practice
When to use light	- All light should have a clear purpose and be useful	- N/A[c]	- No lighting at all	- Only use light where it is needed
Color of lights	- Use warmer color lights where possible and avoid blue-violet light	- Minimize blue-violet light	- LEDs[d] in warm colors, not blue or white	- Use warmer color lights and limit the use of blue-violet light
Level of light	- Low light levels, light should not be brighter than necessary	- Use the right amount of light	- Lowest lumens possible to safely light an area	- Use only as much light as needed for the task
Lighting structure	- Targeted – light should be directed to only where needed (e.g., use shields to point downward)	- Control the distribution of light (e.g., use fixtures to point downward)	- Recessed and fully shielded - No upward facing lights - Proper installation	- Use fixtures and LEDs that direct the light to only the area it is needed
Lighting controls	- Use controls so light is available when needed, and off when not needed	- Use lighting that is dimmable and control ready - Control lighting to reduce energy use and light pollution - Control lighting to respond to seasonal changes	- Use fixtures that include or can accommodate timers, motion detectors, hue adapters, and dimmers	- Use controls to light only when needed, and color/dimmer controls to achieve other lighting goals
Other	N/A	- Consult with local experts and community members	N/A	N/A
Citation	Hartley and Liebel (2020)	Design Lights Consortium, 2022	U.S. National Park Service, 2023a	N/A

[a] IDA - International Dark-Sky Association.
[b] IES - Illuminating Engineering Society.
[c] N/A – not applicable.
[d] LEDs – Light emitting diodes.

2. Methods

2.1. Study locations

Data were collected through an on-site survey administered to visitors at four state parks, four national parks, and one national monument within Utah, U.S. These park units include: Antelope Island State Park, Fremont Indian State Park, Dead Horse Point State Park, Goblin Valley State Park, Arches National Park, Bryce Canyon National Park, Canyonlands National Park, Capitol Reef National Park, and Natural Bridges National Monument (Fig. 1). We use the term "park units" to describe our study sites since one unit, Natural Bridges National Monument, is not explicitly a "park," but is considered a "park unit" by the managing agency (U.S. National Park Service, 2023b).

Visitation to these park units in 2021 ranged from 52,423 (Fremont Indian State Park) to 2.1 million (Bryce Canyon National Park; see Table 2 for the visitation statistics for each park). The ecological characteristics, geographic sizes, amount of visitation, and visitor experiences provided across the nine park units are exceptionally variable. Park units were chosen specifically for diversity on these characteristics. However, all have been certified by the IDA as International Dark Sky Parks, a certification given to parks and protected areas "possessing an exceptional or distinguished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment" (International Dark-Sky Association, 2022). Utah is now home to 24 IDA certified parks and communities, the highest concentration of any state in the United States, and only a minority of the parks in Utah are not IDA certified.

2.2. Survey instrument

The survey instrument (OMB Control Number: 1024-0224) first asked visitors about their trip characteristics and recreational activities. We asked if visitors had or were planning to participate in various activities during their trip, including dark sky dependent activities (e.g., wildlife observation at night, night sky viewing/astronomy, and night sky photography) as well as other outdoor activities that are available at these parks (e.g., hiking, scenic driving, developed camping). We also asked visitors to what degree they opposed or supported seven management actions designed to protect the night sky quality at the park; this was a five-point Likert scale with response options ranging from "completely oppose" to "completely support," With the middle option being "neither oppose nor support." The actions asked about were based on the responsible and sustainable lighting principles outlined in Table 1.

We also asked visitors if they would like to learn more about night sky viewing/astronomy, viewing wildlife at night, Native American connections to the night skies, or ways to improve night sky viewing, on a five-point Likert scale with response options ranging from "strongly disagree" to "strongly agree," With the middle option being "neutral." Other topics on the survey, but not analyzed in this paper, included place dependence, trip expenditures, awe from viewing the night sky, awareness and perceived importance of IDA certification, and visitor demographics. The full survey instrument can be found in the appendix of Smith et al. (2023).

