Planning an International Dark-Sky Place in Aenos National Park, the first steps

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Abstract. This work describes the preparatory steps for the planning of a light pollution protected area in the form of an International Dark-Sky Park in Aenos National Park at the island of Kefalonia that refer to lighting and light pollution. In more detail, we identified and measured luminance, illuminance and spectrum of public lighting at the island of Kefalonia in areas that are adjacent to the National Park and may influence its operation as a Dark Sky Park. This procedure also includes identifying the luminaire types and light sources, judging their suitability, identifying malpractices and proposing changes. In general, many malpractices were identified both in old lighting installations as well as recent LED retrofits or new installations with more common ones being rich sources in blue light and use of non-cut off luminaires. Light pollution measurements were performed that prove that Aenos National Park has dark enough skies to meet requirements.

1. Introduction

The use of artificial lighting in the built environment [1-8] can affect not only the visual perception and wellbeing of humans [9] but also the environment. Light pollution is a type of pollution that climaxes in the cities, but occurs increasingly away from them, due to the increase of artificial lighting but also due to malpractices and improper lighting design [10-17]. Lighting malpractices may involve inappropriate selection of luminaires, aiming or placement, excessive illumination levels but also unwanted spectral characteristics of the emitted light. While there is an effort to establish general rules [18-20] and guides through research [21-30], the lack of lighting design and energy consumption restrictions for areas in the exterior of buildings, such as building façades, and sports and recreation areas has led to an increase in the use of lighting installations. Increasingly, light pollution also affects the countryside due to local lighting but also distant lighting propagating from urban areas. This has significant impact to ecosystems and astronomical observing sites which is a relatively unknown fact to most people. In order to protect sites of significant ecosystems, natural beauty or astronomical interest, it is important that light pollution reduction is included in the top priorities of national parks, protected ecosystem areas and astronomical observatories as well as public policy and ordinances. This work studies a) the first steps of methods, parameters and special requirements for the planning
of a light pollution protected area in the form of an International Dark-Sky Park in Aenos National Park at the island of Kefalonia and b) the early results from identifying the luminaire types of the adjacent villages.

2. About the National Park
The National Park of Mt. Aenos consist of an area of 2,862 ha, which expands at the mountain Aenos and at the adjacent mountain Roudi. Its main feature is its Cephalonian Fir forest (Abies cephalonica), which is unique in the Ionian islands and constitutes the reason for the foundation of the National Park in 1962. Mt. Aenos with alt. of 1,628 m is the highest mountain in the Ionian Islands, whereas Mt. Roudi reaches an alt. of 1,125 m.

In recognition of its significance at the European level, the National Park has been designated as a European Biogenetic Reserve, belongs to the “Natura 2000” European Ecological Network of Protected Areas (GR2220002) and is a Special Protected Area for the protection of avifauna (GR2220006). It has also been declared as a Wildlife Reserve. The Management Body was established in 2002. Its purpose is to manage, protect and promote Mt. Aenos National Park. From the area of National Park there have been recorded more than 400 plant species. The largest part is dominated by the forest of Abies cephalonica, which is Greek endemic species. More than 100 bird species have been recorded in the national Park. A herd of semi-wild horses lives freely in the northern east part of the mountain [31-33].

The most prominent international effort to counteract light pollution is the one conducted by the International Dark-Sky Association (IDA). The international Dark-Sky Places program was founded in 2001 and as of September 2020 there are over 130 certified places globally. In order to be designated as an International Dark Sky Place of any type, a strict application process is required. The scope of this work is to establish the National Park of Aenos as an International Dark Sky Place though IDA.

3. Methodology
Figure 1 presents the basic steps of the methodology that can be followed in order to plan the International Dark-Sky Place in Aenos National Park, namely:

- Lighting inventory survey
- Photometric characteristics
- Light pollution assessment

Sky brightness measurements assist in recording the intensity of skyglow in an area. This is important in order to assess the importance of the area as a site, its risk as well as monitor skyglow progress either increasing or decreasing. There are many methods to record sky brightness including visual, photographic and instrumental. While visual methods, such as the Naked Eye Limiting Magnitude measurement, can be very accurate if executed correctly, they tend to vary widely depending on observer experience, age and effort. The de facto standard device for measuring sky brightness is the Sky Quality Meter (SQM) developed by Unihedron and endorsed by the International Dark Sky association.

