

COMMUNITY-DRIVEN CONSERVATION OF PANTAI KELANANG'S DARK SKIES FOR SUSTAINABLE ASTRO-TOURISM

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ABSTRACT

Dark sky conservation is crucial for sustainable tourism, especially with the rise of astro-tourism. While many countries in Europe and North America have integrated dark sky initiatives through governance and community participation, similar efforts in Southeast Asia, particularly Malaysia, remain limited. Light pollution from urban expansion, unregulated lighting, and development threatens stargazing opportunities and ecological balance. Hence, this study aims to explore community-driven strategies for dark sky conservation that support sustainable astro-tourism of Pantai Kelanang as a pilot site. The objectives are: first, to explore Pantai Kelanang's dark skies and degradation factors; second, to assess stargazing infrastructure; and third, to propose conservation guidelines through community engagement, policy, and sustainable lighting management. Utilising a mixed-methods approach, including site observation, expert interviews, community surveys, and secondary data analysis, the study found strong public interest in



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stargazing, with 78.8% supporting related events and 69.7% advocating for light pollution reduction. Recommendations include zoning enforcement, improved infrastructure, and educational programs to enhance community involvement. Although limited by a small sample size and single-round observation, the study provides valuable insights into Pantai Kelanang's potential as a sustainable astro-tourism destination and serves as a foundation for future research.

Keywords: *Dark sky conservation, Sustainable astro-tourism, Light pollution, Community engagement*

INTRODUCTION

Dark sky conservation has emerged as a key element in sustainable tourism planning, especially with the rise of astro-tourism. Globally, countries in Europe, North America, and Oceania have successfully integrated dark sky reserves into their tourism strategies through strong governance, scientific monitoring, and community participation (Kocifaj & Barentine, 2021; Guo et al., 2023). However, in Southeast Asia, in particular Malaysia, similar initiatives remain underdeveloped. Light pollution caused by urbanisations, unregulated lighting, and infrastructure expansion threatens not only stargazing opportunities but also nocturnal biodiversity and ecological balance (Hufnagel, 2023; Green et al., 2022; Sung, 2022). Despite its rich coastal and rural landscapes, Malaysia lacks empirical studies on dark sky preservation, especially in vulnerable areas such as Pantai Kelanang, where tourism and ecology intersect.

Existing research in Malaysia reflects a fragmented understanding of light pollution's impact. Studies from Langkawi, Johor Bahru, and Shah Alam reveal issues ranging from unregulated lighting and poor spatial planning to the lack of regulatory and educational frameworks (Hailmy & Musa, 2024; Baharim et al., 2022; Tahar et al., 2017; Faid et al., 2016). Although these findings demonstrate the urgency of intervention, prior studies have neither focused on coastal zones such as Pantai Kelanang, nor on community-led conservation models. Broader challenges include weak public engagement, inconsistent data, and the erosion of ethnoastronomical knowledge pertaining to maritime culture (Bely et al., 2024; Ahmad et al.,

2022; Yew, 2020; Hanapi & Hassan, 2017). Compared to international models, Malaysian approaches remain largely technical and top-down, underscoring the need for participatory, place-based solutions.

Hence, this study aims to propose Pantai Kelanang as a pilot site for exploring community-driven strategies in dark sky conservation, with the goal of promoting sustainable astro-tourism. Instead of treating environmental and tourism concerns separately, the research emphasises holistic, locally grounded stewardship through the following objectives. First, to explore the characteristics of Pantai Kelanang's dark skies and the factors contributing to their degradation. Second, to assess the adequacy of existing stargazing infrastructure in Pantai Kelanang for supporting sustainable astro-tourism and finally to propose conservation guidelines for preserving Pantai Kelanang's dark skies through community engagement, policy development, and sustainable lighting management.

This approach contributes to filling gaps in Malaysian research by offering a replicable example grounded in environmental ethics, cultural significance, and inclusive stakeholder engagement.

LITERATURE REVIEW

Dark Sky Conservation

Dark skies, defined as nocturnal environments with minimal artificial light, are increasingly valued for their contributions to celestial visibility, ecological balance, and cultural significance (Lam, 2023). Blundell et al. (2020) emphasise their potential in sustainable regional tourism, offering immersive experiences that connect visitors with natural rhythms and cosmic phenomena. Recognised by UNESCO as part of humanity's universal heritage, dark skies embody both scientific and cultural legacies. However, the integrity of natural darkness is under a growing threat due to the widespread use of artificial lighting, particularly energy-efficient LEDs. Citizen science data reveal that night sky brightness rose by 9.6 per cent annually from 2011 to 2022 (Kyba et al., 2023). This rise contributes to skyglow, defined by Cinzano et al. (2001), which disrupts ecosystems,

hinders star visibility, and impairs nocturnal experiences. Langston and Taylor (2024) further caution that satellite mega constellations now introduce additional light and radio pollution, posing new challenges for astronomical research.

