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Development and testing of the Night Sky Connectedness Index (NSCI)

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ABSTRACT

Whilst there is a growing interest in people's relationship with the natural world, much of the literature in this area tends to focus on daytime behaviour. There is far less research that attempts to understand the importance of people's relationship to natural environments at night and particularly towards the night sky. Therefore, the purpose of this study was to design, develop and validate a new measure - the Night Sky Connectedness Index (NSCI). The items of the NSCI were created and based on relevant theory, similar types of measures, and stakeholder consultation – for both the generation and selection of items. The psychometric properties were assessed using a sample of 406 people from the general population – with any level of interest in the night sky - and of these 115 completed a test-retest follow-up survey. Exploratory Factor Analysis and reliability testing resulted in a 12-item measure with two subscales: Connection to, and Protection of the night sky. The NSCI demonstrated good to excellent internal consistency for the overall scale and for each of its subscales and shows strong test-retest reliability. There was also strong evidence for the scale's convergent, discriminant and construct validity. In addition, the findings indicated that a greater connection to the night sky was significantly and positively related to a person's mental health and happiness. Our research also suggests that those people who live in more light-polluted areas are less connected to the night sky and feel less likely to protect it. The NSCI may be useful when, (i) investigating pro-environmental and conservation behaviour, (ii) assessing the efficacy of strategies or interventions aimed at reducing light pollution, (iii) helping to restore the human-night sky relationship, (iv) informing policy and responsible lighting use, and (v) rewilding our night skies to protect our natural environment and cultural heritage.

1. – Introduction

Nature is in decline, with recent reports indicating that global biodiversity and ecosystem function is deteriorating at an accelerated rate (IPBES, 2019). Though attempts to change this trajectory have been made - through the creation of strategies like the Aichi biodiversity targets (CBD, 2011) – there has been limited success and rapid action is needed to reverse these trends. Consequently, this evidence has led some to suggest that the human-nature relationship is failing (Pocock, Hamlin, Christelow, Passmore, & Richardson, 2023). This, in turn, has resulted in an 'extinction of experience' (Soga & Gaston, 2016) and a reduction in people's connectedness to the natural world (Richardson, Hamlin, Butler, Thomas, & Hunt, 2022).

1.1. - Nature connectedness

Nature connectedness is a multidimensional construct (Harvey, Hallam, Richardson, & Wells, 2020) and reflects an individual's subjective sense of relationship with nature (Martin et al., 2020; Mayer & Frantz, 2004). The process by which people build their relationship with the natural world involves cognitive (e.g. knowledge and understanding, perception and cognitive appraisal) and affective components (e.g. emotions, feelings and experiences) (Mayer & Frantz, 2004; Schultz, 2001) and is therefore related to how they think, feel, and relate to nature (Sheffield, Butler, & Richardson, 2022). The pathways to nature connectedness are a theoretical framework that helps to explain the different ways in which people can develop a sense of connection to nature (Lumber, Richardson, & Sheffield, 2017). The pathways include the *Senses* – our direct sensory experiences of nature, *Emotion* – the positive emotions we experience when in nature (e.g. Awe and wonder), *Beauty* – appreciating the aesthetic qualities of nature, *Meaning* – the personal significance or meaning we find through nature, and *Compassion* – the way we feel towards other living beings, the natural environment and our motivation to protect and care for them. Each pathway

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reflects a different aspect of the human experience and can have unique impacts on people's well-being and attitudes toward the environment. In fact, research has shown that nature connectedness is associated with a range of positive outcomes; including greater mental and physical wellbeing (Pritchard, Richardson, Sheffield, & McEwan, 2020; Howell, Dopko, Passmore, & Buro, 2011; Nisbet, Zelenski, & Murphy, 2011), enhanced quality of life (Baceviciene & Jankauskiene, 2022), increased life satisfaction and a decreased risk of depression (Liu, Nong, Ren, & Liu, 2022). There is also evidence that a connection to nature is associated with pro-environmental behaviours, attitudes, and pro-nature conservation (Barrows, Richardson, Hamlin, & Van Gordon, 2022; Chawla & Derr, 2012; Rosa & Collado, 2019). Furthermore, some of the most beneficial effects come about when we engage in simple nature-based activities – such as smelling flowers, listening to birdsong or watching clouds (Richardson, Passmore, Lumber, Thomas, & Hunt, 2021) – as they involve us actively noticing nature and tuning in, rather than simply spending time in it (Richardson et al., 2022).

Nevertheless, much of the literature written about people's relationship with the natural world tends to focus on daytime behaviour; including bird watching (White et al., 2023), walking in green or blue spaces (Keenan, Lumber, Richardson, & Sheffield, 2021; Nisbet, Zelenski, & Grandpierre, 2019; Samus, Freeman, Van Heezik, Krumme, & Dickinson, 2022), taking part in citizen science projects such as butterfly counts (Pocock et al., 2023) or specific interventions like forest bathing (Kotera, Richardson, & Sheffield, 2020). However, there is considerably less research that explores people's relationship with natural environments at night and the night sky. In fact, there has been only one study that has investigated nature connectedness during nighttime hours as a separable phenomenon from daytime nature-related behaviour. The study by Bell, Irvine, Wilson, and Warber (2014) used the term 'Dark Nature' to refer to activities that promote interaction with nature in the nocturnal environment. Their research involved the recruitment of stargazers, who completed a brief survey asking about their stargazing experience, interaction with and experience of nature (do they see nocturnal animals or not) and the potential wellbeing benefits that may come from time spent stargazing (as an open-ended question - What do you enjoy most about Stargazing? and 'Does Stargazing enhance your life?). Their findings suggest that those who had been into the hobby for a longer period (>5 years) and those who said they saw wildlife whilst stargazing, were more likely to demonstrate a greater connection to nature. However, while this study does contribute some valuable insights, it is important to recognise its limitations. First, the study was limited in scope - no other (quantitative) comparisons were made. The only comparison reported was between Nature Connectedness and (i) years spent stargazing, and (ii) participant age. Second, their sample was very small (N = 29), and whilst they acknowledge their work was a pilot study, it is difficult to make firm conclusions from this number of participants. Third, the study was limited by the specificity of available nature connectedness scales. Existing measures generally refer to nature in broad terms and aren't tailored to the unique aspects of nature at night.

1.2. - *Dark-Skies, light pollution, and their impact*

As villages, towns and cities become more densely populated through the process of urbanisation, it can lead to a significant impact on both natural and designed ecologies (Russo & Cirella, 2020). As more people move into cities and urban areas, natural habitats are destroyed or altered, and wildlife is displaced (Fenoglio, Calviño, González, Salvo, & Videla, 2021; Theodorou, 2022). Urbanisation will also typically result in an increase of artificial light being used to illuminate things like streets, buildings, and other types of infrastructure. Indeed, one of the most significant things likely to impact people's ability to connect to nature at night and the night sky is likely to be the extent of light pollution (Artificial Light at Night is often referred to as ALAN): such as that created by *Glare* – from street lighting, *Light trespass* - that creeps in through the windows, Clutter – the use of excessive lighting, and *Sky Glow* – created from upward reflected light. Light pollution has reached such an extent that around 80% of the world is now impacted and the night sky became brighter by 9.6% per year from 2011 to 2022 (Kyba, Altıntaş, Walker, & Newhouse, 2023).

