

Aenos International Dark-Sky Park: The first officially designated area protected from light pollution in Greece

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Abstract. The scope of this work is to analyse the methodology used for the official designation of the first International Dark-Sky Park in Greece which was Aenos National Park, designated in May 2023. The methodology was based on the official International Dark-Sky Park requirements of the International Dark-Sky Association with many differentiations due to specific technical challenges and administrative circumstances in Greece. The process included both technical works, light measurements, lighting retrofit as well as administrative, social and publicity activities. From beginning to completion, the designation process lasted more than three years and required hundreds of manhours to be completed. The official designation of Aenos International Dark-Sky Park provides an important opportunity for the protection of the skies of Greece from light pollution both as a case study and inspiration as well as a solid example used to push for the dark sky protection agenda which is part of a sustainable

1 Introduction

The designation of Aenos National Park marks the first time that an International Dark-Sky Park is materialized in Greece [1]. This is particularly important since Greece remains, as of today, a darker place than most Western and Central Europe. We believe that this designation will motivate other efforts in Greece to consider such an application and protect Dark Skies in Greece while they still exist. Aenos, alternatively spelled Ainos, is the highest mountain in the Island of Kefalonia in Greece. It has an altitude of 1,628 meters. The National Park of Mt. Aenos, Cephalonia, is the smallest National Park in Greece with a total area of 2,862 ha. In 1962, it was declared a National Park with the Royal Decree 776/1962, having as its main purpose the protection of the *Abies cephalonica* Loudon (Cephalonian Fir) forest, which is an endemic species of Greece. At the same time, however, a second reason for declaring this National Park was the protection of its rich and particularly interesting flora and fauna biodiversity for which it is well established how light pollution impacts it [2]. The core consists of two unconnected, yet neighbouring areas. The larger area is the one around the summit of Megas Soros (alt. 1,627 m), which is 2,316 ha and the second area is the one around the summit named Roudi or Gioupari (alt. 1,125 m), which is 546 ha. Combined the area is 2,862 ha. It should be noted that the summit Megas Soros as well as the summit Roudi or Gioupari make up the total mountain volume attributed to Mt. Aenos. The International Dark-Sky Park was designated for the entirety of Aenos National Park which constitutes of both cores. As a result,

the borders of the IDSP are the same as the National Park, that is comprised of two unconnected areas.



Fig. 1. Aenos National Park borders. Copyright: Aenos National Park.

In 1968, the Greek State bought the area of the National Park from the Charity Institution. For years, the agency responsible for its management as well as for the effort of the IDSP declaration has been the Management Body of the National Park of Mt. Aenos while forestry law is enforced by the Forestry Service of Cephalonia. The Management Body of the National Park was founded by law 3044/2002 (GG 197A/27.8.2002), along with 24 more Management Bodies for Protected Areas and has undertaken the protection, promotion, and sustainable management of its protected areas. As of mid-2022, the management of all National Parks and protected areas in Greece has been operating under the umbrella of a new

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national agency called “Natural Environment & Climate Change Agency”. The Unit responsible for Aenos National Park is called “Argostoli branch of Protected Areas Management unit for Zakynthos, Aenos and the Ionian islands”. Nighttime access to the National Park is possible for people participating in the official park night programs and for those carrying a special license.

2 Lighting in the national park

The National Park per se has never installed and does not use any exterior lighting installations. This was mainly because forest areas in Greece have restrictions for night access, for reasons of protection against fire. The main road of the park is unlit and so are the entrance gate and the two small buildings, the office and forest watch. This has contributed to the preservation of the dark skies in the park which are practically threatened exclusively by light sources coming from other parts of the island.

However, inside the National Park, there exists a small piece of land of approximately 0.6 ha that does not actively form part of the National Park and has long been used for television and telephony transmissions since Aenos is the largest mountain of all the Ionian Islands. These installations, protected by barbed wire fence, contain a building and a few antenna towers. The antenna towers only have the mandatory security red flashing lights at the top, due to height of constructions. The building, which houses power delivery equipment, used to be lit with one floodlight per side installed, of which one floodlight was LED while the other three floodlights were metal halide (400W, 5000K). As part of the effort to become a dark sky park, the antenna complex area has been converted to a night sky friendly installation [3]. LED luminaires were selected that are full cut-off (ULOR 0%), asymmetrical lighting and Correlated Colour Temperature of 2000K that were installed with inclination of 0° (thus RULO = 0%, CIE 150). The luminaires are Philips ClearWay gen2 BGP307 T25 DX10 /420 with installed power of 17.5W and luminous flux of the luminaire 1450 lm (light source 2000K). The new lighting was simulated with RELUX software to exhibit low illuminance levels, but within standards (EN 12464-2), and high uniformity to achieve smooth dark adaptation of the human eye. The lighting levels ranged from 4.27lx to 4.62lx and uniformity from 0.44 to 0.50.