In light of this, dark sky conservation is emerging as a critical strategy to safeguard environmental integrity alongside cultural and recreational values. Dunn and Edensor (2024) stress the role of dark sky parks and reserves in reducing light pollution and fostering inclusive community governance. Meier (2014) underlines the need for multi-stakeholder collaboration to formalise dark sky designations, while Dunn and Edensor (2023) frame dark skies as spaces for future-oriented thinking that challenge artificial lighting norms and nurture renewed cultural relationships with the night. These studies collectively advocate for a holistic approach to dark sky conservation, integrating environmental protection, cultural heritage, public policy, and community stewardship.

Community-Driven Conservation Approaches

Dark sky tourism has emerged as a powerful tool for rural development, offering economic benefits while promoting environmental conservation. Banack and Hvenegaard (2020) illustrate this through the Jasper Dark Sky Festival, which successfully integrates astronomy tourism with rural community growth. Their research highlights how dark sky initiatives not only preserve nocturnal environments but also enhance community pride and engagement. These events demonstrate the potential for rural areas to attract visitors while safeguarding cultural heritage and natural landscapes, aligning tourism efforts with broader conservation goals.

Community-driven conservation is essential for the long-term success of dark sky preservation. Dunn and Edensor (2024) emphasise that involving the local residents in governance and protection leads to more sustainable outcomes, as conservation efforts resonate more when aligned with community values. Jackson et al. (2025) and Ye et al. (2019) note that integrating spatial data and local governance further strengthens these initiatives. Khan (2024) emphasises the value of creative outreach through art, which fosters deeper community engagement and raises awareness. By combining artistic expression with grassroots stewardship, communities can

forge lasting connections with the night sky, ensuring that dark sky reserves retain both ecological and cultural significance.

Astro-Tourism as a Sustainable Development Strategy

Astro-tourism is increasingly recognised as a sustainable tourism strategy that integrates environmental conservation, scientific engagement, and local economic development. In Southeast Asia, it offers opportunities to raise public awareness and generate income in rural and peri-urban communities (Leong, 2023). However, the success of astro-tourism hinges on the quality of the night skies, which are threatened by light pollution. Well-preserved dark skies enhance visitor experiences and minimise ecological disruption (Kanianska et al., 2020). To balance tourism growth with sustainability, policies must regulate artificial lighting and promote eco-conscious infrastructure (Escario-Sierra et al., 2022; Özder, 2024). These efforts are most effective when guided by community-driven strategies that ensure inclusive governance and localised knowledge-sharing. Reagan (2024) emphasises the importance of principles that safeguard the nighttime environment, protect indigenous knowledge, and ensure local communities benefit from astro-tourism.

Beyond environmental and economic gains, astro-tourism fosters cultural enrichment and community stewardship. Storytelling that blends scientific, indigenous, and historical narratives enhances visitor connections to the landscape and strengthens local identity (Gerasimova, 2021; Jacobs et al., 2020). Community involvement in tourism planning encourages conservation values and positions the locals as stewards of dark skies. This participatory approach supports heritage preservation and ecological resilience, aligning astro-tourism with broader sustainability objectives. Mohd Nawawi et al. (2022) highlight that engaging local communities in astro-tourism is vital for reducing light pollution, enhancing night-sky appreciation, promoting scientific literacy, and encouraging responsible tourism practices.

Best Practices for Dark Sky Conservation and Sustainable Astro-Tourism

Dark sky conservation research accentuates the integration of eco-

tourism and sustainable tourism practices to combat light pollution and protect nocturnal environments. Effective policies and regulations are vital in promoting responsible lighting and preserving natural nightscapes (Welsh Government, 2025). For example, the NSW Government's Dark Sky Planning Guideline limits artificial lighting near observatories, supporting both astronomical research and environmental sustainability. Case studies from western China illustrate that conservation success stems from responsible lighting, community participation, and policies that address ecological, cultural, and health concerns (Pan et al., 2025). Silver and Hickey (2020) highlight that dark sky preserves offer valuable models for managing light pollution through planning and community engagement, informing future efforts to balance development with conservation.