Therefore, the collective impact of light pollution is not just limited to the loss of natural dark skies and celestial views, but also to our ecological systems – plant, animal and human. For example, there is evidence from published briefings (Barentine, 2022) and research that suggests light pollution has a significant impact on; (i) animals' ability to hunt, reproduce, navigate or find suitable habitats (Berger, Lozano, Barthel, & Schubert, 2020; Bird & Parker, 2014; Boyes, Evans, Fox, Parsons, & Pocock, 2021; Dutta, 2018; Mariton, Kerbiriou, Bas, Zanda, & Le Viol, 2022; Van Doren et al., 2021), (ii) trees (Bennie, Davies, Cruse, & Gaston, 2016), and (iii) human physical health – such as to sleep, circadian rhythms and obesity (Dominoni, Borniger, & Nelson, 2016; Le-Bing Wang et al., 2022; Paksarian et al., 2020; Walker et al., 2020). In addition, light pollution also results in substantial energy loss when it is used needlessly or ineffectively (Falchi et al., 2019; Meier et al., 2015) and the absence of natural dark skies may also impact our cultural and historical heritages (Dalgleish & Bjelajac, 2022; Falchi, Bará, Cinzano, Lima, & Pawley, 2023). Nevertheless, despite attempts to raise awareness of things like light pollution, to promote responsible outdoor lighting use and encourage interest in the night sky by advocacy groups (including the Dark Sky Association - https://www.darksky.org/), it still remains a significant problem.

1.3. - *The human night sky relationship*

People may experience and access the night sky in many ways. These experiences may occur during incidental events (e.g. such as walking home at night) or through actively sought-after encounters (e.g. at star parties, observatory outreach events or Astro tourism sites), whilst at home or when away at dark sky locations where skies are pristine and away from sources of ALAN, or enjoyed as a solitary event or together with others; as part of clubs or groups – witnessing astronomical events unaided, with a visual telescope, or perhaps where (Astro) photography is used to capture celestial objects.

However, there is a distinct lack of research that investigates people's connection to the 'natural world at night' and their emotional and experiential relationship with the night sky. Indeed, people may experience the same level of awe and wonderment of the night sky and nighttime environment as they do with the daytime one (Liu et al., 2023). Nevertheless, much of the work that has investigated the psychological impact of night sky watching to date has been conducted by Kelly (2003; 2019). In his original work, Kelly proposed that night sky-related behaviours and attitudes (Kelly, 2003; Kelly et al., 2006; Kelly & Kelly, 2003; Kelly & Kelly, 2014) are accounted for by a factor he termed "Noctcaelador" which he defines as an "emotional attachment to, or adoration for, the night sky" (Kelly, 2003, p. 196). Kelly also developed the first measure of Noctcaelador (the Noctcaelador Index). His work has shown differences between Noctcaelador and a person's gender role orientation whereby people who identify as being androgynous – rather than feminine or masculine – engage in significantly more night-sky watching (Kelly & McGee, 2012). Kelly and McGee argue that this is because those who have an androgynous gender role are more open to experience. However, they did not find any significant differences between Noctcaelador and whether someone identified as Male or Female. Likewise, Kelly (2008) has investigated the associations between Noctcaelador, and aesthetic sensitivity toward the night sky. He specifically looked at people's tolerance for complexity, ambiguity and scanning of the night sky, and very specific (psychoanalytic) aspects of personality - what he referred to as, regression in service to the ego – maintaining one's current perspective of reality (mature thought) whilst being able to regress to fantasy based (immature) thoughts. Individuals in this study who were higher in Noctcaelador were also higher in tolerance of

ambiguity, scanning and regression in service to the ego and it is these qualities that are associated with aesthetic sensitivity. Furthermore, Noctcaelador has also been linked to problem-solving and creativity (Kelly, 2005; Kelly & Kelly, 2014) whereby Noctcaelador was positively associated with problem orientation and solving, as well as positively being associated with creative engagement, cognitive style, spontaneity and having a rich and active fantasy life.

However, Kelly's (2009) theoretical position is slightly limited, as it refers to the concept of Noctaelador as related to a person's psychic structures (the ego) and the night sky as an attachment object. Instead, it may be better to conceive of people's affinity for the night sky as 'Night Sky Connectedness' (NSC) and that it can be better explained using the theoretical framework of the pathways to nature connectedness (Lumber et al., 2017). That is to say that people's connection to the night sky and night-time environment can be considered as part of the same theoretical whole (nature connectedness), but thought about and distinguished by its variation in biodiversity, sensations, experience and challenges to access. Therefore, from this perspective, a person's interaction with the night sky and nocturnal environment may be understood and enhanced through similarly themed pathways: the *Senses* - sensory contact with the night sky and nocturnal environment, *Emotion* – the emotional bond with and love for the night, *Beauty* - taking time to appreciate the beauty of the night sky and celestial world – its constellations, moons and planets, galaxies, star clusters, meteor showers and nebulae, *Meaning* - thinking about the (personal and cultural) meaning and signs of the night sky and celestial world, and *Compassion* - showing care for the night sky and celestial world through protecting it. This theoretical position may also offer a useful starting point too, in terms of understanding the barriers that may prohibit or impact the experience or prevent access to the night sky. In the wider literature, we know that factors such as the weather (Elliott et al., 2019), perceived safety (Weimann et al., 2017) and abundance or access to natural spaces (Passmore et al., 2021) collectively impact nature contact and connectedness. The same sorts of factors may also play an important role when accessing natural *dark sky spaces*.

Therefore, the aim of this study was to develop and validate a new measure of Night Sky Connectedness for four main reasons. First, although the evidence supporting the mental health benefits of nature is growing rapidly, the focus often remains on nature connectedness during the daytime. Indeed, there is a severe lack of research that investigates people's connection to the natural environment at night or towards the night sky, and how night sky connectedness may relate to other factors (such as wellbeing). Secondly, whilst there is a substantial and detrimental impact of light pollution on all forms of life, very little is known about the psychological impact of light pollution on the functioning of humans. Thirdly, the existing theoretical conceptualisations, such as Noctcaelador, have limitations. Creating a new scale that incorporates insights from the Pathways to Nature Connectedness may provide a more effective means to measure people's connection with the night sky. The Pathways would provide a more comprehensive framework that would enable a better understanding of people's relationship with (instead of attachment to) the natural environment at night or towards the night sky. Fourthly, existing measures of nature connectedness do not contain items that relate sufficiently to the natural environment at night or the night sky. A measure of this kind may open up a new avenue of research and allow researchers, policymakers, and organisations to …

- Identify and develop a more sustainable relationship with the natural world at night.
- Design, implement and assess the types of behaviour change policies that have benefits to our natural environment, biodiversity and human health.
- Evaluate the effectiveness of broad-based interventions that attempt to rewild the nightsky and restore natural darkness (e.g. when establishing darksky reserves).
- Investigate the factors that may be of the most importance to the human-night sky relationship.