2.3. Survey administration

Between April 2021 and May 2022, we intercepted visitors on 82 distinct site-nights across the nine sampled park units. While sampling did occur during the COVID-19 pandemic, by 2021 and 2022 visitation numbers for park units in Utah had rebounded from the low numbers observed at the height of the pandemic in 2020 (U.S. National Park Service, 2023c). We attempted to evenly distribute site-nights across state park and national park units as well as between weekdays (Monday through Friday) and weekends (Saturday and Sunday), but occasionally needed to adjust the sampling schedule due to weather and the availability of survey technicians. Sampling locations within each park unit were identified based upon discussions with park staff; these included campgrounds, popular overlooks, roadside pull-offs, and parking areas.

The study population consisted of individuals who recreate in state and national park units just before and after sunset. We surveyed visitors from 1-h before sunset to 2-h after sunset. Each survey-night lasted approximately 3-h. We deliberately focused on visitors within parks during this time to maximize the likelihood of contacting recreationists participating in a night sky dependent recreation activity. Conducting surveys more than 2-h after sunset often does not result in many visitor encounters or surveys, while conducting surveys during daylight would likely sample visitors that had not, or would not, experience night lighting in the park units.

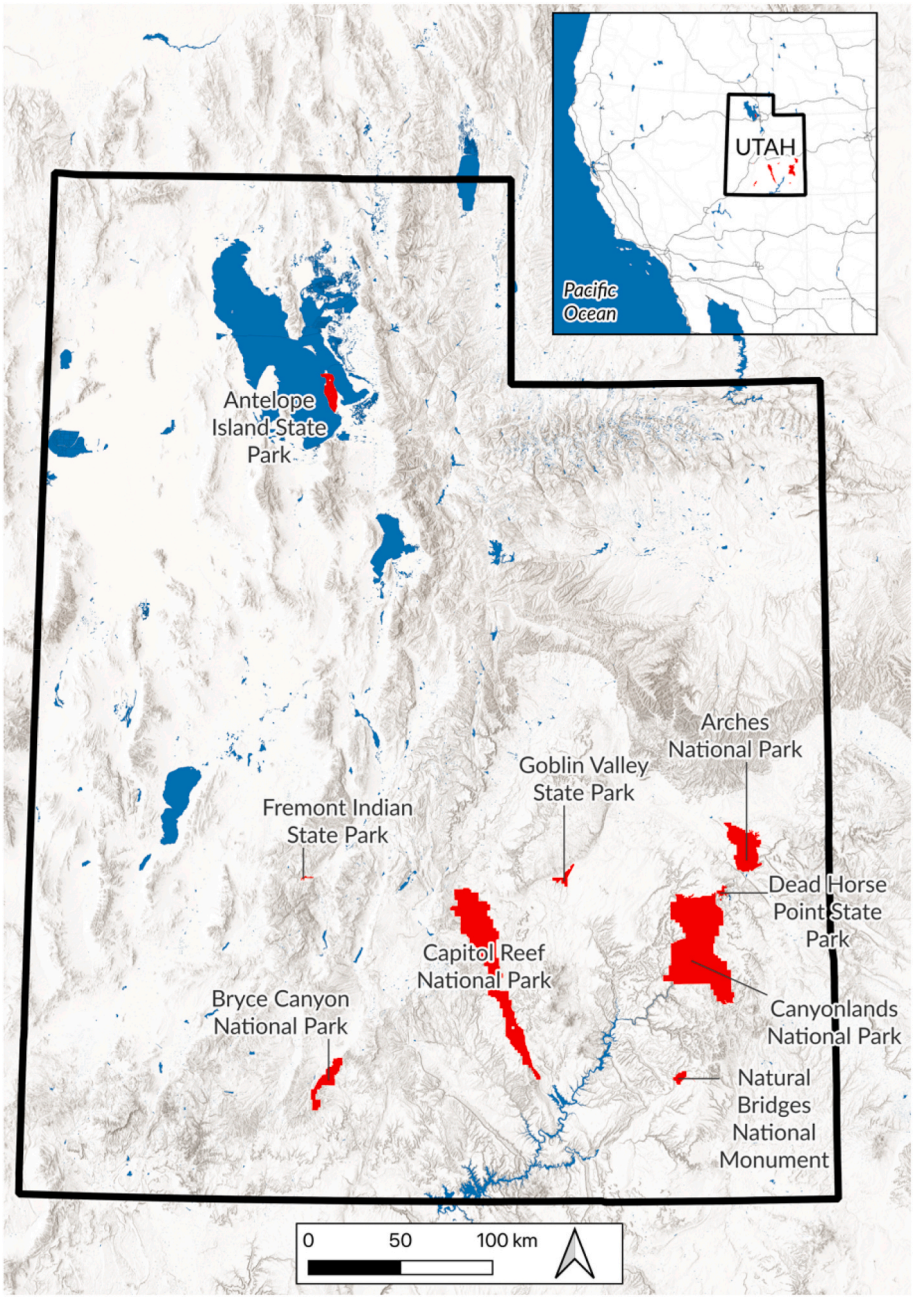

Fig. 1. Map of state parks, national parks, and the national monument included in this study. The center of the state is at 39.3210° N, 111.0937° W.

At each park unit, technicians used a systematic protocol that involved sampling groups at campsites first, followed by overlooks, roadside pull-outs, and finally parking areas. We asked only one visitor from each group – the one with the most recent birthday – to participate in the survey. At overlooks and parking areas, the survey technician stood near a bi-fold display that read "Recreation survey. Please stop." Technicians were equipped with red lights to illuminate the display and the survey site, when needed. Surveys were completed using tablet computers and took approximately 10 min to complete. Pre-testing of the survey protocol occurred through two nights of sampling visitors at Antelope Island State Park in early April 2021.

2.4. Defining dark sky dependent recreationists and data analysis