The establishment of Dark Sky Parks, as highlighted by Alva et al. (2023), demonstrates the importance of interdisciplinary collaboration among conservationists, astronomers, policymakers, and communities. Areas such as Pantai Kelanang can adopt such models by promoting responsible outdoor lighting and involving the locals in conservation efforts. This approach not only safeguards nocturnal ecosystems but also fosters economic opportunities and strengthens community awareness (Silver & Hickey, 2020). The increasing recognition of dark sky initiatives as drivers of both environmental and tourism benefits reinforces the value of community-driven conservation. By integrating ecological, cultural, and social dimensions, collaborative efforts can ensure that dark sky preservation becomes a sustainable and widely shared goal.

STUDY AREA

Pantai Kelanang is located in Banting, Selangor, along the Straits of Malacca (Figure 1); it is known for its sandy beaches, mangrove forests, and biodiversity. It attracts nature lovers for stargazing, birdwatching, and coastal activities. The area holds ecological significance as a habitat for various wildlife, but is increasingly threatened by urban expansion. Its proximity to both urban centres and natural resources makes it a key site for urgent conservation. Additionally, its historical and cultural value enhances its role in heritage preservation and sustainable tourism.

The justification for selecting Pantai Kelanang as a case study lies in its combination of natural beauty, ecological importance, and vulnerability to urbanisation. As a once-renowned stargazing destination, its dark skies are now threatened by the expanding urban infrastructures in nearby areas.



Figure 1. Key Plan (left) and Location Plan (right) of Pantai Kelanang, Kampung Kelanang, Banting

Source: <https://www.google.com/maps/place/Pantai+Kelanang/@2.7905207,101.4101038,1011m>

This presents a key opportunity to explore community-driven conservation strategies that can safeguard its natural nightscape while promoting sustainable astro-tourism. The criteria for this case study align with the research parameters of dark sky conservation, sustainable tourism, and community engagement. Pantai Kelanang offers a compelling setting to examine how responsible tourism practices and dark sky preservation can coexist to protect both the environment and the local heritage. Moreover, the area's capacity to balance tourism development with environmental sustainability makes it an ideal candidate for understanding the integration of conservation and tourism in a rapidly urbanising context.

RESEARCH METHODOLOGY

This study employed both qualitative and quantitative research methods, combining site observations, expert interviews, and a survey questionnaire to gather comprehensive data on the conditions affecting Pantai Kelanang's dark skies and its potential for sustainable astro-tourism.

Site observations were conducted from October to November 2024, with a focus on assessing Pantai Kelanang's dark sky quality

and infrastructure. Using the Bortle Light Pollution Scale, the site was classified as Class 5 (Suburban Sky), indicating moderate light pollution. Observational data included the visibility of celestial objects, the presence and intensity of artificial light sources, cloud cover, and the influence of nearby urban development. Additionally, observations evaluated existing stargazing infrastructure such as benches and nearby mosques, identifying safety concerns related to the presence of monkeys and stray dogs, and the general suitability of the facilities for astro-tourism.

Expert interviews were conducted with professionals from Planetarium Negara, the Majlis Perbandaran Kuala Langat (MPKL), and SALUT (Sahabat Langit Utara). These interviews provided qualitative insights into the current infrastructure limitations, the challenges of managing light pollution, and potential strategies for community participation in dark sky preservation. Experts also offered recommendations for infrastructure improvement and emphasised the importance of policy support and community engagement in promoting sustainable astro-tourism.

A survey questionnaire was distributed to 33 respondents, including both experts and local visitors. The data collected focused on perceptions of night sky quality, concerns regarding light pollution, and opinions on the adequacy of existing facilities for stargazing. Responses highlighted key issues affecting the stargazing experience and informed the development of community-driven conservation strategies, including sustainable lighting practices and participatory approaches for long-term dark sky preservation.

Limitation of the Study

This study faced several limitations, including a small sample size—only three expert interviews and 33 survey respondents, which may limit the diversity of perspectives. Observations were conducted only once, without accounting for seasonal variations in light pollution. The focus on Pantai Kelanang also limits broader generalisation to other coastal areas. Additionally, infrastructure assessment lacked quantitative analysis, and socio-cultural aspects of dark sky preservation were not fully explored, highlighting the need for deeper community and cultural engagement in future research.

RESEARCH FINDINGS

The following findings were derived from a combination of on-site observations and expert interviews with representatives from relevant agencies, including Planetarium Negara, Majlis Perbandaran Kuala Langat (MPKL), and SALUT. These insights provide an inclusive understanding of the current conditions, challenges, and potential of Pantai Kelanang in relation to dark sky conservation and astro-tourism development.