2. - Methods

2.1. - Design

This study was divided into two parts: Part-1 – which involved the generation and selection of items, and *Part-2* – which tested the reliability and validity of the NSCI. *Part-1* included interviews and consultation with, (i) Experts in Nature Connectedness and dark-sky advocates, (ii) Professional or Amateur astronomers, and (iii) anyone from the general public with an interest in the night sky or celestial phenomenon. Participants were recruited through advertisements on social media (Facebook) groups and personal/university Twitter/LinkedIn/Reddit. Interviews were conducted with participants and a separate rating process for items (assessing their suitability and phrasing) was also conducted. In *Part-2* a cross-sectional survey design was used and the pilot measure and accompanying questionnaires were uploaded to Qualtrics [TM]. The online survey was advertised through social media too. Ethical clearance was gained from the College Research Ethics Committee at the University, and adhered to guidelines set out by the British Psychological Society.

2.2. - Participants & procedure

2.2.1. Part-1 – Item generation and selection

In this part of the study, items were generated based on interview data, a consultation with experts and darksky advocates, and a review of the literature. Fourteen interviews were carried out in MS Teams, where participants either had a formalised (e.g. visual astronomers, astrophotographers, dark-sky advocates) or non-formalised interest in the night sky (e.g. not pursued as a hobby, professionally or some sort of voluntary role). In our sample nine people identified as male and five as female. Eight resided in the UK, with one each from Greece, Bangladesh, Israel, Belgium, Australia, and North America. A total of eight participants specified an interest in visual astronomy, two had an interest in astrophotography in addition to visual astronomy, and four did not own a telescope of any kind and instead preferred using their eyes to view the night sky. The age of participants ranged from 24 to 59 (mean = 42). Participants were asked a range of questions to build up a picture of how they would define night-sky connection, their relationship to the natural world at night and whether they saw the night sky as inclusive of the broader natural environment. Interviews were conducted with each person individually by the lead author, were audio recorded and transcribed verbatim, and on average lasted 50 min. Participants spoke about what interested them in the night sky, whether they felt a connection or not to it, how they experienced the night sky and the nighttime environment through their senses, its potential beauty, what it meant to them, how the experience made them feel emotionally, and whether they felt a sense of compassion to protect it (from things such as light pollution). The primary purpose of this part (of our study) was to generate an initial set of questions for the NSCI from these conversations. An item pool of 12 questions was generated and is available in the supplementary information file. All participants in the interviews were then followed up and asked to comment on the items in terms of their relevance to their connection with the night sky, general suitability and appropriateness, and wording – clarity, independence (from other questions), readability, and conciseness. Of note, we did go on to analyse the interview data using a reflexive thematic analysis (Braun & Clarke, 2006) though the findings from that qualitative analysis are not reported here.

2.2.2. Part-2 – Reliability and validity testing

The 12-item measure was then taken forward and full psychometric testing was conducted with participants (aged 18+) who had any level

of interest in the night sky (N = 406). Our inclusion criteria were purposefully broad and it did not matter whether participants' interest in the night sky was frequent or not – any level of interest was fine. The sample demographic characteristics for these participants appear in Table 1. The sample size was determined according to best practices for scale development (Boateng, Neilands, Frongillo, Melgar-Quinonez, & Young, 2018), where it is considered that there should be a ratio of at least 10 participants per item in order to reliably compare patterns in the data (Irvine et al., 2023).

2.3. Measures

2.3.1. Night Sky Connectedness Index (NSCI)

The scale developed and reported in this paper has 12 items and 2 subscales ([i] Connection [9 items], and [ii] Protection [3 items]) and is a measure of a person's connectedness to the nightsky. Participants rate their responses on a 10-point Likert scale (0 = Strongly Disagree, and 10 = Strongly Agree) and can score between 0 and 120; 0–90 for Subscale-1, and 0–30 for Subscale-2, where a higher score indicates a greater connection with the night sky. Each item score is summed and there are no reverse-scored items. The readability statistics for the measure were provided as part of the functionality of MS Word and included a Flesch Reading Ease (FRE) of 84%, and a Flesch-Kincaid Grade level of 3.6 - the closer to 100% the FRE value is the better or easier it is to read meaning that the text in the NSCI scale can be read and understood by a 3–4th-grade student (8–10 years old). The scale takes an average of 3–4 min to complete, and no cut-off scores have been established or reported in this paper. The items and measure were informed by Nature Connectedness theory (Lumber et al., 2017), and similar types of measures; the Nature Connectedness Index (NCI, Richardson et al., 2019) and the Noctcaeladador Inventory (NI, Kelly, 2004). In line with these guidelines, our measure has been worded to mirror the pathways to nature connection and people's relationship to the natural world at night. The Cronbach Alpha's for this measure and all others mentioned below can be seen in Table 2.

Table 1
Characteristics of respondents (n %) for the Phase-2 (part-2) reliability and validity testing.

	Sample N = 406 n (%) or Mean (S.D.)	Retest/follow-up Sample (n = 115) n (%) or Mean (S.D.)
Age	42.92 (15.57)	46.43 (16.60)
Gender (Male/Female/Prefer to self-define)	172 (42.4%)/224 (55.2%)/10 (2.5%)	56 (48.7%)/57 (49.6%)/ 2 (1.7%)
Bortle Scale (light pollution rating at home address)	5.63 (1.55)	5.47 (1.38)
How often do they view or take pictures of the night sky?		
Rarely (Less than 2–3 times per year)	56 (13.80%)	11 (9.6)
Casually (A small number of times every few months)	102 (25.12)	23 (20)
Regularly (Frequently, and most months)	145 (35.71%)	51 (44.3)
Always (Almost every opportunity I get)	103 (25.37%)	30 (26.1)
Which of the following ways do you view/photograph the night sky?		
Eyes	387 (95.3%)	110 (95.7%)
Binoculars	122 (31%)	39 (33.9%)
Visual telescope	138 (34%)	44 (38.3%)
Smartphone	263 (64.8%))	71 (61.7%))
Digital/DSLR	148 (36.5%)	36 (31.3%)
Dedicated Astronomy Camera	39 (9.6%)	11 (9.6%)
Where do you view or photograph the night sky?		
At home (in or around my property)	346 (85.2%)	104 (90.4%)
Away from home (a short walk or commute from home)	170 (41.9%)	53 (46.1%)
Away from home (whilst on holiday)	199 (49%)	56 (48.7%)
Away from home (at an astronomy event or dark site)	82 (20.2%)	28 (24.3%)
Would you describe yourself as any of the following?		
I'm a visual astronomer	108 (26.6%)	43 (37.4%)
I'm an astrophotographer	51 (12.56%)	12 (10.4%)
I'm both a visual astronomer and astrophotographer	41 (10.10%)	14 (12.2%)
None of these	206 (50.74%)	46 (40%)
Do you attend an astronomy club?	Yes – n = 51 (12.56%)/No – n = 355 (87.44%)	Yes – n = 17 (14.78%)/ No – n = 98 (85.22%)

2.3.2. Noctcaelador Inventory (NI; Kelly, 2004)

We used the 10-item version of this measure. It is reported to assess people's attachment to the night sky. Items are measured on a 5-point Likert scale ranging from Strongly Disagree to Strongly Agree. Scores can range from 10 to 50 where a higher score indicates a greater attachment to the night sky. The scale has been established to be valid and reliable and exists in other forms (Kelly, 2019).