We first distinguished between two groups of visitors: those whose activities *depend* on the dark sky or natural darkness, and other recreationists whose activities either involve the night environment or have nothing to do with the night sky. We distinguished between these two groups of visitors to answer our fourth research question asking if there are differences in support for management actions to protect night sky quality and interest in learning about night skies between these two different groups of visitors. There is currently no standard definition in the literature for what activities qualify as being a dark sky recreation activity. We consider dark sky dependent activities to include: wildlife observation at night, night sky viewing/astronomy, and night sky photography. When we refer to dark sky dependent recreationists, we are referring to individuals who said they participated in at least one of the three activities above. While backcountry and developed camping *involve* the night sky, they are not *dependent* upon it, nor are they dependent on a *dark* sky, so we exclude these two activities from our set of dark sky dependent activities.

This approach to defining dark sky dependent outdoor recreation

Table 2
Survey periods, responses, and response rates.

Park Unit	Survey Periods	Contacts	Completed Surveys	Response Rate (%)	2021 Reported Visitation
State Parks	44	373	290	77.7	
Dead Horse Point State Park	20	189	148	78.3	1,265,223
Goblin Valley State Park	15	121	95	78.5	453,937
Fremont Indian State Park	4	31	27	87.1	52,423
Antelope Island State Park	5	32	20	62.5	1,074,569
National Park Units	**38**	**403**	**344**	**85.4**	
Bryce Canyon National Park	15	197	170	86.3	2,104,600
Canyonlands National Park	3	85	71	83.5	911,594
Arches National Park	6	73	61	83.6	1,806,865
Natural Bridges National Monument	5	27	25	92.6	73,484
Capitol Reef National Park	9	21	17	81.0	1,405,353

activities, and dark sky dependent recreationists, uses very clear and discrete criteria. Because it is grounded in individuals' activity choices, it is a behavioral approach. We contend that if an individual chooses to participate in an activity that inherently requires a dark sky, then that person can be defined as a dark sky dependent recreationist. An analogous example would be classifying someone who hunts as a wildlife-dependent recreationist, which is common in the literature and is codified into U.S. law (16 U.S.C. § 668ee).

We first use univariate statistics to describe recreational activity participation, general support for management actions, and interest in receiving information about night skies. We compare the activities, support for management actions, and preferences for night sky related information of dark sky dependent recreationists to other recreationists using Fisher's Exact tests and Chi-Square tests of independence (Franke et al., 2012; Upton, 1992). We interpret statistical significance to be $p \leq 0.05$.