Fig. 2. The new luminaires of the antenna complex.

The antenna complex can be seen in public since it is located inside the public area of the National Park. To increase awareness of this project, a poster was made which is exhibited in the buildings of Aenos National Park and was communicated to social and traditional media.

3 Lighting on the island

A thorough survey of lighting on the island of Kefalonia was performed to provide the appropriate local authorities with guidelines on how to improve their lighting in order to reduce light pollution and protect the upcoming dark-sky park. We surveyed lighting installation surrounding areas inside a radius of 15km from the national park. The towns where we surveyed include Argostoli, Sami, Grizata, Digaletto, Poros, Skala, Kateleios, Lourdata and Melissata. In the main area of the City of Argostoli, new LED luminaires were installed. Most 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 of the types were street luminaires Type C and D. 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, projectors).

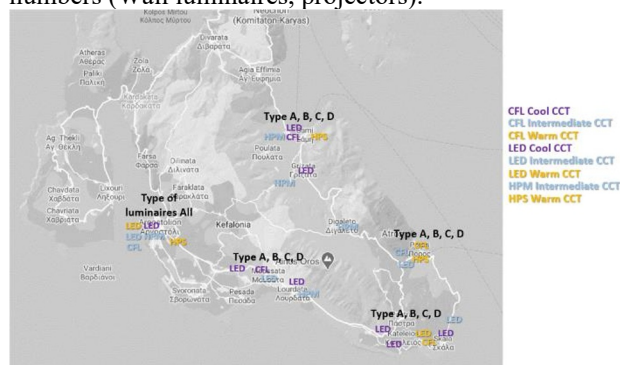


Fig. 3. Types of light sources in Kefalonia.

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 habitants 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, luminance measurements were performed using LS-100 luminance meter, Corelated Colour Temperature and spectrum measurements were performed using Konica Minolta CL-500A spectrometer. 68 measurements of the spectrum of the lighting sources were identified. In 18 areas illuminance measurements were performed according to EN 13201-3 and 4 [4]. In 12 areas luminance measurements were performed. It must also be noted that more spectrum measurements were performed because it simply required pointing the spectrometer to the light source. Illuminance measurements are made by taking many measurements on a fixed canvas. 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. Figure 4 presents the calculated G index from the spectrum measurements. The spectral G-Index is a measure of how much short wavelength light is contained in a visible light source relative to its visible emission. It can also be considered as blue light per lumen. The smaller the index, the more blue, violet, or ultraviolet light a lamp emits. Very few areas had installation with warm CCT light sources. 84% of the light sources were identified with G index less than 1.5.

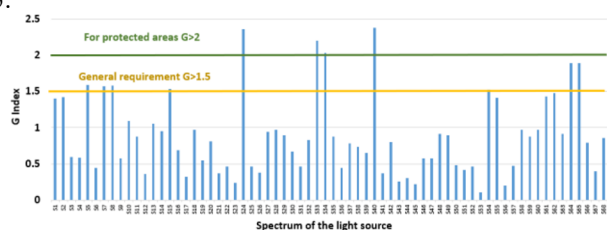


Fig. 4. Calculated values of G index using the spectrum measurements.

Since the summer of 2020, Aenos National Park has organized several astronomy oriented educational nights, with the help of Astronomical Society of Patras as well as amateur astronomers of the island. This led to the National Park personnel acquiring considerable experience with such events. Hundreds of participants had the chance to observe from a dark-sky location for the first time, strongly communicating the importance and beauty of dark skies, learn about the night wildlife of the national park and how it is threatened by light pollution.

4 Light pollution overview

An overview from “The New World Atlas of Artificial Night Sky Brightness” [5] suggests that the island of Cephalonia contains some quite dark areas that are

however threatened by lighting in main installations and mostly the capital of Argostoli. The roads of the island connecting the various settlements are mostly unlit leaving the light pollution to emerge from the inhabited areas. The mountainous core of the island and the establishment of a national park have contributed to keeping parts of the island dark since there are extended areas with no settlements and no lighting. Light pollution maps from “The New World Atlas of Artificial Night Sky Brightness” suggested that the National Park would have Bortle 3 class dark skies which belong to the “rural sky” category. However, it is well known that more accurate estimations can be made with a field survey. Estimates of the lightpollution.info website at 21.86 mag/arcsec² were considered optimistic and needed to be verified. The antenna complex was the sole source of exterior lighting and therefore light pollution inside the national park.