2.3.3. Nature Connectedness Index (NCI, Richardson et al., 2019)

The NCI is a (6-item) measure of nature connectedness based upon the pathways to nature connectedness – emotion, beauty, senses, meaning and compassion. A 7-point response scale, (completely agree – completely disagree) is used for the participant's rating, and a weighted points index from zero to a maximum score of 100 is used for scoring. A higher score indicates a greater nature connectedness. The measure has been widely used, has a unidimensional factor structure – Nature Connectedness, and excellent reliability and validity.

2.3.4. Difficulty in Emotion Regulation Scale (DERS-18; Victor & Klonsky, 2016)

The DERS-18 is a (18-item) measure of emotion regulation – consisting of an awareness, emotional acceptance, impulse control and access to strategies of emotion regulation – that assesses the difficulties in emotion regulation at a clinical level (Victor & Klonsky, 2016). Items are rated on a 5-point Likert scale (1 = almost never, to 5 = almost always) and summed to create a final score. Total scores can range from 18 to 90, with higher scores indicating greater difficulty with emotion regulation (Gratz & Roemer, 2004).

Table 2
Cronbach's alpha, mean (s.d.) values for all measures.

Measure	Cronbach's Alpha	Mean (S.D.)/ Range
NSCI Total Scale	.90	100.30 (15.26)/ 58-120
NCPS-E Sub-Scales (n = items)		
Subscale-1 - Connection (9)	.90	78.32 (10.94)/ 42-90
Subscale-2 - Protection (3)	.75	21.98 (6.14)/1-30
Noctcaelador Inventory (NI)	0.89	42.93 (6.09)
Nature Connectedness Index (NCI)	0.90	71.16 (25.31)
Brief Resilience Scale (BRS)	0.91	19.56 (5.84)
Difficulties in Emotion Regulation Scale (DERS)	0.87	90.00 (18.31)
Oxford Happiness Scale (OHS)	0.82	32.39 (7.93)
Five Facet Mindfulness Questionnaire (FFMQ)	0.75	393.17 (45.18)
Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS)	0.86	22.30 (3.88)

*Cronbach's α value range and rating – 0.70–0.79 = good; 0.80–0.89 = very good; 0.90–0.95 = excellent.

2.3.5. The Five Facet Mindfulness Questionnaire (FFMQ; Bohlmeijer, Ten Klooster, Fledderus, Veehof, & Baer, 2011)

The FFMQ measures facets of describing, observing, non-judging of inner experience, acting with awareness and non-reactivity to inner experience (Bohlmeijer et al., 2011). The short form uses 24 items, 11 of which are reverse scored. It uses a Likert scale from 1 = never or very rarely true, to 5 = very often or always true. Scores can range from 24 to 120, where higher scores indicate greater mindfulness. The short form has been used in both clinical and non-clinical populations to explore the efficacy of mindfulness in coping with real-life problems (Baer, 2019).

2.3.6. Brief Resilience Scale (BRS; Smith et al., 2008)

The BRS is a valid and reliable measure of trait resilience providing a good indication of an individual's capability to 'bounce back' from challenges. The BRS is a 6-item scale (Smith et al., 2008). It is rated on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree, with items summed and averaged to create a total score, whereby higher scores indicate greater resilience.

2.3.7. The Oxford Happiness Questionnaire (OHS; Hills & Argyle, 2002)

The Oxford Happiness Questionnaire is designed to measure individual happiness and is based on the Oxford Happiness Inventory (OHI). The OHQ is valid and reliable; researchers found "a battery of personality variables known to be associated with well-being [that] were stronger for OHQ than for the OHI" (Hills & Argyle, 2002, p. 1073). This questionnaire has 29 self-report statements for responses on a 6-point Likert scale. We are using the shortened 8-item version.

2.3.8. The Short Warwick-Edinburgh Mental Well-Being Scale (SWEMWBS)

This 7-item scale is comprised of only positively worded items relating to different aspects of positive mental health measured on a 1–5 Likert scale (1 – none of the time; 5 – all of the time).

2.3.9. Demographic information

We also asked participants to provide their gender, age, ethnicity, Post or Zipcode (used for light pollution information*[1]), Country, night sky viewing frequency (Rarely [Less than 2–3 times per year]; Casually [A small number of times every few months]; Regularly [Frequently, and most months]; and Always [Almost every opportunity I get]), if they considered themselves to be an astronomer (Visual/Astrophotographer/Both), if they belonged to an astronomy club, how they view (Eyes only, telescope, binoculars) or take photographs (Dedicated camera, DSLR, Smartphone) of the night sky.

2.4. - Data analysis

Data, in Part-2 of the study, were analysed in one of two main ways to provide information about the NSCI's psychometric properties. The tests described below are separated into those that relate to reliability and those that concern the validity of our measure.

Firstly, we performed reliability analyses using Cronbach's α coefficient (internal reliability/consistency), and a Pearson's correlation was employed to examine the external/test-retest reliability. We expected to find Cronbach's alpha and Pearson's correlation values of >0.7.

Secondly, we investigated the scale's convergent, discriminant, and construct validity. When examining the scale's convergent/discriminant validity we conducted a Pearson's correlation between the total scores of the NSCI and the other psychological measures. We expected to find nonsignificant or weak correlations (0–0.39) with factors of dissimilar constructs (BRS, DERS, FFMQ) and moderate correlations (0.40–0.59) with those that were similar (i.e. Noctcaelador and Nature Connectedness).

It was also expected that our scale would respond in theoretically predictable ways in order to test the construct validity of our measure. We anticipated that, in keeping with the literature on nature connectedness, we would find that a greater connection to the night sky would be positively correlated (Pearsons) to wellbeing (as measured by the SWEMWBS and OHS), as well as negatively correlated to Bortle score – the greater light pollution is where someone lives, the less connected they will feel towards the night sky. Furthermore, we predicted that those participants who, (i) identified themselves as having a more formalised status/interest in astronomy and/or (ii) reported taking part in more frequent night-sky-related activities would also have a higher connection to the night sky. We tested the latter hypothesis using a two-way ANCOVA – controlling for age and used pairwise comparisons for post-hoc analyses.

A one-way ANOVA was also used to test whether there were sex-based differences between NSCI scores. In the work by Kelly and McGee (2012) there have been nonsignificant differences reported between Noctcaelador and sex, and we expected to find the same. In addition, we used multiple linear regression to assess the combined effect of all factors correlated with wellbeing. The purpose of the test was to examine the extent to which NSCI contributed to the model and whether there were independent effects of NSCI on wellbeing.