3. Results

3.1. Response rates and demographic characteristics of the sample

The total number of contacts made, completed surveys, and resulting response rates by park unit are shown in Table 2. In total, we made 776 contacts with visitors (373 at state park units and 403 at national park units) and received 634 completed surveys (290 at state park units and 344 at national park units). The overall response rate was 81.7%. Overall, the sample tended to be slightly more male than female (54% male), highly educated (81% with a Bachelor's degree or higher), higher income (51% with an annual household income of $100,000 or more), predominately white (96%), and with a mean age of 46 years old.

3.2. Participation in recreational activities

Over half (56%) of all respondents reported that they participated in night sky viewing/astronomy, while approximately 15% participated in night sky photography, and 14% participated in wildlife observation at night (Table 3). Just under 62% of respondents reported participating in at least one dark sky dependent outdoor recreation activity; this proportion was similar across both state parks (64%) and national park units (60%). We did not observe any statistically significant differences across state and national park units in the proportion of visitors participating in the three dark sky dependent activities. Two percent of respondents indicated that their *primary* activity was night sky photography, while 5% indicated their primary activity was night sky viewing/astronomy. No respondents indicated their primary activity was viewing wildlife at night.

We examined differences between dark sky dependent recreationists and other recreationists in the activities they reported participating in (Table 3). A significantly larger proportion of dark sky dependent recreationists participated in scenic driving (+12.8%), developed camping (+13.5%), wildlife observation during the day (+24.2%), and visiting historic or cultural sites (+19.4%) relative to other recreationists. Dark sky dependent recreationists also reported participating in more activities (mean = 5.5) than other recreationists (mean = 3.4); the difference was significant ($t(626) = 16.34$, $p < 0.001$).

3.3. Support for night sky related management actions

Respondents tended to support management actions that improved night sky recreation-related experiences (Table 4). Specifically, between 85 and 89% of all respondents supported six of the seven distinct types of management actions we asked about. The management action of "restricting the number of lights visitors can use at night" was significantly less supported than all other management actions asked about, yet 74.2% of respondents still indicated some level of support for that action. Adjusting hues of lights to be wildlife friendly had slightly more support than adjusting hues of lights to preserve human's night vision; this difference was statistically significant, but small. See supplementary material, Table S1, for mean differences in respondents' level of support for each management action and which differences are statistically significant.

Dark sky dependent recreationists did exhibit more support for management actions to protect night sky quality; this difference was statistically significant for four out of the seven management actions asked about (Fig. 2). There was no significant difference between the two groups regarding their support for "adjusting hues to be wildlife friendly," "reducing the number of outdoor lights in the park," and "restricting the number of lights visitors can use at night."

3.4. Preferences for night sky related information

Not only do visitors largely support management actions to protect night sky quality at the parks, but there was also a high level of interest in learning more about night sky-related topics across all nighttime recreationists (Table 5). Specifically, 75.1% of recreationists were interested in learning more about "night sky viewing/astronomy", and 70.4% were interested in learning more about "ways to improve night sky viewing."

There were some differences in interest between dark sky dependent recreationists and other recreationists (Fig. 3). For instance, 80.4% of dark sky dependent recreationists agreed with the statement that they would like to learn more about "night sky viewing/astronomy," while only 66.3% of other recreationists indicated they would like to learn more about this topic. Similarly, 77.7% of dark sky dependent recreationists indicated they wanted to learn more about "ways to improve night sky viewing," compared to 58.5% of other recreationists. The only topic not having statistically significant differences between dark sky

Table 3
Percentage of respondents who participated in different recreation activities during their trip to a state or national park unit in 2021–2022.

