Quantifying Night Sky Brightness Discovers Pristine Night Skies in Auckland for Protection (extracts from the November 2016 report)

By Nalayini Davies

1. Abstract

This pioneering study, quantifying the night sky brightness (NSB) with Sky Quality Meters (SQMs), reveals pristine night skies in a Local Board area, Great Barrier Island (GBI), just 83 km from the centre of New Zealand's largest city, Auckland (which hosts a third of the country's population). The local authority is progressing the application for GBI to be certified as a Dark Sky Sanctuary by the International Dark-Sky Association (IDA) on the strength of study findings. The other Local Board area surveyed, Waiheke Island (Waiheke), has commenced action to combat increasing local light pollution identified through the study. By measuring the 'actual' NSB, it has had a real and immediate impact. The study findings are in general agreement with the 'theoretical' NSB predictions of the highly regarded June 2016 World Atlas of Artificial Night Sky brightness (World Atlas). They are however viewed as more robust and credible as the *in situ* measurements were undertaken with custom-designed coverage to take particular account of site specific features for each area.

2. Aims, Approach and Methodology

Aim: As a pioneering effort, the aim of the project was (i) to measure the NSB of selected areas of Auckland, and (ii) to identify any areas that merit protection/preservation of their dark skies.

Approach: SQMs, the de facto industry standard for scientific quality NSB, were selected for quantifying NSB in mag/arcsec^2 (mpsas). Figure 1 shows how mpsas scales against other NSB measures and naked-eye observations. As early measurements generally accorded with the predictions of the World Atlas, site selection was focused on areas with greater promise for containing dark skies (Figure 2).

Figure 1: NSB Nomogram

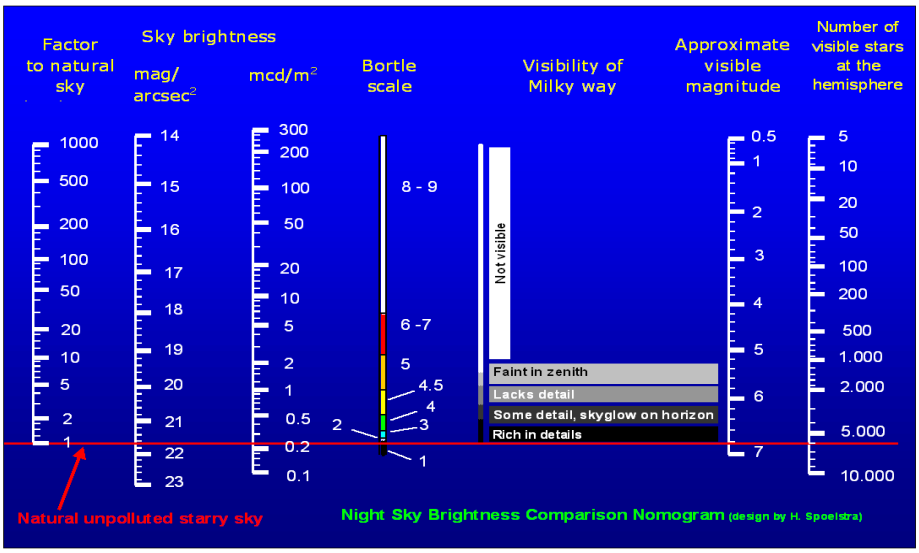
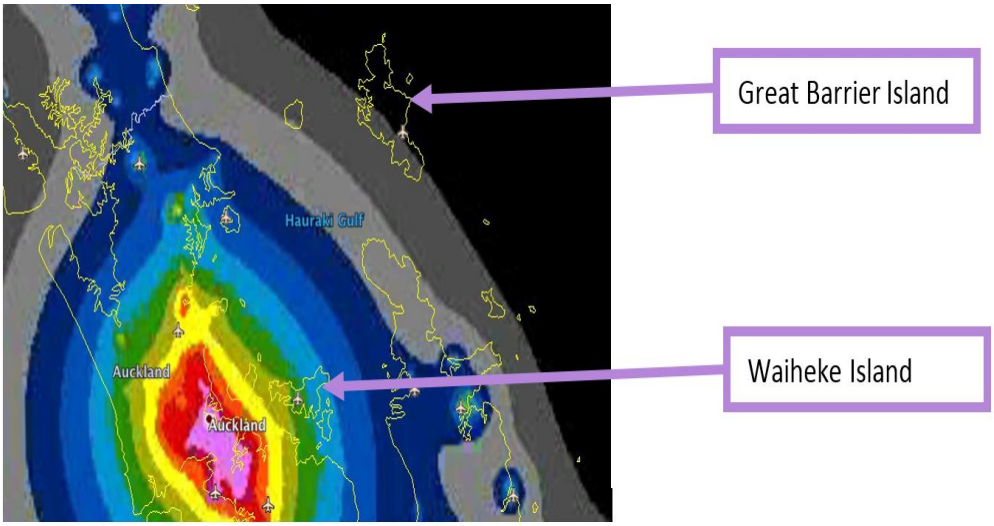