Finally, we used Exploratory Factor Analysis (EFA) with a principal components analysis extraction method and a direct Oblimin (oblique) rotation to explore the factor structure of the NSCI. An Oblique rotation is generally chosen when there is a theoretical or empirical basis to expect that the factors/subscales are correlated. Factors can be correlated to varying degrees, reflecting potential real-world relationships among them. Orthogonal rotations (such as Varimax) on the other hand assume that the factors are independent of each other. When we examined the component correlation matrix table there was evidence that the factors were related and above the threshold value of 0.32 - all factors were in fact above $r = 0.40$. Therefore, we chose to implement an oblique rotation. All analyses were conducted in SPSS version 28, tests were two-tailed with a significance level set at $p < 0.05$, and we also report the 95% confidence intervals following analyses [Lower Bound (LB)/Upper Bound (HB)]

3. - Results

Cronbach Alphas, as well as mean (s.d.) scores for all measures are shown in Table 2; the Exploratory Factor Analysis (EFA) in Table 3; and

Table 3
Factor analysis for the NSCI scale.

Item		Factor Loading	
Subscale-1 - Connection			
1	I find beauty in the night sky.	.74	
2	Spending time under the night sky is important to me.	.51	
3	Being under the night sky is an incredible feeling.	.82	
4	I feel completely absorbed by the night sky.	.81	
5	Being under the night sky is an amazing experience.	.90	
6	Being under the night sky makes me happy.	.79	
7	Being under the night sky makes me feel calm and relaxed.	.77	
8	I feel at home under the night sky.	.43	
9	I feel part of the night sky and universe.	.52	
Subscale-2 – Protection			
10	I protect the night sky from light pollution.		.89
11	Preserving dark night skies is important to me.		.72
12	The night sky is an important part of my natural and cultural heritage		.81

[1] *Bortle Scale scores can be obtained from Postal/Zip codes to gain a broad indication of the relative light pollution at their home address. The Bortle Scale is a nine-level numeric scale that measures the night sky's and stars' brightness (naked-eye and stellar limiting magnitude) at a particular location. The higher the Bortle number, the higher the severity of light pollution. We used satellite (VIIRS) data – from www.lightpollutionmap.info – to obtain each Bortle Score.

inter-measure correlations in Table 4.

3.1. - Internal and external (test-retest) reliability

As can be seen in Table 2 the NSCI has an excellent Cronbach's α value for the overall scale and Subscale-1. It was good for Subscale-2. The analysis also indicated that none of these values could be increased through the deletion of an item. Therefore, the final scale consisted of 12 items, with scores for each item summed together to form either an overall NSCI score or a subscale score. In addition, test-retest reliability was done with a sub-sample of participants three months following their initial completion of the survey. Only the NSCI scale was completed by participants at follow-up. The test-retest/intra-class correlation (n = 115) was good and significant (r = 0.80, p < 0.001) and this was also the case for Subscale-1 (r = 0.82, p < 0.001), and Subscale-2 (r = 0.72, p < 0.001).

3.2. - Factor structure

To investigate the factor structure of the measure a principle components analysis with a direct Oblimin rotation was conducted on the 12 items of the NSCI. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, which assesses the suitability of the data for factor analysis, was found to be 0.92. This value exceeded the recommended threshold of 0.6, indicating a high degree of sampling adequacy (Li, Huang, & Feng, 2020). In addition, Bartlett's Test of Sphericity reached statistical significance (2554.08, *df* = 66, p < 0.001), indicating that there was significant shared variance among the variables and supporting the factorability of the correlation matrix. To ensure a meaningful factor structure, loadings below 0.4 were suppressed as they indicate weaker associations between the items and the factors (Shrestha, 2021). A two-factor structure emerged with an Eigenvalue over 1, explaining a total of 63.29% of the variance in the scores. Factor loadings and the retained 12 items are reported in Table 3.

3.3. - Validity

As predicted the total Night Sky Connectedness Index (NSCI) score significantly (and positively) correlated with the Noctcaelador Inventory (NI), and the Nature Connectedness Index (NCI), due to their conceptual similarity and provides evidence for the convergent validity of the measure. In line with expectations the NSCI also weakly correlated with measures that were conceptually dissimilar (BRS, DERS, FFMQ) which provides evidence for the divergent validity of the measure. Inter-measure correlations can be seen in Table 4.

In relation to the construct validity of our measure, we also investigated the association between NSCI score and (i) Light pollution (Bortle Score), (ii) Astronomer status and frequency of night sky viewing, (iii)sex-based differences, and (iv) wellbeing. The findings below are reported in that order.

3.3.1. Light pollution

As can be seen in Table 4, Pearson's correlations indicated that the overall NSCI total score was significantly (and negatively) correlated with the amount of light pollution at a participant's home address. This would appear to indicate that the more light-polluted it is (where someone lives) the less overall connection a person will feel towards the night sky. However, we also found that it was only Subscale-2 (Protection) that reached significance, and not Subscale-1 (Connection - p = 0.29). This would seem to suggest that it is people's willingness to protect the night sky from light pollution that is accounting for their overall connection and that people who live under more light-polluted skies will be less likely to protect it.

3.3.2. Astronomer status and frequency of night sky viewing

We also used a two-way ANCOVA to investigate whether people who identified themselves (i) as having a more formalised status/interest in astronomy and/or (ii) reported taking part in more frequent night-sky-related activities would have an increased connection to the night sky. We controlled for participant age as it was significantly correlated with NSCI score. Our results indicate that those people who considered themselves to be astronomers (n = 200; mean = 105.12, s.d. = 12.57, 95% CI [100.63,105.27]) had significantly higher NSCI total scores compared to those who did not (n = 206; mean = 95.61, s.d. = 16.18, 95% CI [94.83,98.74]) – (F = 15.39, df = 1, p < 0.001, η2 = 0.04). Furthermore, participants who viewed or took pictures of the night sky more frequently (Rarely (Less than 2–3 times per year; mean = 92.87, s.d. = 19.28), Casually (A small number of times every few months; mean = 96.19, s.d. = 15.84), Regularly (Frequently, and most months; mean = 101.10, s.d. = 13.53), and Always (Almost every opportunity I get; mean = 107.27, s.d. = 10.95) had significantly higher NSCI total scores compared to those who did this less frequently – (F = 8.76, df = 3, p < 0.001, η2 = 0.06). However, there was not a significant interaction between Astronomer status (astronomer or not) and frequency of engagement with the night sky by total NSCI score (F = 1.95, df = 3, p > 0.05, η2 = 0.02, power = 0.50). Table 5 provides descriptive

Table 4
Inter-measure correlations with the NSCI and its subscales.