Recreational Activity	Total (%) (n = 630)	State Park Units (%) (n = 288)	National Park Units (%) (n = 342)	Sig. Diff. (p-value)[b]	Dark Sky Dependent Recreationists (%) (n = 388)	Other Recreationists (%) (n = 240)	Sig. Diff. (p-value)[b]
Hiking	90.6	85.4	95.0	< **0.001**	92.5	88.3	0.052
Scenic driving	81.0	75.3	85.7	< **0.001**	86.1	73.3	< **0.001**
Developed camping	80.2	71.9	87.1	< **0.001**	85.6	72.1	< **0.001**
Night sky viewing/ astronomy[a]	56.0	56.3	55.8	0.280	91.0	0.0	< **0.001**
Wildlife observation during the day	48.1	38.9	55.8	< **0.001**	57.5	33.3	< **0.001**
Visiting historic or cultural sites	34.8	30.2	38.6	**0.004**	42.3	22.9	< **0.001**
Mountain biking	16.7	22.9	11.4	**0.002**	16.5	17.1	0.465
Night sky photography[a]	14.9	17.4	12.9	0.322	24.2	0.0	< **0.001**
Wildlife observation at night[a]	14.0	14.9	13.2	0.910	22.7	0.0	< **0.001**
Backcountry camping	10.6	4.5	15.8	< **0.001**	9.0	13.3	0.060
Road cycling	7.1	7.6	6.7	1.000	8.3	5.4	0.119
Rock climbing	4.8	6.3	3.5	0.197	4.1	5.8	0.215
Rafting or canoeing	3.3	4.5	2.3	0.268	3.9	2.5	0.246
Horseback riding	2.9	1.7	3.8	0.097	3.6	1.7	0.119
Other	2.5	2.4	2.6	n/a	2.1	2.5	n/a
Fishing	0.5	1.0	0.0	0.111	0.8	0.0	0.235
Hunting	0.2	0.3	0.0	0.481	0.3	0.0	0.618

[a] Activities classified as "night sky dependent" (also highlighted).
[b] Fisher's exact test n/a – Not Applicable

Table 4
Levels of support from all nighttime recreationists in the sample for different management actions designed to protect night sky quality at the park units ($n \geq 609$). Management actions are ordered by level of support (combining somewhat support and completely support), with those receiving the most support listed at the top.

Management Action	Completely oppose (%)	Somewhat oppose (%)	Neither oppose nor support (%)	Somewhat support (%)	Completely support (%)
Setting lights to the minimum necessary brightness	0.3	2.3	8.1	24.0	65.4
Installing sensors/timers that turn lights on only when needed	1.5	1.5	8.8	21.5	66.7
Adjusting hues of lights to be wildlife friendly	0.3	1.6	10.6	20.6	66.8
Reducing the number of outdoor lights in the park	0.7	2.1	10.6	22.3	64.4
Creating shields on lights that direct light only to intended areas	0.7	2.3	12.1	20.6	64.4
Adjusting hues of lights to preserve human's night vision	0.5	1.6	13.3	25.0	59.5
Restricting the number of lights visitors can use at night	1.5	7.3	17.0	25.0	49.3

dependent recreationists and other recreationists was "viewing wildlife at night." While there are significant differences in preferences for night sky related information between dark sky dependent recreationists and other recreationists across the other three topics, it is important to note that there was a high level of interest across all recreationists in learning more about night sky topics. Between 50.0% and 66.3% of other recreationists responded that they were somewhat or strongly interested in these topics.

4. Discussion

This study is one of the first to examine the activities of nighttime visitors to parks and protected areas and their level of support for management actions to protect night sky quality. Additionally, this research provides insights from visitors across multiple types of protected areas (state parks, national parks, and a national monument) to provide a holistic picture of night-sky recreation across the state of Utah in the United States. The first research question sought to identify what activities nighttime recreationists participate in, and what percentage of nighttime recreationists participate in activities that are dark sky dependent. Over half of visitors at night were participating in activities that are dark sky dependent. This was true at both the state parks and national park units included in this study. This suggests, as prior studies have (Beeco et al., 2011), that the night sky is a critical component of nighttime experiences in park units. Yet, this study found only 2% of respondents' primary activity was night sky photography, and only 5% indicated their primary activity was night sky viewing/astronomy. Although only a small portion of nighttime visitors may specialize in astronomy and night sky photography, many more visitors depend on a naturally dark night sky for high-quality outdoor recreation experiences.