Creating a lighting inventory consists of surveying existing outdoor light fixtures in the nearby area. This includes outdoor fixture location, design, light source type, intensity and spectrum.
4. Results
This section presents the main results of the study.

4.1. Lighting installation
There is no exterior lighting installation inside the national park. The lighting installation was identified in the nearby surrounding areas inside a radius of 15km from the national park (Fig. 2). Lighting inventory in the nearby area consists mainly of old, unshielded or semi-shielded luminaires either in their original form using older technology lamps (High Pressure Mercury, HPM lamps and High-Pressure Sodium, HPS lamps in few cases) or retro-fitted with LED or Compact Fluorescent Lamps (CFL) light lamps. In the main area of the City of Argostoli, capital of the island, and more specific in the main square of the city, new LED luminaires were installed. More specifically, the main types of luminaires that were identified are presented in Table 1. The majority of the luminaires (approximately 50% of the total number of luminaires) were of type A (Non-cut off traditional type luminaire - Lantern luminaire) and type B (Ball shape type street luminaire). The rest types were street luminaires Type C and D (Table 1). A small-scale new installation of LED luminaires was performed in the city of Argostoli with 4000K LED luminaires (Type E and F). Various other types of luminaires were also identified but in small numbers (Wall luminaires and floodlights).

Table 1. Main existing types of luminaires in the surrounding areas from the Aenos National Park.

| Type of luminaire                          | Location                     | Type of luminaire                          | Location                  |
|-------------------------------------------|------------------------------|--------------------------------------------|----------------------------|
| **Type A**: Non-cut off traditional type   | All towns and villages       | **Type D**: “Plate” type luminaire          | City of Argostoli, Nearby  |
| luminaire (Lantern luminaire) with CFL or|                              | luminaire                                 | small villages             |
| LED retrofit lamp                          |                              | Compact Fluorescent Lamp                   |                           |
| **Type B**: Non-cut off ball shape type    | All towns and villages       | **Type E**: New                           | City of Argostoli, Main    |
| street luminaire with Compact Fluorescent |                              | LED street luminaires                      | road, Central Square       |
| Lamp CFL or LED retrofit lamp              |                              |                                            |                            |
4.2. Road classes and corresponding light levels
According to the EN 13201-1 [18] the corresponding levels should vary from 0.3 cd/m² (average value for class M6, connecting roads between towns, ports and villages if should be lit) to 0.75 cd/m² (average value for class M4, main streets inside towns). The main road trespassing villages levels should be 0.50 cd/m² (average value for class M5). For main crossroads in main road levels should be 7.5lx (C5 class) while in main roads in towns they should be 10lx (C4 class). For the secondary streets inside towns levels should be 5lx (P4 class) while in villages they should be 3lx (P5 class). In curfew hours the lighting levels should be dimmed 50% according to the EU Green Public Procurement Criteria for Road Lighting and traffic signals [20].

Figure 2. Type of light sources (LED, CFL, HPM, HPS, cool [>5300K], intermediate [3300K>, <5300K], and warm [<3300K] CCT) and luminaires (Types A to F) in the examined areas (within a radius of 15km from the National Park).