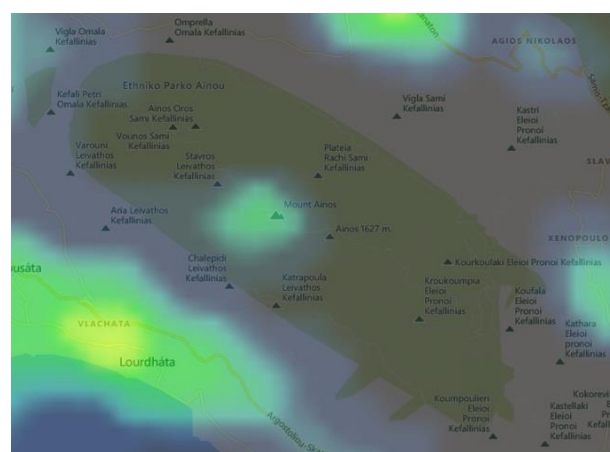


Fig. 5. Light pollution map of Aenos National Park based on data from VIRS 2020 with visualization and SQM estimate by lighpollution.info website BEFORE light upgrade of the antenna complex.

As seen in Figure 5, the antenna complex is visible as a bright area inside the national park in the latest available satellite info from 2020. This area was retrofitted to dark-sky friendly exterior lighting in the Summer of 2021 and has become almost completely dark now as will be described in the corresponding section. More detailed SQM surveys were then initially scheduled by the Greek chapter of IDA in two different periods, July and September 2020 with appropriate permission for after dark entrance in the national park. These months coincide with peak traffic and presence of people in the island which is a popular place for summer homes. Measurements at night were taken along the only road that crosses the national park. At night it is safer not to diverge from areas adjacent to the road and use the trails. The two open areas adjacent to the road most suitable for stargazing are the Pic-Nic area and Thea. Though not explicitly mentioned in the official night access rules, there are suggested sites for stargazing and camping and where night education programs take place, and they are indicated on the website. Measurements were taken at specific points along the road according to standard methodology [6][7]. Three different Unihedron SQM-L

devices were used in order to avoid the presence of a problematic device. Five measurements were taken with each device and measurements were averaged on the spot and rounded to nearest .05 after averaging. This method was chosen because variation and accuracy of SQM devices is such that it is easier to compare steps of .05 than an arbitrary number of digits. It must be noted that measurement expeditions were only carried out on moonless, clear nights since it was not useful to have other types of measurements. Points of measurement and average SQM values appear in figure 5. Measurements were taken after astronomical twilight and increased somewhat at midnight but not more than the rounding cutoff we implemented. Surveys lasted up to three nights each to minimize temporal fluctuations. The points of measurement selected offered a significant view of the sky, which few points inside the park do when going off the road offer since the forest of the national park is quite dense. We can conclude that all national park points have a zenithal sky brightness of 21.20 mag/arcsec² or better with darkest skies in the middle of the park reaching 21.45 mag/arcsec². The average of the whole park after averaging and rounding is 21.35 mag/arcsec². Roudi core is slightly less dark. The personnel of the management body of Aenos National Park have performed continuous periodic measurements every three months starting in Winter of 2021 with the latest ones in the Winter of 2022 without observing steady fluctuations that placed any part of the park lower than the 21.20 cutoff point.



Fig. 6. SQM measurement points and values

Starting summer of 2022, a total of three detailed measurement sessions were performed with the following protocol that will also be valid for future measurements.

- Two SQM-L, each taking 6 measurements.
- All raw measurements are logged.
- Averages of 12 measurements are made per location and then for the whole park.
- No moon over the horizon.
- After astronomical twilight.
- SQM-L pointed to zenith.
- SQM-L left to take environmental temperature for 5 minutes before start.
- First 5 measurements of each set are not logged.

Most of the national park has minimal horizon view due to the dense Cephallonian fir forest. To take wide-field horizon photos, one must select specific points where there are openings to the horizon.

It must be noted that Aenos National Park is located near the top of the highest mountain in the Ionian Islands. This means that from the horizon viewing points, one can see not only parts of the island of Cephalonia, but also neighbouring islands and it is expected that lit locations are visible. This means that Photos taken in such openings reveal the expected light pollution domes due to the presence of settlements at altitudes lower than the horizon. Most orientations provide limited light pollution domes that are mostly confined to the horizon. The largest light pollution domes originate from the nearby island of Zakynthos which is significantly more light-polluted than Kefalonia.

