



Going for The Gold: Quantifying and Ranking Visual Night Sky Quality in International Dark Sky Places

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THE PROGRAM

The International Dark-Sky Association (IDA), a U.S.-based NGO, offers accreditation through its International Dark Sky Places (IDSP) Program to protected public and private lands that proactively manage their use of outdoor light at night and educate visitors on the value of natural nighttime darkness. IDA Dark Sky Parks, Reserves and Sanctuaries must establish their eligibility for participation in the program in part by submitting night sky zenith luminance measurements.

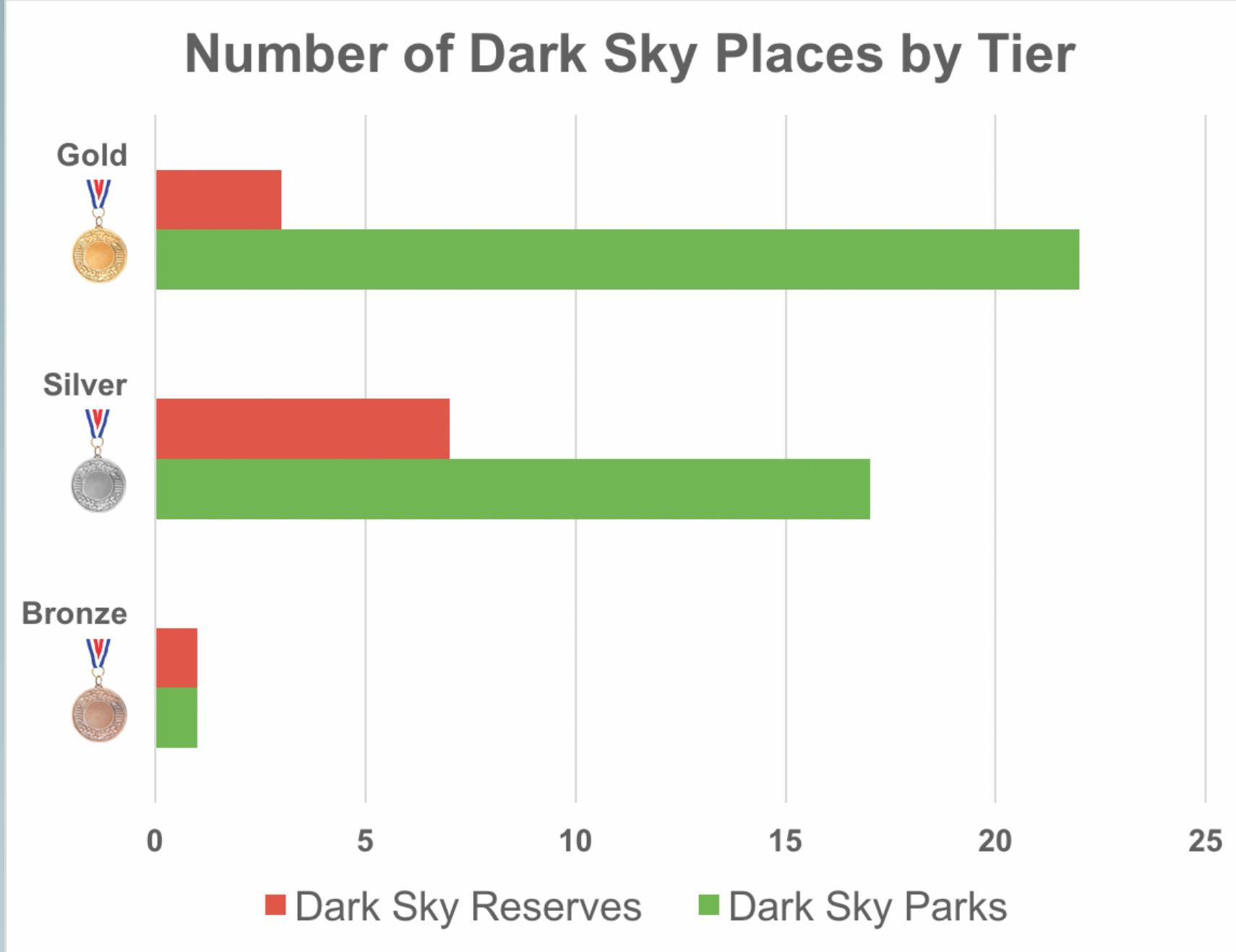


A map of all IDA Dark Sky Places designated as of September 2016. Symbols are: blue circles (Dark Sky Communities), red squares (Dark Sky Parks), green diamonds (Dark Sky Reserves) and gold stars (Dark Sky Sanctuaries).

Candidates are ranked according to increasing mean zenith luminance in ‘Gold’ (>21.75 magnitudes per square arcsecond, or mpsa), ‘Silver’ (21.74-21.00 mpsa) and ‘Bronze’ (20.99-20.00 mpsa) tiers:

GOLD, SILVER, AND BRONZE TIER DESIGNATION			
Indicator	Gold	Silver	Bronze
Philosophy	Nighttime environments that have negligible to minor impacts from light pollution and other artificial light disturbance, yet still display outstanding quality night skies and have superior nighttime lightscapes.	Nighttime environments that have minor impacts from light pollution and other artificial light disturbance, yet still display good quality night skies and have exemplary nighttime lightscapes.	Areas not meeting the requirements of Silver, yet still offering people, plants, and animals a respite from a degraded nocturnal environment and suitable for communicating the issue of light pollution and connecting people with the many aspects of the night sky.