The second research question investigated the level of support nighttime recreationists have for management actions to protect night sky quality. These recommended management actions are very similar to the best lighting practices outlined in Table 1, and collectively account for feasible management actions that can be taken by parks to improve existing lighting or included in new lighting projects. Results show nighttime visitors overwhelmingly support management actions to protect night sky quality at state parks and national park units. Interestingly, even visitors who are not dependent on dark skies support these actions. The least supported management action asked about was restricting the number of lights visitors can use at night; this is the one action we asked about that is not on the list of recommended lighting practices. The other idiosyncrasy worth noting is that visitors had slightly higher support for adjusting hues of lights to be wildlife friendly

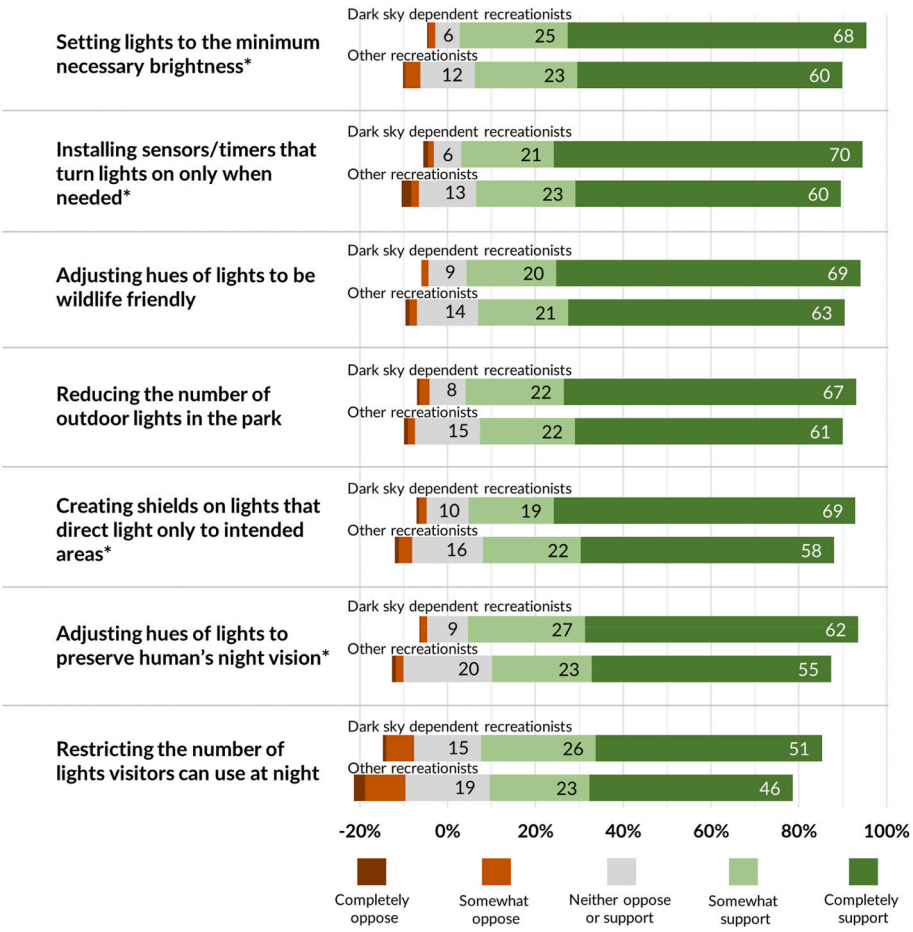

Fig. 2. Levels of support from dark sky dependent recreationists ($n \geq 378$) and other recreationists ($n \geq 229$) for different management actions designed to protect night sky quality at the park units. Asterisks indicate statistically significant differences between night sky dependent recreationists and other recreationists ($p \leq 0.05$); numbers represent percentages.

Table 5
Topics related to the night sky and how interested nighttime visitors are in learning more about each topic ($n \geq 591$). Topics are ordered by level of interest/agreement (combining somewhat agree and completely agree), with topics of most interest at the top.

Topic	Strongly disagree (%)	Somewhat disagree (%)	Neutral (%)	Somewhat agree (%)	Strongly agree (%)
Night sky viewing/ astronomy	3.6	4.4	16.9	38.7	36.4
Ways to improve night sky viewing	2.5	5.7	21.3	37.5	32.9
Native American connections to the night skies	5.3	6.6	24.0	32.8	31.3
Viewing wildlife at night	4.6	9.1	29.1	31.6	25.7

compared to adjusting hues of lights to preserve human night vision. This indicates when communicating with the public to gain support for dark skies management actions, messages focusing on benefits to wildlife may be more persuasive than those highlighting only benefits to people.