Degrading Sky Quality Due to Light and Air Pollution

Pantai Kelanang is classified as Bortle Class 5, indicating moderate light pollution. Experts suggest that urbanisation and unregulated lighting may have already shifted the site towards Bortle Class 6 or 7, further degrading celestial visibility. Additionally, air pollution, particularly haze from nearby agricultural activities, intensifies skyglow and diminishes sky clarity, compromising stargazing opportunities and making the site less suitable for astro-tourism.

Lack of Astro-Tourism Infrastructure and Safety Concerns

Pantai Kelanang lacks purpose-built infrastructure for astro-tourism, such as observation platforms and adequate lighting for safety and convenience. Existing amenities, such as benches and the nearby mosque, are insufficient for night-time use. Additionally, the presence of stray dogs and monkeys creates safety risks for visitors, limiting the site's potential to host organised stargazing events and attract tourists.

Absence of Lighting Regulations and Need for Management

Unregulated artificial lighting is a significant source of skyglow at Pantai Kelanang. There are no formal lighting guidelines or measures to control light pollution. Experts recommend implementing dark-sky-friendly solutions, such as shielded lighting and lighting curfews, to reduce brightness and protect the nocturnal environment. These measures are essential to mitigating light pollution and maintaining the site's suitability for dark sky preservation and astro-tourism.

Need for Collaborative, Community-Driven Conservation

Experts highlighted the importance of collaboration among local authorities, advocacy groups, and the community in preserving Pantai Kelanang's dark sky environment. Currently, there is no formal dark sky conservation initiative, and efforts are fragmented. Successful conservation requires technical solutions, public education, and community involvement. Engaging local stakeholders is crucial for fostering shared responsibility and ensuring the long-term protection of the site's natural nightscape.

ii. Survey Questionnaire

The survey questionnaire was organised into four sections to comprehensively assess various aspects of Pantai Kelanang's dark sky environment and its potential for astro-tourism development. These sections were designed to gather insights into visitor profiles and engagement, perceptions of the stargazing experience, infrastructure and safety concerns, and the level of community involvement and support for dark sky conservation. Below is a summary of the significant findings from each section:

Section A: Location and Frequency of Visits

The survey found that 39.4% of respondents live near Pantai Kelanang, with 33.3% from Kampung Kelanang. Despite the proximity, only 21.2% visit the beach daily, while 45.5% visit infrequently, suggesting limited public engagement. This highlights the need for improved access and amenities to encourage more regular visits and increase community connection to the site.

Section B: Stargazing Experience and Environmental Perception

Only 9.1% of respondents stargaze regularly; 48.5% describe their experiences as moderate and 27.3% as disappointing. More than half (54.5%) of the participants cited light and air pollution as the main factors diminishing the quality of the dark sky. This finding stresses the need for targeted environmental management strategies to improve the stargazing experience and enhance the site's appeal as an astro-tourism destination.

Section C: Infrastructure, Amenities, and Safety Awareness

Safety was a major concern for 84.8% of respondents, with 66.7%

requesting clear signage and 57.6% seeking improved accessibility. However, only 30.3% prioritised dark-sky-friendly lighting, highlighting a lack of awareness among the public about its importance. Over half of the respondents (51.5%) were unaware of the existing stargazing facilities, suggesting a need for better infrastructure and public education to enhance the site's readiness for astro-tourism.

Section D: Conservation Guidelines and Community Involvement

A strong 69.7% of respondents expressed support for dark sky conservation, with urban development (78.8%) and light pollution (45.5%) identified as major threats. While most considered conservation guidelines important, 21.2% were uncertain, indicating a need for further awareness efforts. There was widespread support for community-driven activities such as stargazing events (78.8%) and workshops, showing a readiness for collaborative action and greater public involvement in conservation initiatives.

DISCUSSION

i. Environmental Threats and Fragmented Responsibility

There is alignment between expert concern and public awareness regarding the impact of pollution on Pantai Kelanang's night sky, with experts understanding technical details like Bortle classifications and the community recognising the decline in sky quality. However, this awareness lacks mechanisms for effective action due to fragmented responsibility across local authorities, agricultural actors, industries, and residents. As Bjelajac et al. (2021) suggest, dark sky preservation requires coordinated efforts across various sectors. Notably, Edensor and Dunn (2024) emphasise that integrating dark sky preservation into broader societal goals, such as sustainability and community engagement, is essential. While awareness is crucial, it must be supported by multi-level governance and regulatory measures, as highlighted by Tahar et al. (2020), to achieve meaningful change in mitigating light pollution.