Artificial Light and Skyglow	Typical observer is not distracted by glare light sources. Light domes are only dim and restricted to sky close to horizon.	Point light sources and glare lights do not dominate nighttime scene. Light domes present around horizon but do not stretch to zenith.	Areas with greater artificial light and skyglow than Silver, but where aspects of the natural sky are still visible.
Observable Sky Phenomena	The full array of visible sky phenomena can be viewed—e.g. aurora, airglow, Milky Way, zodiacal light, and faint meteors.	Brighter sky phenomena can be regularly viewed, with fainter ones sometimes visible. Milky Way is visible in summer and winter.	Many sky phenomena cannot be seen. Milky Way is seen when pointed out to the average person, as is the Andromeda Galaxy.
Nocturnal Environment	Area is devoid of obvious lights that can cause wildlife disorientation. Artificial light levels are thought to be below the threshold for plant and animal impact. Ecological processes related to nocturnality are unaltered. No lighting atop towers or buildings within Park boundary.	Areas that have minor to moderate ground illumination from artificial skyglow. Lights that may cause disorientation to wildlife are distant. Disruption of ecological processes is minor with no impairment to plants or wildlife.	Areas with greater nocturnal impact than Silver, but where ecosystems are still functional.
Visual Limiting Magnitude	Equal or greater than 6.8 under clear skies and good seeing conditions	6.0 to 6.7 under clear skies and good conditions	5.0 to 5.9 under clear skies and good seeing conditions
Bortle Sky Class	1-3	3-5	5-6
Unihedron Sky Quality Meter	> 21.75	21.74-21.00	20.99-20.00

The number of designated Dark Sky Parks and Reserves is not evenly distributed among the tiers:



References

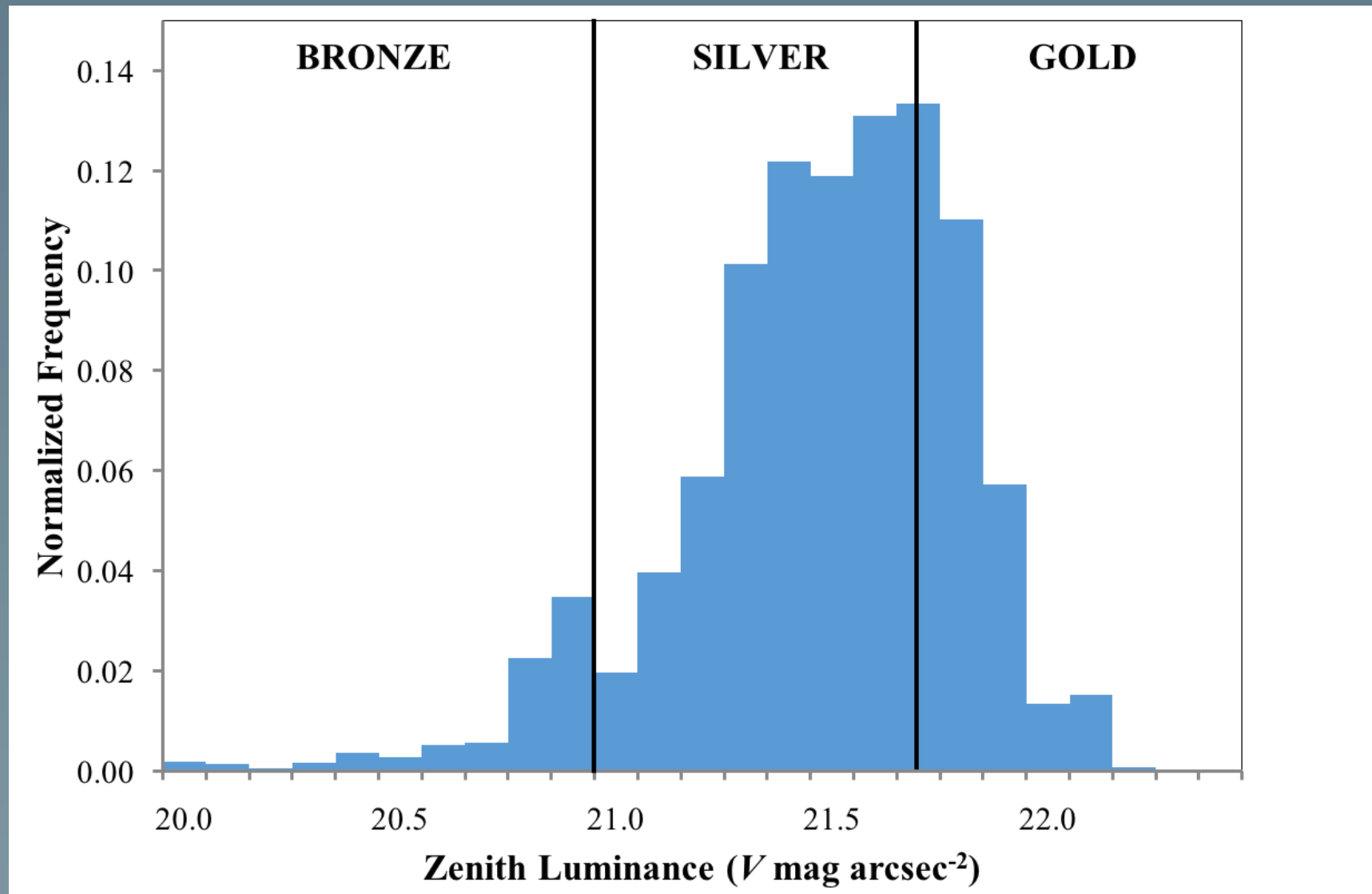
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THE PROBLEM

To properly assess the eligibility of candidate Dark Sky Parks, Reserves and Sanctuaries for IDA accreditation, we must gather sufficiently objective night sky brightness data in order to make meaningful comparisons of different sites. Further, for Parks and Reserves, we must establish the proper sky quality tier under the existing scheme (see left). **This has proven to be difficult in practice.**

Reliance on qualitative descriptions of night sky quality and quantitative measurements obtained solely at the zenith anecdotally undercuts the integrity of the Gold/Silver/Bronze tier scheme, which itself has been criticized on the basis of visibility studies (Crume, 2014). Even the names of the tier labels are problematic, evoking a psychology of winners and losers, and creating the potential for misrepresentation of sky conditions by IDSP applicants when site reputation and future tourism revenue are considered to be at stake.

