BIODIVERSITY DESKTOP REVIEW REPORT

Saint Lucia

Streetlights and CCTV Cameras Project

KLED Capital Limited

MAY 2021

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Biodiversity Desktop Assessment Review Report

Report for KLED Capital Limited

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1. INTRODUCTION

1.1 KLED Capital Ltd. has been awarded a Fixed Price Lump Sum contract by the Government of Saint Lucia ("GoSL") to install 22,000 new LED streetlights on the island of Saint Lucia with an addendum adding a further 2,460 street lights.

1.2 The energy savings from the new LED lighting are being used to fund an island-wide CCTV video surveillance system. Together the street lighting and CCTV initiatives are referred to herein as the "Project".

1.3 KLED Capital Ltd. is working with an equity Investor called MPC Renewable Energies GmbH, "MPC" and a lender called Corporación Interamericana para el Financiamiento de Infraestructura, S.A. , "CIFI" on the funding for the Project. MPC and CIFI have agreed to invest in the Project subject to successful due diligence, terms and conditions.

1.4 As part of the due diligence process, a Biodiversity Desktop Review was commissioned to assess the potential impacts of the proposed LED lighting on receptors within the three Protected Areas identified as being potentially impacted by the scheme proposals.

2. SITE CONTEXT AND STATUS

2.1 Saint Lucia's total land area is approximately 616 km^2. Surrounded by the Atlantic Ocean and the Caribbean Sea, the mountainous landscape and tropical location of Saint Lucia have endowed the island with a range of terrestrial and aquatic habitats. Ecosystems range from dry cactus scrubs to rainforest, as well as mangroves and coral reefs. Within these ecosystems, there are over 1,300 plant species, 160 birds, 250 reef fish and 50 coral species. Endemic species include the Saint Lucia parrot and the Saint Lucia whiptail lizard. With the exception of the rainforest and the montane forest formations, terrestrial environments have been radically transformed by human activity, mainly by the building of monoculture plantations. Between 1977 and 1989, 22.5% of the forest was lost and it is estimated that 40% of the once thriving mangroves have been lost. In addition, over 12% of Saint Lucia's beach length is being mined for sand and 50% of the wetlands have been converted for cultivation, marinas and for construction https://www.cbd.int/countries/profile/?country=lc.

2.2 Saint Lucia supports a network of protected areas. Currently, the principal protected areas in Saint Lucia are the Forest Reserve and Protected Forests, together with the Pitons Management Area (also a World Heritage Site), the Pointe Sable Environmental Protection Area and the Soufriere Local Fisheries Management Area. A network of 24 Marine Reserves (two of which are RAMSAR sites) also exists but these are not managed by any effective means (Haffey 2009).

2.3 Three of St Lucia's protected areas have been identified as potentially subject to impacts due to the changes to new LED street lights as part of the proposed scheme. These protected areas are:

- Castries and Dennery Waterworks Reserve and Marquis (8,184 ha), is largely afforested, at Lat: 13.89 Long: -60.97, and located approximately in the centre of the island. This protected area is identified as a Key Biodiversity Area (KBA) of global importance / international significance and meets the thresholds for at least one criterion described in the Global Standard for the Identification of KBAs. It is a KBA identified in the CEPF Ecosystem Profile of the Caribbean Islands Hotspot (2019).