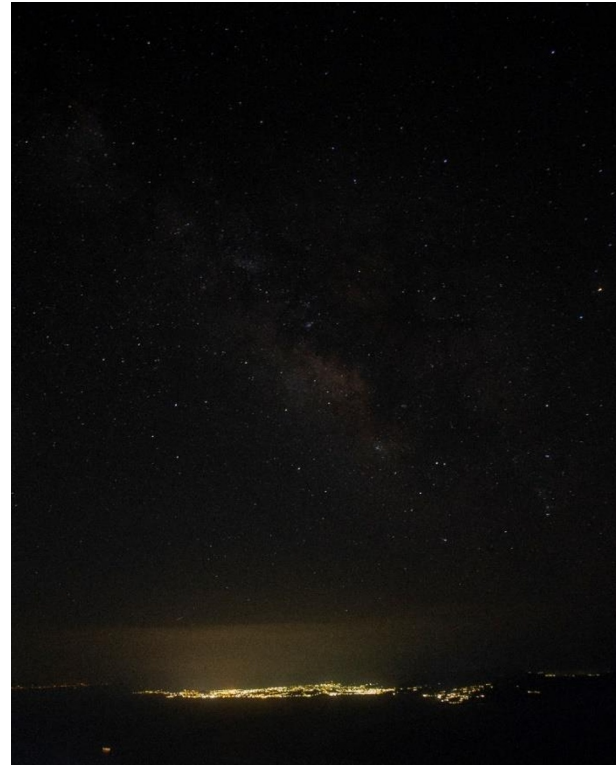


Fig. 7. Worst light pollution dome is towards Zakynthos

5 Public lighting project

A public lighting project was necessary in order to inform public about responsible street lighting [8]. The village Lourdas (also called Lourdata) is set against a steep hillside and in one of the largest bays on Kefalonia. There's no real village centre in Lourdas, just a collection of hotels, restaurants and shops dotted about around the road and down by the fabulous Lourdas beach which is about a kilometre long. Lourdas beach is also one of the beaches of Kefalonia where loggerhead sea turtles lay eggs. Public lighting in the streets were problematic, consisting mostly of cool CCT LED and CFL. Streetlights used were unshielded, light polluting the beach and sky and offering poor illumination to users.

The cases of Lourdas and Skala as a community project were chosen for both practical as well as symbolic reasons and are as follows:

- They are found underneath Mount Aenos, so they are related to the National Park and the general effort.
- They are turtle egg laying sites, with important ecological significance.

•The beaches are popular tourist destination in summer so the project will not only be publicly visible, but it will be exposed to thousands of visitors.

Initially, the project would consist only of Lourdas, but the municipalities asked for an extended area to be covered.

Following market research, we located a luminaire manufactured by a Greek company that provides an alternative for the omnipresent green dish-type luminaires found in Greece. This luminaire is powered by LED's, is fully cut-off and can be fitted with warm, even amber LED's. It features a rotating base and with an arm support it can be installed facing downwards. The luminaire provides a similar style to the old luminaires but with completely different technology. Since the luminaires are manufactured in Greece, it was possible to request custom CCT (we chose amber LED's at 2000K) and the factory also provided additional shields in case it was necessary to modify the direction of the light. 30 luminaires were purchased to cover the beach and nearby streets for a total cost of 3000€ from the budget of Aenos National Park. For all this, we needed the permission of the municipality of Argostoli.

To choose the right customization, a photometric study was performed with the software Relux.

The luminaires were installed with the cost and equipment of the Municipality. In the road along the beach, the additional shield provided by the manufacturer was installed to limit illumination towards that direction.

The result was judged to be according to expectations. The amber LED lights have a very decreased scattering, there is no illumination towards the sky and the low illumination levels on the pavement are sufficient for safe use by citizens. Illumination on the beach is extremely low. It must be noted that the upgrade refers only to public street lighting. There still exist luminaires in private properties over which we currently have no control.



Fig. 7. New luminaires installed in Lourda beach along the sidewalk.

6 Future plans and conclusions

In summary, these are the plans that the designation of Aenos National Park as IDSP will assist in implementing.

- Increased number of outreach events in at least 1 and perhaps 2 per month, based on potential of increased demand that will result from positive media coverage from the designation.
- Increase outreach towards the international community. Currently, almost all the interest to the astronomical and night sky activities are limited to Greek visitors which are inherently limited. Publicity through the channels of IDA will provide an opportunity for visitors from other countries to visit the first IDSP in Greece.
- Use funds from potential increased sales of memorabilia to purchase equipment for a permanent SQM monitoring program with permanent monitoring stations.
- Seek funding from both national and international sources that would not be feasible without the recognition from an international organization.
- Use the status of IDSP as an additional motive to convince the communities of Kefalonia to install night sky friendly lights. Combined with the extended study that has been performed about lighting in the island, we believe it will be easier to push for lighting changes than without having an official status.
- Become the paradigm for other protected areas in Greece and communicate our success story in the community of park managers.
- Inspire for the creation of other types of international dark-sky places besides parks such as dark-sky communities.

Acknowledgements



ΕΣΠΑ. Operational Program "Transport Infrastructures, Environment and Sustainable Development". With the co-financing of Greece and the European Union

The authors would like to thank Signify Hellas and specifically Mr. Polydeykis Loukopoulos Chairman and Managing Director and Mr. George Gounaris Key Account Manager Systems & Services Public for the donation of luminaires in the antenna complex.

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