ii. Community Readiness and Capacity Gaps

At Pantai Kelanang, strong community enthusiasm for dark sky conservation is evident, with local participation in stargazing activities and awareness programs. However, without consistent engagement, technical training, and leadership development, this initial excitement may fade. To ensure lasting impact, structured support systems are necessary, as seen in community-led urban agriculture efforts, where meaningful partnerships with local authorities foster long-term involvement (Nazuri et al., 2025). Providing opportunities for contribution, accessible resources, and empowerment frameworks- such as those demonstrated by participatory mapping in Seberang Perai (Zakariya et al., 2025), can strengthen community stewardship. Additionally, motivating rural communities for sustainable tourism participation has proven effective in achieving long-term sustainability goals (Abdul Kadir & Chew, 2024). Thus, community support must be cultivated through inclusive planning, capacity-building, and long-term facilitation.

iii. Infrastructure as Challenge and Opportunity

The lack of stargazing platforms, safety signage, and basic amenities at Pantai Kelanang limits accessibility and discourages night-time engagement, particularly for families and vulnerable groups. However, this gap presents an opportunity for community-led initiatives to develop culturally relevant and inclusive facilities. Effective governance and partnerships, as seen in the Al-Khawarizmi Astronomy Complex, can enhance tourism and educational outcomes through active community involvement (Muttaqin et al., 2024). Stargazing infrastructure should prioritize natural darkness, scenic beauty, and remoteness, which can be compromised by poorly planned development (Fernández-Hernández et al., 2022). Drawing from Jordan's experience, strategic investment in astronomy infrastructure, coupled with public engagement, can promote astro-tourism as both a scientific and economic driver (Abushattal et al., 2023). For Pantai Kelanang, the focus should be on co-designing infrastructure that balances conservation, safety, and sustainable tourism while enhancing place identity and community stewardship.

iv. Rethinking Lighting Awareness

The low prioritisation of dark-sky-friendly lighting at Pantai Kelanang reflects a knowledge gap and cultural perceptions linking brighter lights with safety and security. Despite technical awareness of light pollution's environmental impact (Shariff et al., 2020), local resistance may arise when proposed changes conflict with established values or practical concerns. Engaging with community narratives and values is essential, emphasising how dark-sky practices can coexist with safety and functionality. Anderson (2024) highlights the need to communicate the ecological benefits of dark skies in ways that resonate with local experiences, while Shrimplin (2023) highlights the role of cultural and historical ties to the night sky in shaping lighting attitudes. Shifting lighting behaviours will require dialogue, trust-building, and collaborative approaches that align dark-sky conservation with local values and practices.

v. Balancing Astro-Tourism Potential

Pantai Kelanang holds significant potential as a sustainable astro-tourism destination, offering natural darkness, coastal beauty, and cultural heritage. Both experts and locals view this as an opportunity to enhance the local economy and well-being. However, without careful planning, tourism growth could strain the environment and infrastructure. Sustainable astro-tourism requires balancing visitor attraction with ecosystem protection and equitable benefits. Jacobs et al. (2019) stress the importance of community-driven approaches to support conservation and local livelihoods. Examples like the Al Khawarizmi Astronomy Complex (Ahmad et al., 2022) and Dimiyati and Safiai (2024) demonstrate how local participation in astro-tourism can drive economic growth. For Pantai Kelanang, success hinges on inclusive, long-term management that benefits both the environment and the community.

CONCLUSION

This study developed a community-driven conservation strategy for protecting Pantai Kelanang's dark skies, focusing on sustainable astro-tourism. By assessing the area's dark sky environment, vulnerabilities, and existing infrastructure, key intervention areas were identified. Despite its

potential as an astro-tourism destination, light pollution and inadequate infrastructure pose significant threats, requiring strategic conservation efforts that involve the local community's participation.

The proposed guidelines emphasise responsible lighting practices, the establishment of stargazing facilities, and public awareness initiatives to preserve the nocturnal environment. These actions aim to protect the ecological and cultural heritage of Pantai Kelanang while promoting it as a sustainable astro-tourism destination. The research aligns with the global objectives of SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action), highlighting the importance of community-centred environmental sustainability.

While the study offers valuable insights, it is limited by a small sample size, including just three expert interviews and 33 community surveys, which may not fully capture local attitudes. Future research should expand the sample, include comparative studies across other coastal areas, and assess light pollution variations over time. Additionally, a more detailed infrastructure evaluation, socio-cultural aspects of dark sky preservation, and the integration of nature-based solutions and digital platforms should be explored to enhance community engagement and ensure long-term sustainability.

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DECLARATION OF AI-GENERATED CONTENT

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AUTHOR CONTRIBUTIONS

All authors contributed significantly to the conception, design, execution, and interpretation of the study. Each author was involved in data collection, analysis, and manuscript preparation, and all authors reviewed and approved the final version of the manuscript prior to submission.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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