- Pointe Sables Environmental Protection Area (PSEPA), located in the south-west of the island. This 1038 hectare site was designated an environmental protection area under the Physical Planning and Development Act of 2001 in August 2007. The PSEPA possesses the largest basin like mangrove in Saint Lucia known as the Mankote Mangrove. This mangrove is home to a variety of flora and fauna, in particular seventeen (17) species of fish. It is also a marine reserve and is declared as a wetland of significant value under the RAMSAR convention of 2002.
- Pitons Management Area, a UNESCO World Heritage Site The 2909 hectare site near the town of Soufriere includes the Pitons, two volcanic spires rising side by side from the sea (770 m and 743 m high respectively), linked by the Piton Mitan ridge. The volcanic complex includes a geothermal field with sulphurous fumeroles and hot springs. Coral reefs cover almost 60% of the site's marine area. A survey has revealed 168 species of finfish, 60 species of cnidaria, including corals, eight molluscs, 14 sponges, 11 echinoderms, 15 arthropods and eight annelid worms. The dominant terrestrial vegetation is tropical moist forest grading to subtropical wet forest, with small areas of dry forest and wet elfin woodland on the summits. At least 148 plant species have been recorded on Gros Piton, 97 on Petit Piton and the intervening ridge, among them eight rare tree species. The Gros Piton is home to some 27 bird species (five of them endemic), three indigenous rodents, one opossum, three bats, eight reptiles and three amphibians.

3. METHODOLOGY

Review of Available Relevant Documents

3.1 The following documents were reviewed include but are not limited to the following**:**

- Project design documents and specifications (specifics of the LED technology used);
- Publicly available documentation related to natural and critical habitats in Pitons Management Area, Castries and Dennery Waterworks Reserve and Marquis and Pointe Sable; and
- Available project Environmental and Social Due Diligence (ESDD) documentation.

Biodiversity Impact Assessment

3.2 A Biodiversity Impact Assessment was undertaken following the literature review to ascertain the following:

- Significant biodiversity values including the species of conservation concern that might be affected by the project; and
- Project direct and indirect impacts such as disturbance or reduction in species' populations or their habitats as a result of light and noise pollution.

Mitigation Measures to Achieve No Net Loss or Net Gain of Biodiversity Values which included the following:

- Viable alternatives (alternative LED technology, reduced intensity or adjustments to the angle of light);
- Impact avoidance and minimization measures to be followed by Contractors and included in the environmental management plan; and

- Additional recommendations for monitoring program to validate net gains.

4. REVIEW OF AVAILABLE DOCUMENTATION

4.1 In addition to sources listed in 2.1, a number of additional sources were consulted – these are listed in 8. References. In my opinion and brief time window, the availability on the impacts of artificial light in relation to birds, and specifically relating to the relative merits of LED versus sodium lighting seems to be lacking and is very much a new field of study; there is a lack of studies in relation to tropical areas, and no studies were identified from the natural environment. More studies have been undertaken on bats, but these appear to be mainly from Europe rather than the tropical regions, or from St Lucia.

KLED Project Design Documents and Specifications

4.2 Kled Capital Ltd. are replacing street lights across the island. The indicative map (Figure 1) below indicates the island's lighting but please note that the lighting survey is still in progress so this map is not entire. However, there are no new installations within the three protected areas, rather the replacement of existing sodium lights with LED lights.

4.3 Two types of light are being replaced as part of the works:

- sodium 250 W bulbs with 75 W LED lights
- sodium 70 W bulbs with 21 W LED lights.

4.4 The indicative locations of proposed replacement LEDs in relation to the three protected areas are shown in Figures 2 – 6 below.

4.5 High Pressure sodium (HPS), and LED luminaires are constructed with different methods of light distribution. The light output from sodium lamps is directed by a reflective plate, diffusing the light in all directions. LED are manufactured using individual lenses on each diode, directing the light toward the road. The effect of lensing each diode is less light diffusion to unwanted areas thus producing lower levels of light pollution, glare and importantly lower lux levels to the rear of the luminaire. Another effect of lensing LEDs is increased intensity of light on the road surface increasing efficiency. Most LEDs emit light at 4000K to 6000K, KLED luminaires will emit light at 5000K compared to 2000K emitted from the HPS lamps giving a whiter cooler light when compared with the yellow hue given off by HPS.