Figure 2: World Atlas's Light Pollution Forecasts



[**Note 1**: Colour coding of the World Atlas (Figure 2) in mpsas - Black: >21.97; Dark Grey: 21.96 to 21.97; Light Blue: 21.68 to 21.82; Dark Green: 21.45 to 21.68; Yellowy Green: 21.09 to 21.45; Pink: 17.93 to 18.65; White: <17.93]

Methodology: Using Unihedron's models SQM (~42° Half Width Half Maximum i.e. HWHM), SQM-L (~10° HWHM) and SQM-LU-DL (continual autonomous datalogging at customised intervals with ~10° HWHM) on Moonless cloudless nights, i.e. when the impact of natural NSB factors is minimal, observations were made following a consistent data capturing protocol. Many locations of target areas were covered on the same night to maximize the comparability of data obtained under similar conditions. Same location calibration data was obtained when Waiheke was surveyed over two nights. After mainland Auckland observations in the lead up and surveys of Waiheke (28 August and 6 September 2016) and GBI (1 September 2016), an in-depth survey (31 October 2016) custom designed for GBI's IDA application data was undertaken. The methodology was improved to a drive-through approach of integrating the SQM with GPS via a laptop computer.

Key process steps included equipment calibration, observing-time/location/route selection, data capturing protocol, observations, cleaning /analyzing/interpreting data and presenting the findings. The analysis included considering and reconciling any variations observed at the same location and between locations. All locations permitting access and reachable by motorized vehicles were surveyed.

The more efficient and less human-error prone GPS integrated drive-through methodology is the approach of choice for future observations as it allows many locations to be covered under similar conditions, a larger sample size to be taken and it allows the ongoing monitoring of progress and reasonableness of data through live-view of the observations on the laptop computer.