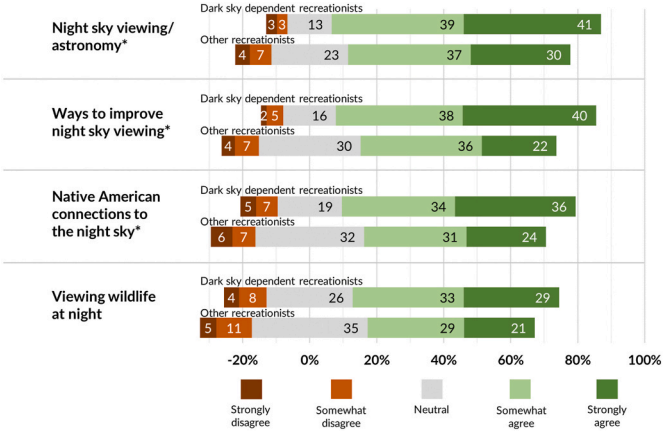

Fig. 3. Topics related to the night sky and how agreeable dark sky dependent recreationists ($n \geq 362$) and other recreationists ($n \geq 219$) who visited park units are in learning more about each topic. Asterisks indicate statistically significant differences between night sky dependent recreationists and other recreationists ($p \leq 0.05$). Numbers represent percentages and may not sum to 100 due to rounding.

Research question three explored if nighttime recreationists were interested in learning more about night sky topics. Similar to a prior study in Bryce Canyon National Park (Holmes et al., 2010), results across these nine park units indicate the majority of visitors want to learn more

about night skies. While there may be some level of social desirability bias inherent in these questions (i.e., survey respondents may be more likely to answer these questions in a way that will be viewed favorably), the varying support between each question is enlightening. Learning more about "night sky viewing/astronomy" had the most interest, but it is noteworthy that "ways to improve night sky viewing" had the second highest level of interest. This suggests educational programs or content about sustainable lighting practices would be of interest to nighttime park visitors, even if they are not participating in dark sky dependent activities. Teaching conservation behaviors, such as ways to reduce light pollution, "directly supports the preservation mission [of the NPS]. Interpretation is driven by a philosophy that charges interpreters to help audiences care *about* park resources so they might support the care *for* park resources" (U.S. National Park Service, 2007).

The final research question aimed to understand differences between dark sky dependent recreationists and other recreationists. To distinguish between visitors who were simply present in the parks at night versus nighttime visitors whose recreation depends on a quality night environment (defined in this study as 'dark sky dependent'), this study took a self-reported behavioral approach to characterize what a dark sky dependent outdoor recreationist is. Specifically, if visitors stated they engaged in night sky viewing/astronomy, night sky photography, or wildlife observation at night, they were categorized as dark sky dependent. Some may argue that many people gaze up at the night sky, but that does not *really* make them a dark sky recreationist. This argument points to a different way of conceptualizing and studying what a dark sky dependent recreationist is, an approach grounded more in recreationists' perceptions of themselves than in their behaviors (this would be a cognitive approach). The self-reported behavioral approach did reveal differences between these groups. Specifically, dark sky dependent recreationists displayed statistically significant and stronger support for four of the seven management actions and three out of the four educational topics. Yet, as discussed above, perhaps more important was the overwhelming support for management actions and interest in learning about night skies related topics across the entire sample.

4.1. Limitations and future research

The findings in the study are limited in scope to nighttime visitors and are not representative of all park visitors, particularly daytime visitors. However, unlike other management actions, the installation or use of artificial lighting only affects visitors who experience the park at night. Our sample, which occurred between 1-h prior to sunset to 2-hours after sunset, is more relevant than a sample of all park users because the visitors in a nighttime sample are much more likely to encounter lighting at night and participate in nighttime programming. Although this study took place across nine different park units, all of these were in the state of Utah, which has some of the darkest skies in the United States (Falchi et al., 2016). Future research in other locations could determine if similar results are found in other contexts as well.