SQM measurements reliably characterize sky luminances in the presence of significant skyglow from anthropogenic light pollution, but their reliability breaks down in situations where there is little or no artificial skyglow (Bará+ 2014). Thus, while the SQM is valuable in assessing light-polluted locations, its value is compromised in places that are naturally very dark.



Frequency histogram of 5,343 SQM-L measurements obtained in IDA Dark Sky Parks, Reserves and Sanctuaries from 2011-2016. Thresholds for the Gold, Silver and Bronze IDA sky quality tiers are indicated.

Any relative rating scheme for IDSPs involves subjective demarcations of the labels, which is problematic when we attempt to impose arbitrary limits or ranges on real data. As an example, the figure above shows the particular difficulty in deciding between awarding the Silver and Gold tiers.

There are **two fundamental unanswered questions of natural nighttime landscape protection**:

- What is a ‘dark sky’?
- How do we describe the quality of ‘darkness’?

There are also **two specific and increasingly acute programmatic needs**:

- To amend or replace the current tier system according to our best understanding of human visual perception of the night sky and the various natural and artificial light sources that influence it
- To develop low-cost, readily deployable best-practice methods and data collection protocols for characterizing and monitoring night sky quality

THE SOLUTION(S?)

Find new ways to more reliably quantify nighttime conditions in candidate IDSPs

The problem we face is partially one of measurement, and another of deciding which things to measure. It seems clear that we can no longer rely solely on point measurements made with the SQM(-L) at the zenith as our main source of information on the conditions of nighttime darkness in Dark Sky Places. Alternate approaches include:

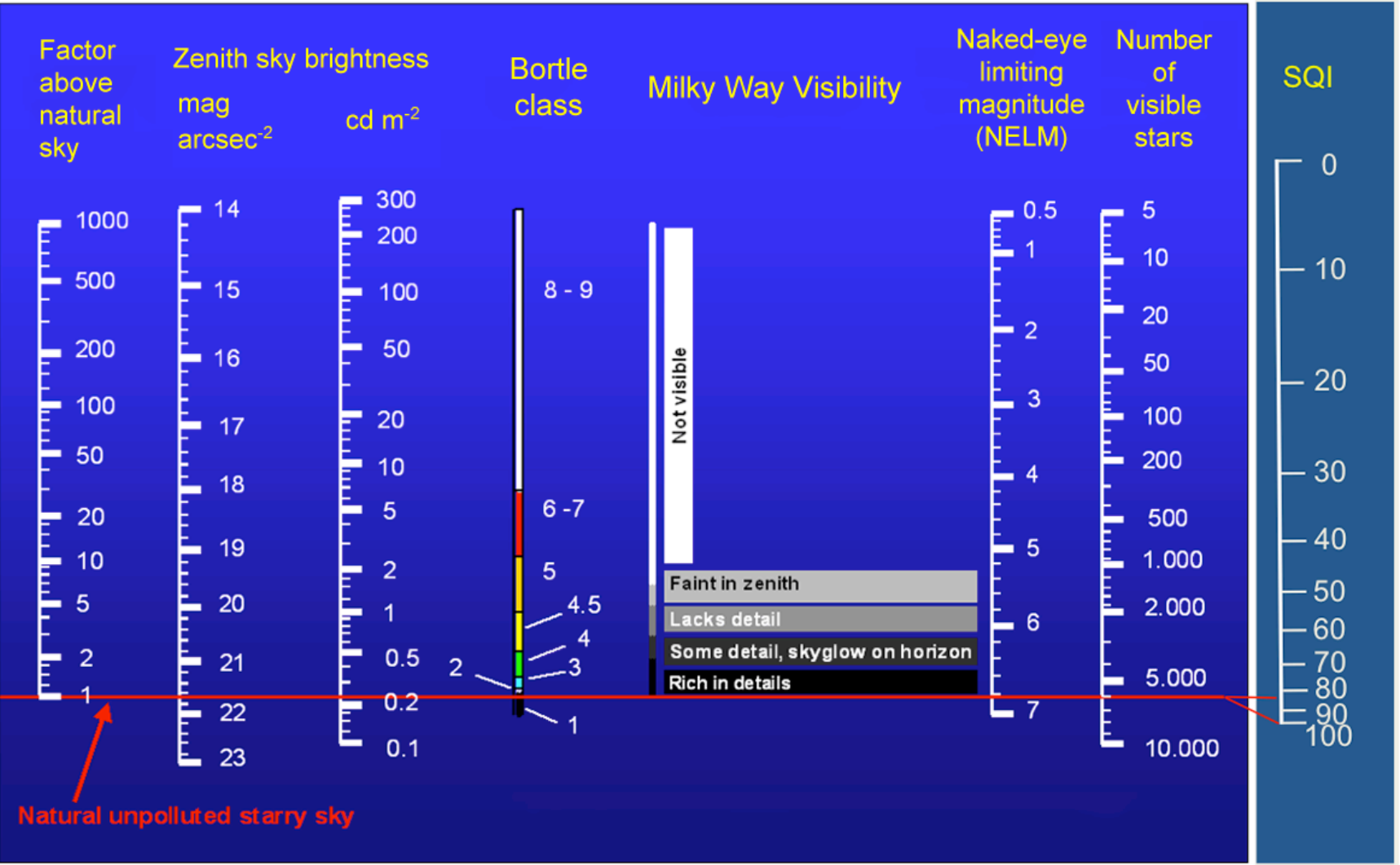
Approach	Advantage	Disadvantage	Reference
Interpolate grids of SQM measurements taken around the sky to produce crude all-sky luminance maps	Makes use of existing, inexpensive and widely-available SQM devices	Lacks good spatial resolution of individual light domes on the local horizon	Zamorano Calvo+ 2014
Use all-sky camera systems to provide information on the spatial distribution of both natural and artificial sources of light	Gives more precise information on the brightness and extent of light domes impacting nighttime environment	Systems are generally expensive to procure and often require expertise to properly operate	Duriscoe+ 2007; Rabaza+ 2010; Kolláth 2010; Aceituno+ 2011; Nieves Rosillo 2013; Rabaza+ 2014
Combining zenith SQM measurements with uncalibrated horizon photography	Involves readily available instruments not requiring special calibration	Uncalibrated imagery is of limited use for tracking quantitative changes to light domes	Aubé and Roby 2014

There is presently an increasing demand for an affordable, off-the-shelf imagery system for obtaining simultaneous all-sky measurements of night sky luminance for both initial site evaluation and ongoing monitoring. Duriscoe (2016) suggests a number of useful metrics that can be extracted from spatially-resolved luminance data; combined with visibility studies, these may lead toward a more robust and objective means of deciding which candidates are best suited for IDA accreditation.

Develop new metrics of the human visual experience of dark-sky sites

Characterizing IDA Dark Sky Places in terms of their night sky brightness has scientific value, but the program is equally oriented toward aesthetic appreciation of night skies by visitors.

One possible improvement on the current tier scheme is to cite a range of statistically likely values on one or more scales. These scales may be intuitive and user friendly. For example, the Sky Quality Index (SQI; far right, below) is an experimental 1-100 index developed by the U.S. National Park Service that features units of equal aesthetic value.



Nomogram of various sky brightness measures illustrating the U.S. National Park Service Sky Quality Index (SQI) metric. Figure by Henk Spoelstra.

Contact

Do you have ideas that may help improve our program?
If so, please contact me!



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