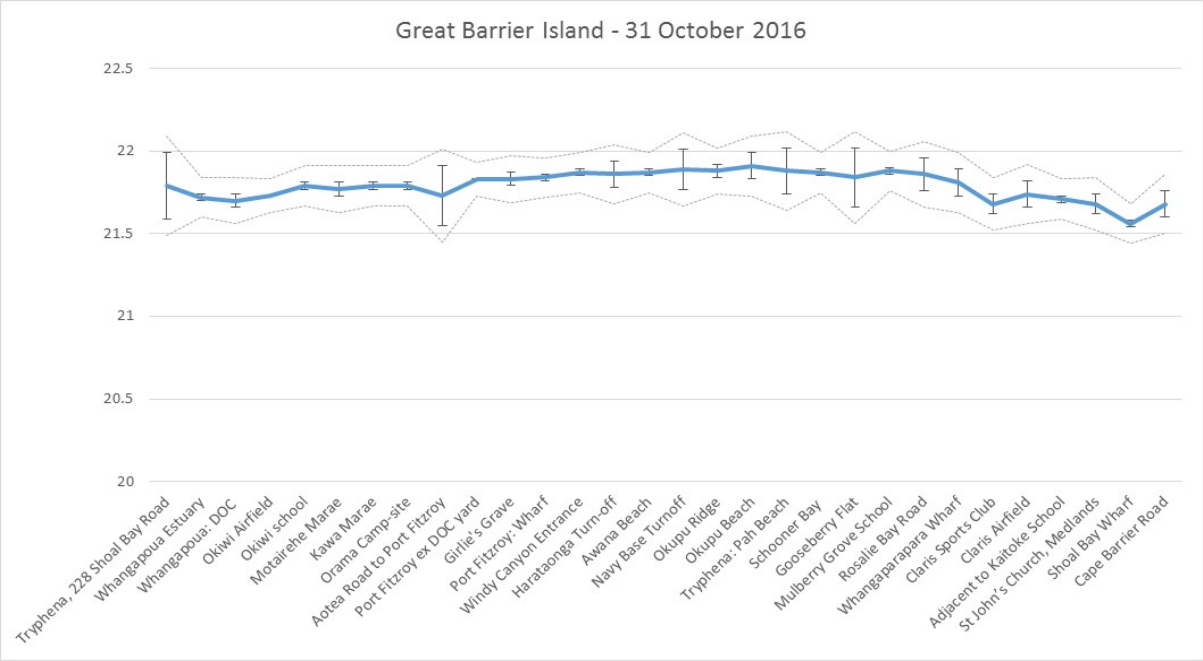
Results

The results for GBI (83 km from central city, no mains power, 56% in mainly conservation public lands, no street lights or well-lit public or commercial facilities and exceptionally low population density) form the in-depth survey and are presented in Figure 3 and Chart 1.

Figure 3: Map of the GBI In-depth NSB Survey

The NSB of GBI ranges from 21.56 to 21.91 mpsas, with all surveyed locations meeting the Dark-Sky Sanctuary standard of >21.5 mpsas.

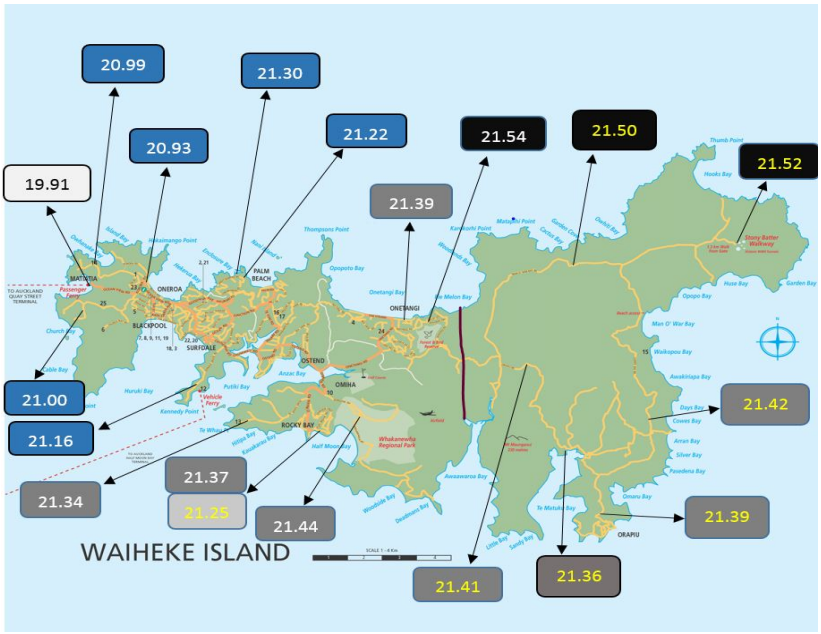
Chart 1: NSB of 30 locations in GBI inclusive of error bars and 95% confidence levels



Even the lower end NSB adjusted for (i) variations at 95% confidence level (error bars on Chart 1) and (ii) equipment precision error of +/-0.1 mpsas (dotted lines in Chart 1, and (iii) with no compensation for any impact from the Milky Way (which could result in 0.1 – 0.3 mpsas darker data), still meets the IDA standard.

The NSB results for Waiheke (31 km from central city, very low population density, significantly reduced levels of street, public and commercial lighting compared to the mainland Auckland) are summarised in Figure 4.

Figure 4: Map of the Waiheke Survey



[Note 2: colour coding of Figure4 in mpsas - Black = > 21.5; dark grey = 21.3- 21.5; blue = 20- 20.3; white = <20; light grey = same location calibration.

Waiheke NSB range is 19.91 – 21.54 mpsas with an average of 21.3 mpsas. These are at the bronze (20-20.99 mpsas) to silver (21 – 21.74 mpsas) standards for Dark-Sky Parks/Reserves of IDA.

3. Discussion

The results from the initial survey of 6 representative GBI locations, which led to GBI Local Board's wish to progress with IDA, were consistent with the later in-depth survey of 30 locations to support the IDA application. The variations ranged from 0.04-0.23 mpsas which could be explained by the 2 x +/-0.1 equipment precision error and/or the changing position of the Milky Way for which no adjustment was made due to a preference to avoid favourable adjustments to the data.