		NSCI Subscale										
	NSCI Total	1 - Connection	2 - Protection	NI	NCI	BRS	DERS	FFMQ	SWEMWBS	OHS	Age	Bortle Score
NSCI Total	–											
NSCI Sub-Scale												
1 - Connection	0.94***	–										
2 - Protection	0.81***	0.56***	–									
NI	0.75***	0.79***	0.46***	–								
NCI	0.49***	0.46***	0.39***	0.36***	–							
BRS	0.08	0.04	0.12*	0.02	0.16**	–						
DERS	−0.15**	−0.11*	−0.19***	−0.03	−0.15**	−0.55***	–					
FFMQ	−0.05	0.08	0.007	0.05	−0.05	−0.19***	0.31***	–				
SWEMWBS	0.17***	0.14***	0.17***	0.08	0.23***	0.59***	−0.49***	−0.27***	–			
OHS	0.24***	0.20***	0.23***	0.09	0.29***	0.59***	−0.51***	−0.24***	0.69***	–		
Age	0.33***	0.28***	0.33***	0.22***	0.08	0.14**	−0.39***	−0.17***	0.19***	0.16**	–	
Bortle Score (Light Pollution)	−0.1*	−0.05	−0.16***	−0.03	−0.08	−0.006	0.08	−0.02	0.01	0.03	−0.20***	–

*<0.05; **<0.01; ***<0.001 - (NSCI – Night Sky Connectedness Index; NI = Noctcaelador Inventory; NCI = Nature Connectedness Index; BRS = Brief Resilience Scale; DERS = Difficulties in Emotion Regulation Scale; FFMQ = Five Facet Mindfulness Questionnaire; SWEMWBS = Short Warwick-Edinburgh Mental Wellbeing Scale; OHS = Oxford Happiness Scale).

Table 5
Descriptive statistics for astronomer status and frequency of night sky viewing on changes in Night Sky Connectedness score.

Astronomer Status	Frequency	Mean	Standard Deviation	N
Astronomer	Rarely	99.20	16.38	15
	Casually	103.93	12.39	44
	Regularly	103.35	12.96	75
	Always	109.27	10.15	66
	Total	*105.12*	*12.57*	*200*
Non-Astronomer	Rarely	90.56	19.91	41
	Casually	90.31	15.72	58
	Regularly	98.69	13.80	70
	Always	103.70	11.55	37
	Total	*95.61*	*16.18*	*206*

information (mean/s.d.) for NSCI score by astronomer status and the frequency of night sky viewing within each of these groups. As predicted, these findings illustrate that a formalised interest and increased frequency of viewing the night sky result in a stronger connection to the night sky.

However, we also conducted post-hoc pairwise comparisons (see Table 6) to examine differences in night sky connectedness scores based on the frequency of night sky viewing among astronomers and non-astronomers. The findings indicate that for astronomers - there were no significant differences between night sky connectedness score and frequency of night sky viewing ($p > 0.05$) whatsoever. This means that night sky viewing frequency is less likely to be an important factor in differentiating NSCI score for astronomers. For non-astronomers, on the other hand, there were significant differences between those who reported viewing the night sky *Rarely* and those who view it *Regularly* (<0.05) or *Always* (<0.001). There were also significant differences between those who reported viewing the night sky *Casually* and those who view it *Regularly* (<0.05) or *Always* (<0.001). The results for the other comparisons were not significant. This means that when people have a less formalised interest in the night sky, the amount of time that they spend going out in an attempt to view the night sky is an important factor dictating the extent to which they feel connected to the night sky.

Table 6
Pairwise comparisons of changes in Night Sky Connectedness score by astronomer status and frequency of night sky viewing.

			95% Confidence Interval	
	Mean Difference	Standard Error	Lower Bound	Upper Bound
Astronomer				
Rarely Vs Casually	−4.57	4.05	−15.32	6.18
Rarely Vs Regularly	−4.12	3.84	−14.29	6.05
Rarely Vs Always	−9.06	3.88	−19.36	1.23
Casually Vs Regularly	0.45	2.58	−6.38	7.28
Casually Vs Always	−4.50	2.64	−11.51	2.52
Regularly Vs Always	−4.94	2.30	−11.03	1.15
Non-Astronomer				
Rarely Vs Casually	−0.63	2.77	−7.98	6.72
Rarely Vs Regularly	−8.11*|	2.67	−15.18	−1.04
Rarely Vs Always	−12.55***	3.08	−20.71	−4.39
Casually Vs Regularly	−7.48*	2.41	−13.88	−1.08
Casually Vs Always	−11.92***	2.87	−19.53	−4.32
Regularly Vs Always	−4.44	2.76	−11.75	2.87

*<0.05; **<0.01; ***<0.001.

3.3.3. Sex-based differences

The literature on Noctcaelador has previously shown that there are no sex-based (Male or Female) differences when it comes to night sky attachment. Therefore, we also wanted to investigate whether this was the case in our sample. Firstly, our findings replicated the ones found in studies about Noctcaelador – we conducted a One-Way ANOVA and found a nonsignificant main effect of Noctcaelador total score and whether the person was Male (n = 172; mean = 43.31, s.d. = 5.56, 95% CI [42.47, 44.14]) or Female (n = 221; mean = 42.95, s.d. = 5.98, 95% CI [42.16, 43.75]) – ($F = 0.724$, df = 1, 23, $p = 0.822$, $\eta 2 = 0.043$). There was also a non-significant difference in NSCI total score between Males (n = 172; mean = 101.84, s.d. = 14.00, 95% CI [99.74, 103.95]) and Females (n = 221; mean = 99.50, s.d. = 15.91, 95% CI [97.39, 101.61]) – ($F = 0.815$, df = 1, 59, $p = 0.829$, $\eta 2 = 0.126$).

3.3.4. Wellbeing

Research in the field of Nature Connectedness has consistently found that a greater connection to the natural world results in better outcomes for people's wellbeing. Therefore, in this study we also wanted to investigate whether this was the case. In line with our expectations, the total NSCI score was significantly (and positively) correlated with the Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) and Oxford Happiness Scale (OHS), demonstrating that greater NSCI was related to greater mental well-being and happiness. Following this we explored whether NSCI was predictive of wellbeing scores, in combination with the other factors we measured (BRS, DERS, FFMQ). Multiple linear regression was conducted using the enter method to determine the extent to which a person's wellbeing (SWEMWBS/OHS – see Table 7.) was predicted by Night Sky Connectedness (NSCI), Resilience (BRS), Emotion Regulation (DERS-18) and Mindfulness (FFMQ). The regression equation was significant ($F(4, 386) = 66.81$, $p < 0.001$/$F(4, 386) = 74.63$, $p < 0.001$) and produced a large effect size ($R^2 = 0.41$, $R^2adj = 0.40$/$R^2 = 0.44$, $R^2adj = 0.43$), indicating that all factors, together, predicted wellbeing. There was a significant positive relationship between Night Sky Connectedness and wellbeing, a significant positive relationship between Resilience and wellbeing, a significant negative relationship between Emotion Regulation and wellbeing, and a significant negative relationship between Mindfulness and wellbeing. All factors also produced independent effects on wellbeing.

4. - Discussion

The Night Sky Connectedness Index (NSCI) is one of the first measures of its kind developed to assess the human-night sky relationship. It has been created using robust psychometric methods and is based on the pathways to nature connectedness (Lumber et al., 2017) and other similar measures (Kelly, 2004; Richardson et al., 2019). Therefore, just as those measures have enhanced our understanding of the human-nature relationship (Richardson et al., 2022), the NSCI may equip researchers, policymakers, and organisations with a means to assess people's connection to the natural environment at night and assess interventions and factors that impact the human-night sky relationship.