This study highlights numerous opportunities for future research on the visitor experience at night. First, future work could use our behavioral definition of dark sky dependent recreation as a starting point, and then dig deeper into the more cognitive topics such as what it means to be a dark sky dependent recreationist and how dependent individuals are on naturally dark skies. Some work along these lines has already been done (Derrien and Stokowski, 2020), but more is certainly needed to better understand dark sky dependent recreationists. Additionally, more research could clarify why there is an overwhelming amount of support for management action to protect the night sky quality when almost 40% of the visitors surveyed did not, as we defined them, depend on a quality dark sky environment. Our current hypothesis is that the nighttime experience in a park is about more than just the night sky and is more about the whole nighttime environment. A prior study examining guided night hikes came to a similar conclusion (Beeco et al., 2011). Specifically, we asked visitors about their support for management actions designed to protect "the night sky quality at the park." Future research could examine support for similar management actions, framed as protecting a "natural night environment" rather than only sky quality.

Additionally, more research could help identify effective communication strategies for educating visitors on the impact of light pollution and other night skies related topics, such as short- and long-term behavioral changes (e.g., turning off lights at home) and effectiveness of specific messaging (e.g., emphasis on wildlife impacts, safety, or waste). Future research could also examine how tourism itself may lead to increased light pollution and strategies for reducing these impacts (Shannon et al., 2017), including using artificial lighting for wildlife spotting (Rodriguez et al., 2018).

4.2. Management implications

Our findings indicate strong support from nighttime visitors across nine parks and protected areas for feasible management actions to help improve night sky quality and increase the sustainability of lighting in parks and protected areas. This is an important finding because artificial lighting is only for humans, and impacts to wildlife from artificial lighting are overwhelmingly negative, particularly for insects and avian species (Desouhant et al., 2019; Horton et al., 2019). Managers can use results from this study as a barometer to assess possible lighting improvement actions, most of which are highly supported. Further, the management actions discussed in this study were partially derived from IDA recommended practices and align with actions needed to obtain an IDA Dark Sky Park certification. While all the state and national park units in this sample were already certified Dark Sky Parks, managers in other parks could use this information to determine whether to pursue IDA Dark Sky Park certification, albeit with the ultimate goal of preservation of the night sky regardless of certification.

Additionally, environmental education about the effects of light pollution and conservation of the night sky may play an important role in support for management actions. While not specifically measured in this study, all of these parks provide environmental education (e.g., websites, signage, and programs) about the night sky. Further the results in Table 5 do suggest visitors are interested in "ways to improve night sky viewing" which would include reducing lighting pollution. Finally, few studies in the recreation literature collect data for 82 sampling days (or nights in this study), and those that do often result in more contacts than the 776 visitors contacted in the present study (e.g., see Mace and McDaniel, 2013). This resulted in an average encounter rate of less than 10 groups per night, or 3 groups per hour sampled. This indicates that fewer visitors are recreating in these parks at night compared to during the day. The costs of installing and maintaining lighting infrastructure are thus likely only benefiting a small portion of park visitors. This paper is not suggesting any specific management actions on behalf of these or other parks. Rather we present this analysis for managers to consider the visitors' attitudes towards specific management actions that could improve the natural night environment and views of the night skies for visitors.

Naturally dark night skies are a rapidly dwindling natural resource. Parks and protected areas now provide some of the last vestiges where humans can go, gaze up, and experience the vastness of the cosmos. The scientific value and educational opportunities provided by the dark skies are also invaluable. This research provides some valuable insights suggesting many outdoor recreationists depend on dark skies. More importantly, it suggests these visitors *as well as those visitors who do not participate in dark sky dependent activities*, overwhelmingly support park management actions that limit light pollution. While there are many issues over which visitors hold widely different and conflicting preferences, preserving naturally dark skies does not appear to be one of them.

Credit author statement

J. Adam Beeco: Conceptualization, Methodology; Writing – original draft; Supervision; Project administration; Funding acquisition. Emily J. Wilkins: Conceptualization, Methodology; Writing – original draft; Investigation. Anna B. Miller: Conceptualization, Methodology; Investigation; Writing – review & editing. Chase C. Lamborn: Methodology; Investigation; Writing – review & editing. Sharolyn J. Anderson: Conceptualization, Methodology; Writing – review & editing. Zachary D. Miller: Conceptualization, Methodology; Funding acquisition; Writing – review & editing. Jordan W. Smith: Conceptualization, Methodology; Funding acquisition; Writing – review & editing; Formal analysis; Data curation; Supervision; Project administration; Visualization

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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.118878.

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