The results transposed on the colour coded predictions of the World Atlas (quantified in Note 1 below Figure 2) for GBI and Waiheke are presented in Figures 5 and 6 respectively.

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Figure 5: NSB for GBI on the World Atlas

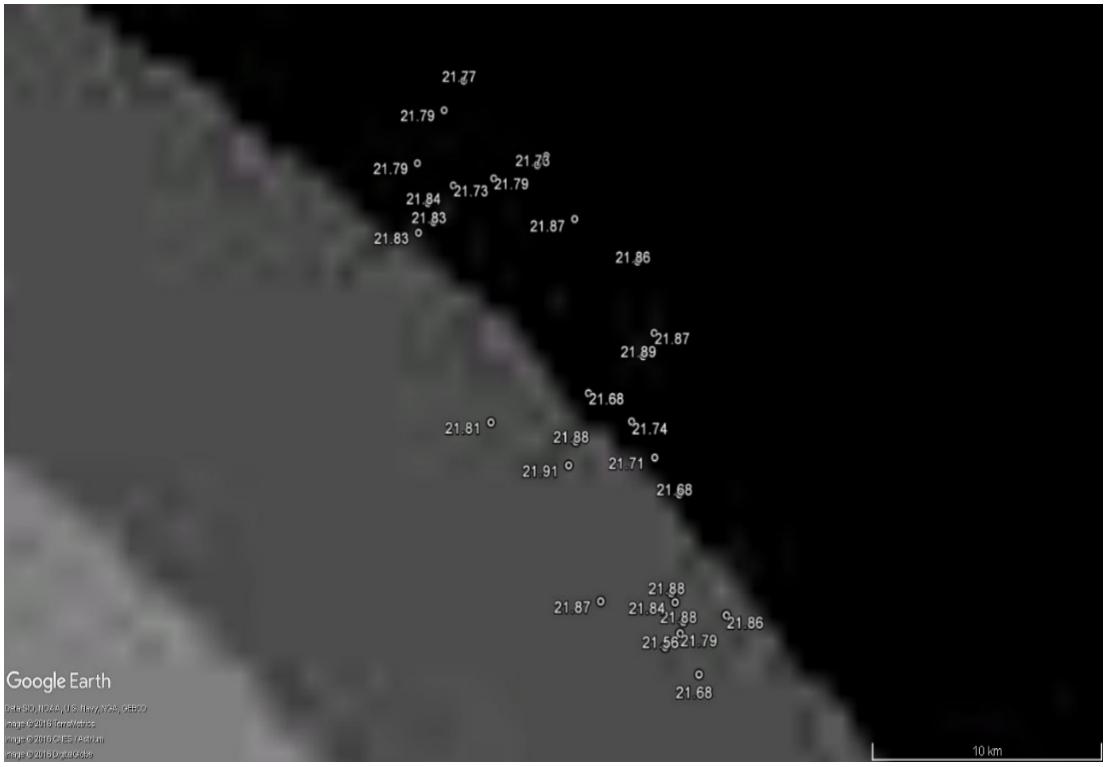
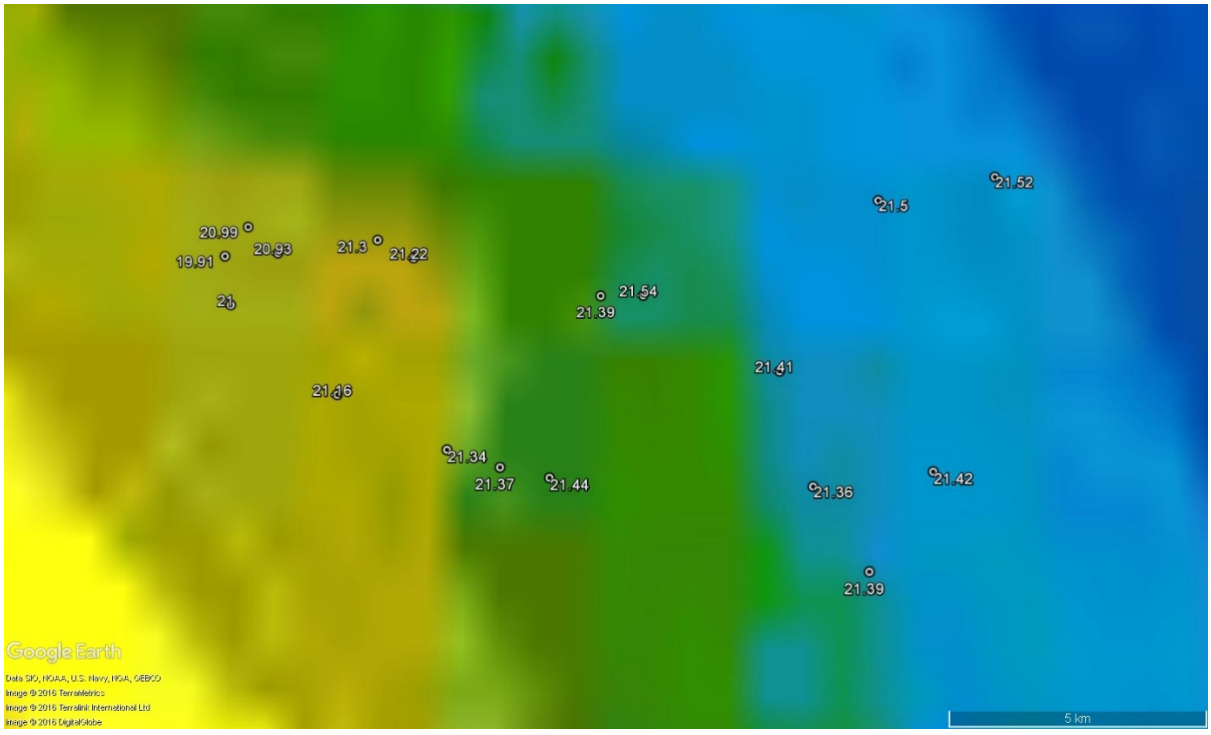