Indeed, the evidence presented in this paper demonstrates the scale's validity, reliability, and strong psychometric properties. The measure has excellent overall reliability, and this was the case for its subscales too. Scores on the NSCI were likewise found to be stable and consistent over time as illustrated by the test-retest values. Convergent validity was evidenced through significant positive correlations with theoretically similar constructs (Nature Connectedness and Noctcaelador). This finding provides evidence for the construct validity of the NSCI too and suggests that those who feel a greater connection to the night sky are also likely to have a stronger connection to nature. In addition, the NSCI was found to have either weak or non-significant relationships with

Table 7
Multiple Linear regression analyses – predictors of wellbeing.

	SWEMWBS					OHS				
	B	*t*	*p*	95% CI		*β*	*t*	*p*	95% CI	
				Lower	Upper				Lower	Upper
NSCI	0.10	2.40	<.05	.004	.045	0.17	4.31	<0.001	.048	.13
BRS	0.46	9.76	<0.001	.25	.37	0.45	9.67	<0.001	.48	.73
DERS	−0.19	−3.78	<0.001	−.06	−.02	−0.22	−4.57	<0.001	−.14	−.054
FFMQ	−0.12	−2.82	<.01	−.02	−.003	−0.08	−2.01	<0.05	−.03	.0002

SWEMWBS = Short Warwick-Edinburgh Mental Wellbeing Scale); OHS = Oxford Happiness Scale; NSCI = Night Sky Connectedness Index; BRS = Brief Resilience Scale; DERS = Difficulties in Emotion Regulation Scale; FFMQ = Five Facet Mindfulness Questionnaire.

measures of unrelated constructs (Resilience, Emotion Regulation and Mindfulness). This further supports the validity and conceptual distinctness of the NSCI from other scales. Lastly, an exploratory factor analysis was conducted and demonstrated that the items of the NSCI loaded onto two unique subscales: (i) Connection to, and (ii) Protection of the night sky. No cross-loading items were identified in the pattern matrix, and all items loaded cleanly and strongly onto their respective factors.

More widely, there was a significant relationship observed between Night Sky Connectedness and wellbeing; this included both the SWEMWBS (a measure of different aspects of positive mental health) and the OHS (a measure of an individual's happiness). The association between the Nature Connectedness Index and wellbeing was found to be similar in magnitude to the NSCI, though no such relationship existed between Noctcaelador and wellbeing. Therefore, Night Sky Connectedness matters because it is associated with significant benefits to a person's mental health and happiness. This finding aligns with the broader literature on nature connectedness, where there are well-established links to mental and physical wellbeing (Pritchard et al., 2020; Howell et al., 2011; Nisbet et al., 2011) and happiness too (Capaldi, Dopko, & Zelenski, 2014).

It is also important to note that all the measures employed in this work (except for Noctcaelador) were related to wellbeing to varying degrees. Therefore, we examined the predictive nature of these factors and the extent to which they explained any variance in wellbeing scores. Whilst the model was significant overall, each factor produced its own independent effects, and resilience accounted for the greatest impact on wellbeing. This is interesting because studies have shown that a connection to nature is positively related to resilience (Ingulli & Lindbloom, 2013). Furthermore, when people engage in nature-based activities - such as community gardening - this enhances resilience, enables adaptation to stressful situations and results in mental health benefits (Koay & Dillon, 2020). Therefore, activities that promote the human-night sky relationship or incorporate engagement with natural spaces at night may also explain the findings in our study. For example, Bell et al. (2014) suggests that 'dark nature' activities such as stargazing may play an important role in promoting human (physical) wellbeing.

However, there are also factors, from research that more broadly explores nature connectedness and wellbeing, that may further explain how a greater connection to the night sky contributes to mental wellbeing and happiness. For example, people who feel a deep connection to nature tend to experience lower levels of stress, anxiety, and depression. Indeed, when people engage with nature regularly, such as through outdoor activities, they tend to be more physically active, which can lead to improved physical as well as mental well-being (Sheffield et al., 2022). Perhaps this is unsurprising, since when people are out underneath the night sky it may provide opportunities for restoration, contemplation and mindfulness, and relaxation – as is the case when people enjoy nature during the day (Albrecht, 2020; Koivisto, Jalava, Kuusisto, Railo, & Grassini, 2022; Rickard & White, 2021). Feeling connected to nature can give individuals a sense of purpose and meaning in life too. When people go out underneath the night sky it can be for a variety of reasons, but those that give purpose might further enhance the connection people feel to the natural environment (including the sky) at night. For example, those who take part in bat-watching or conservation (Tanalgo & Hughes, 2021), night hiking (Ramirez, Allison, Scott, Palmer, & Fraser, 2018), astronomy or astrotourism (Bjelajac, Đerčan, & Kovačić, 2021) also demonstrate increased nature connectedness. Therefore, it is logical to assume that these sorts of activities will help build and enhance the relationship that people have towards the night sky. Indeed, experiencing the beauty and wonder of the natural world can evoke positive emotions and a sense of awe (Garza-Teran, Tapia Fonllem, Fraijo-Sing, & Moreno-Barahona, 2022), which can lead to increased overall happiness (Pritchard et al., 2020). At night there are likely to be a multitude of celestial phenomena that have the potential to make stand-out experiences that are filled with wonder and reinforce their sense of connection. Therefore, whilst there are likely to be a multitude of complex factors associated with a person's wellbeing, our findings suggest that night sky connectedness itself—tuning into the night— may fulfil an important role and psychological function in our lives.

Furthermore, we found significant associations between night sky connectedness and (i) age, (ii) frequency of engagement in night sky activities, and (iii) having a specialist interest in astronomy. This is important to know since - in keeping with the wider literature about nature connectedness - research shows that older people tend to use natural spaces more frequently compared to those who are younger (Elbakidze et al., 2022) and have greater opportunities for engaging in nature (Colley, Currie, & Irvine, 2019). As people get older, they may also accumulate more knowledge or have developed a greater interest in biodiversity and exposure to biodiverse environments (Southon et al., 2018). Likewise, when people belong to clubs or organisations with a specific focus on nature – such as The Wildlife Trust or the RSPB in the UK (Harvey, Sheffield, Richardson, & Wells, 2023) – then this is also likely to foster a deeper connection to nature. Our findings illustrated that - independent of age – people who reported to be astronomers were more likely to have a significantly greater connection to the night sky than those who weren't. There was also evidence that those who viewed the night sky (or took pictures of it) more also had a greater connection to the night sky. Though pairwise comparisons show that any differences attributable to frequency of contact with the night sky, were limited to non-astronomers. In fact, there were no differences in scores at all between astronomers who engaged with the night sky more or those who did it less. In fact, the only significant differences we found were between the levels (Rarely, Casually, Regularly, Always) in the non-astronomer group. This indicates that those who actively pursue their interest in the night sky (astronomers) are likely to feel connected to the night sky no matter how frequently they engage with it (i.e. they have an established human night-sky relationship). Whereas those who do not have a formalised interest in the night sky (non-astronomers) are less likely to develop a connection to the night-sky when they have fewer opportunities for contact.