4.3. Photometric measurements
Photometric measurements are presented in the following subsections.

4.3.1. SQM measurements. In order for SQM measurements to be taken, the SQL-L instrument was fixed to a tripod containing a bubble level, so it can point to zenith when fixed perpendicularly. Each time three successive measurements of the same area were averaged and rounded to nearest 0.05. The zenithal measurement of the astronomical site in Aenos National Park averaged at 21.35 visual magnitudes per square arc second, peaking at 21.45 under favourable conditions with lowest (worst) readings of 21.25 under busier summer periods. This makes all measurements better than the required minimum of 21.20 even under unfavourable conditions and for all time periods and the extend of the national park. Dark skies were evident both visually and photographically as captured with long exposure photos (Figure 3).
4.3.2. Illuminance and luminance measurements. Various sets of photometric measurements were performed in the surrounding area of Aenos National Park, an area of 15km radius. The surrounding area included the capital of the island, town of Argostoli, two main ports with adjustment towns, Sami and Poros, and various villages with permanent inhabitants and summer houses. The photometric measurements were performed from 6 to 8 of July 2020. Illuminance measurements were performed using Konica Minolta T-10A illuminance meter and luminance measurements were performed using LS-100 luminance meter, Correlated Colour Temperature.

Fig. 4 presents the areas where the photometric measurements were performed (I1-I18 are the 18 areas in which illuminance measurements were performed according to EN 13201-3 and 4, and L1-L12 are the 12 areas in where luminance measurements were performed).

Figure 3. Long exposure photo of the sky in Aenos National Park. Pictured is the constellation of Orion. Photo by Andreas Papalambrou.

Figure 4. Areas in which the photometric measurements were performed. I1 to I18 are the illuminance measurements and L1 to L12 are the luminance measurements.
The illuminance and luminance measurements were identified as typical cases as the type of lighting installation, that was measured, was met in most of the areas that were investigated. Table 2 presents the illuminance measurements. Excluding the areas in the center of the city, in which the light installation was over illuminated, the other areas were either illuminated in accordance with EN 13201 (Paragraph 4.2) or were under illuminated. Extreme over illumination was identified also in Poros city which is characterized as lighting malpractice. Due to obsolete luminaires or improper type of luminaires the uniformity values were below the minimum maintained value according EN 13201. According the luminance values 3 cases were identified with higher values (L1, L3 and L7).

| Grid/Area | L1 | L2 | L3 | L4 | L5 | L6 |
|-----------|----|----|----|----|----|----|
| Average Luminance | 1.07 | 0.29 | 5.07 | 0.71 | 0.76 | 0.50 |
| Uo (min/ave) | 0.41 | 0.1 | 0.5 | 0.14 | 0.20 | 0.1 |

| Grid/Area | L7 | L8 | L9 | L10 | L11 | L12 |
|-----------|----|----|----|-----|-----|-----|
| Average Luminance | 2.84 | 0.10 | 0.31 | 0.26 | 0.44 | 0.89 |
| Uo (min/ave) | - | 0.18 | 0.36 | - | 0.55 | 0.45 |

5. Conclusions
The awareness of the negative effects of light pollution is affecting the lighting design of streets and small cities near national parks and protected areas. Today, with the advent of energy-efficient luminaires (LED) and state-of-the-art lighting control, the need for a better living environment should be placed along with environmentally friendly lighting design techniques. The first steps before an area of a city enters the LED era is to a) recognize the existing malpractices and avoid them in the new light masterplan, b) set the proper guidelines (not only in lighting design but also in luminaires), c) identify if it is compatible with protected areas or national parks (to set extra promotions).

This paper presents a) the first steps for identifying a protected area (National Park of Aenos) suitable for a dark sky nomination and b) the early results from identifying the luminaire types of the adjusted area of the National Park. Various malpractices were identified, mainly in the areas with the new installations of LED luminaires. This is evident of how important the early planning of lighting design and the selection of proper luminaires is, especially in the areas that affect the National Park.

The main problem of the area is the blue rich radiation that was measured from the existing luminaires. While the HPM luminaires were around 4000K, Cool CCT Compact Fluorescent lamps (5400K) were installed resulting in the enormous amount of blue radiation. However, the most important issue that should alert the decision makers of the street lighting design is the awareness of the technical characteristics that were chosen for the newly installed LED luminaires that blue light was also high in some cases. The future work of this research is to identify the lighting malpractices in a more detailed way and propose the necessary actions for minimizing light pollution in the surrounding area.

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