Figure 6: NSB for Waiheke on the World Atlas



The upper end results for GBI are totally consistent with the World Atlas predictions. The slightly lower average results can be explained by variations in Chart 1 (detailed under the chart). Both the process and results were independently quality assured through communications with the co-founder-inventor-manufacturer of SQMs and the lead author of the World Atlas (both leading international experts in this newly evolving area of science).

However, for Waiheke, Table 2 shows brighter than predicted *in situ* NSB particularly for the North-eastern area furthest from Auckland city. This suggests possible impact of local light pollution in line with Waiheke's increasing 'urbanization' from more frequent ferry service, rapid growth in population and related amenities/services growth.

Table 1: Observed NSB for Waiheke compared to World Atlas predictions

Region	World Atlas Range	
Light Blue	2168 - 2182	21
Dark Green	2145 - 2168	21
Yellowy Green	2109 - 2145	20

The NSB of Waiheke should be regularly monitored on an ongoing basis because, left uncontrolled, the balance could tip resulting in a significant night sky deterioration. Waiheke Local Board has been responsive to project findings and is commencing action to control local light pollution.

4. Conclusions

(i) GBI Local Board is progressing IDA certification of the entire island based on the following NSB findings from this study:

- With a 95% confidence average of 21.63 mpsas and a range of 21.54 to 21.86 mpsas, the entire island comfortably meets the IDA's NSB qualifying criteria of >21.5 mpsas
- With an average of 21.79 mpsas, GBI is on a par with New Zealand's only other IDA certified area, Tekapo Aoraki McKenzie with a NSB of 21.72 mpsas that gives it a Gold standard
- GBI generally conforms with the predictions of the World Atlas with only a small explainable difference of 0.18 mpsas between the survey mean measurement of 21.79 mpsas and World Atlas prediction of >21.97 mpsas
- NSB is uniform around the island as shown from the survey results and also the World Atlas where the difference between grey and dark areas shown for the island is a negligible 0.1 mpsas.

(ii) Supported by the study, Waiheke's Local Board is starting to fight the increasing levels of local light pollution to ensure Waiheke's dark skies (averaging 21.3 mpsas), from which the Milky Way can still be viewed, is protected.

(iii) The GBI/ Waiheke results indicate that (i) distance from brightly lit areas (e.g. cities/towns, public/commercial lighting), (ii) street/advertising lighting, and (iii) land use (e.g. conservation purposes, low residential population) have the most impact on NSB.

Postscipt: On 7 June 2017, IDA approved GBI as an International Dark-Sky Sanctuary.

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