However, a greater connection to the night sky may not simply be about the duration of time spent underneath it, or whether you have a hobby or interest in that topic area too. While these factors provide opportunities to establish a connection, it's the extraordinary night sky-

related moments that are likely to have a more profound impact. Indeed, research by Richardson et al. (2021) suggests that nature connectedness and engagement in simple activities (such as smelling flowers) are some of the most prominent factors that predict an individual's mental health and wellbeing. Therefore, what happens during our time in natural environments at night and the richness, quality and depth of these experiences may be crucial. In the daytime, this may include noticing the simple things in everyday nature from trees and flowering plants, or the sound of birds (McEwan, Richardson, Sheffield, Ferguson, & Brindley, 2019, 2020; Richardson et al., 2021). At night, there will be different sorts of moments to appreciate the awe and wonder as well as the beauty of the sky - observing the constellations, the moon and its phases, galaxies, star clusters, meteor showers and the Milky Way. Though naturally, these moments may only be possible when people are properly tuned in to the night and when issues related to the weather, safety and access to inclusive natural darksky spaces are accounted for - as is the case with the natural environment during the day (Elliott et al., 2019; Weimann et al., 2017; Passmore et al., 2021).

4.1. Night sky connectedness (NSCI) and light pollution

Research shows that light pollution (and Skyglow in particular) now impacts more than 80% of all people in the world and 99% of populations across the US and Europe (Falchi et al., 2019). Clearly, one of the main factors that is likely to impact the connectedness people feel towards the night sky is their ability to see it. Artificial Light at Night (ALAN) shrouds many of the celestial objects – such as the fainter stars, galaxies and the arc of the Milky Way. However, the matter goes beyond merely seeing the night sky; it pertains to the vital role natural darkness plays in our well-being and the functioning of all other life forms. Therefore, it is important to consider the wider context and implications of ALAN and the impact it has on our environment.

Indeed, there is a growing body of work indicating that the consequences of excessive ALAN are catastrophic and have far-reaching effects across our entire ecological systems; including to many species of plant and animal life (Bennie et al., 2016; Berger et al., 2020; Bird & Parker, 2014; Boyes et al., 2021; Dutta, 2018; Mariton et al., 2022; Van Doren et al., 2021). There are indications that human health is (physically) impacted by ALAN too – in terms of our sleep, circadian rhythms and risk of obesity (Paksarian et al., 2020; Le-Bing Wang et al., 2022; Walker et al., 2020; Dominoni et al., 2016; McFadden et al., 2014) - though there has been limited research conducted in this area.

Therefore, light pollution is likely to result in a substantial decline in biodiversity, and loss of natural habitats, as well as a reduction in the quantity and quality of natural dark-sky spaces. However, in our study, we did not find a direct relationship between light pollution severity and psychological wellbeing. Perhaps this is because there are other much more widely acknowledged contextual, or person-specific factors that more strongly impact a person's mental health. For example, this might include, *Environmental factors* – like living in areas of multiple deprivation (Cooper & Stewart, 2015; Knifton & Inglis, 2020) or having access to a strong support network (Ghosh & Alee, 2023), *Lifestyle* – such as being physically active (Baceviciene, Jankauskiene, & Swami, 2021), getting sufficient and good quality sleep (Ma, Williams, Morris, & Chan, 2023), and having a healthy diet (Bremner et al., 2020), or *Psychosocial factors* – such as the experience and handling of stress (Baceviciene & Jankauskiene, 2022) or the ability to cope with challenging life demands (Samus et al., 2022).

Nonetheless, we did find that those people who live in more light-polluted areas are less connected to the night sky and feel less likely to protect it. This finding is in keeping with research that suggests people who have a greater connection to nature are also more likely to hold stronger pro-environmental behaviour and attitudes, and pro-nature conservation behaviour (Barrows et al., 2022; Chawla & Derr, 2012; Rosa & Collado, 2019) that often leads to increased concern for environmental issues and a willingness to take actions to protect the natural environment.

Consequently, the loss of natural dark skies may contribute to our failing relationship with nature and the night. Indeed, we propose that human-dark sky relationships are an integral component of the broader human-nature one. For this reason, it is important to emphasise that dark skies are part of human natural habitats too as well as all ecological systems and life on Earth. Therefore, it is just as important to the success of climate change efforts, to protect habitats, prevent biodiversity loss, and promote human well-being by restoring and preserving dark skies.

4.1.1. Strengths, limitations, and future directions

One of the main strengths of this study is the development of a new measure that enables us to understand the human night sky relationship. We used a robust and rigorous design to develop and test this measure with a large randomly selected general population from across the world. We believe our scale is robust due to its inclusion of individuals from various contexts and cultures in both Part-1 and Part-2 of the study. However, even when sampling is random, studies may still get those people with an established interest in a particular topic. In order to avoid this we recruited people with all levels of interest in the night sky, and targeted a broad range of social media forums – and not just ones dedicated to things like astronomy. We also believe there are other reasons why this will have been less of an issue in this study. For example, there was a broad range of participants with vastly different patterns of behaviour exhibited towards the night sky; slightly over half regularly engaged in activities related to the night sky, and there was a full range of ways in which people accessed the night sky beyond those that may have identified our participants as dedicated hobbyists or professionals (e.g. the proportion of those using specific types of equipment). In addition, only half of those recruited considered themselves to have an interest in astronomy of some kind (visual or astrophotography) and just over 10% reported belonging to an astronomy club.

Consequently, we believe this suggests that our sample is reasonably representative of the general population. However, it is worth noting that the sample may still be somewhat skewed toward individuals with formalised interests, and further testing in broader populations is required to gain a more comprehensive understanding of night-sky connectedness. However, whilst the NSCI is a reliable and valid measure of connection to the natural night sky further testing is needed to establish the confirmed factor structure of the measure (CFA). Nonetheless, the NSCI can now be utilised by professionals seeking to understand the impact of night sky connectedness on aspects such as (i) pro-environmental and conservation behaviour, (ii) the assessment of strategies or interventions aimed at mitigating light pollution and promoting sustainable lighting practices, (iii) the restoration of the human-night sky relationship, contributing to our own well-being as well as that of all other living beings, (iv) informing policies and promoting responsible lighting practices in areas such as housing, urban planning, and dark-sky sites, and (v) rewilding our night skies to safeguard our natural environment and cultural heritage.

4.2. - Conclusion

Globally there is a substantial threat to our natural dark skies and the literature indicates that light pollution has devastating effects across all ecological systems. The impact of light pollution is not limited to health-related outcomes but also extends to our ability to connect to the night, as we do with any other aspect of our natural environment. This study reports on the development and psychometric testing of a new measure – The Night Sky Connectedness Index (NSCI). The scale is valid and reliable and provides a simple and straightforward way to assess the human-night sky relationship. Our findings indicate that when people establish a strong relationship with the night sky environment, they are more likely to feel a sense of connection and protection towards it. Future research is now needed to safeguard our dark sky spaces, restore natural

darkness, and encourage sustainable and responsible lighting use for the benefit of all.

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CRediT authorship contribution statement

Christopher Barnes: Conceptualization, Methodology, Project administration, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Holli-Anne Passmore:** Investigation, Writing – review & editing.

Declaration of competing interest

None.

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Appendix A. Supplementary data

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