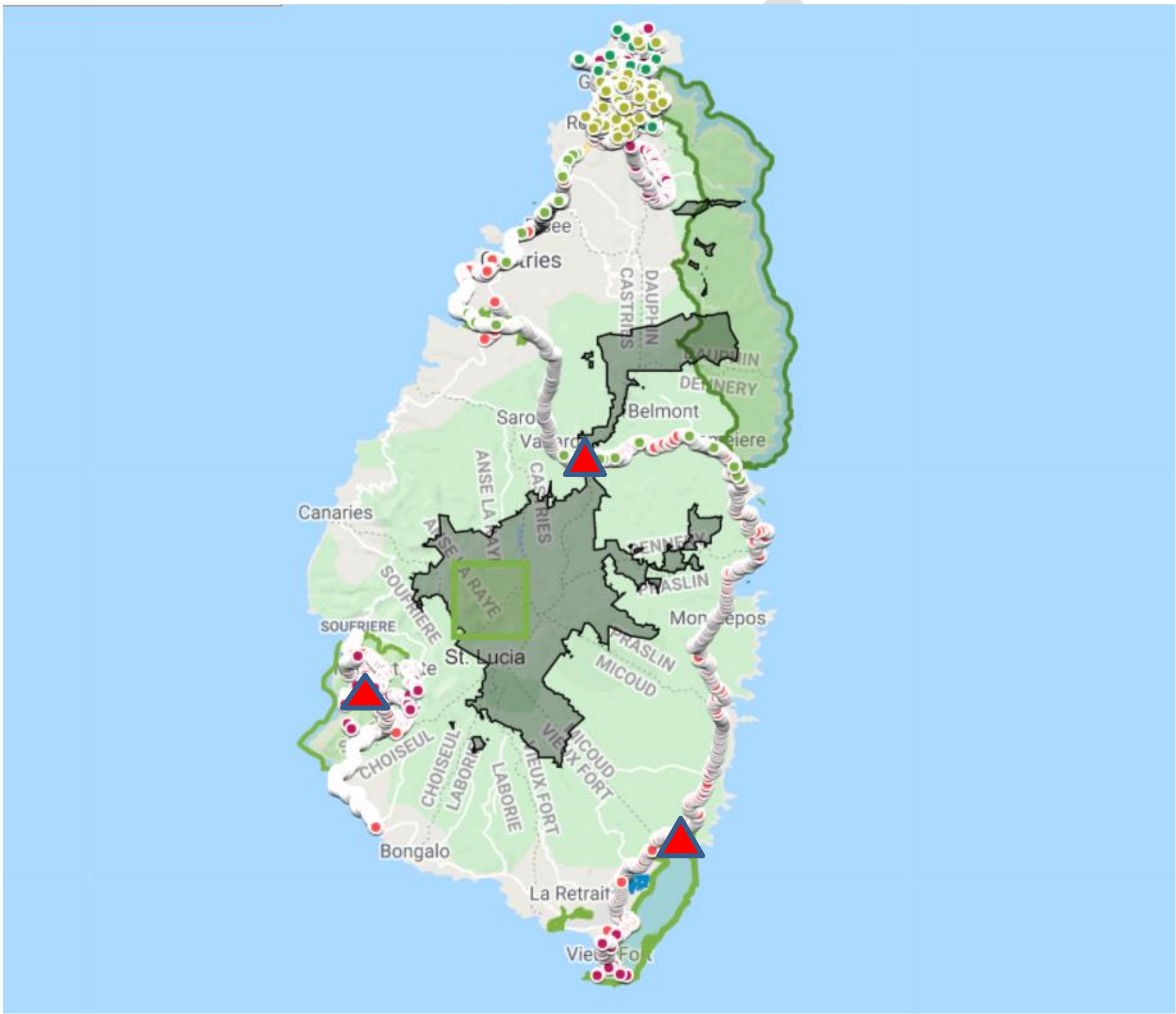

Figure 1: Map Showing Indicative Location of Lighting Plan, St Lucia (note countrywide lighting survey still in progress)

The red triangles indicate the approximate location of where lighting is to be replaced within / bordering protected areas.

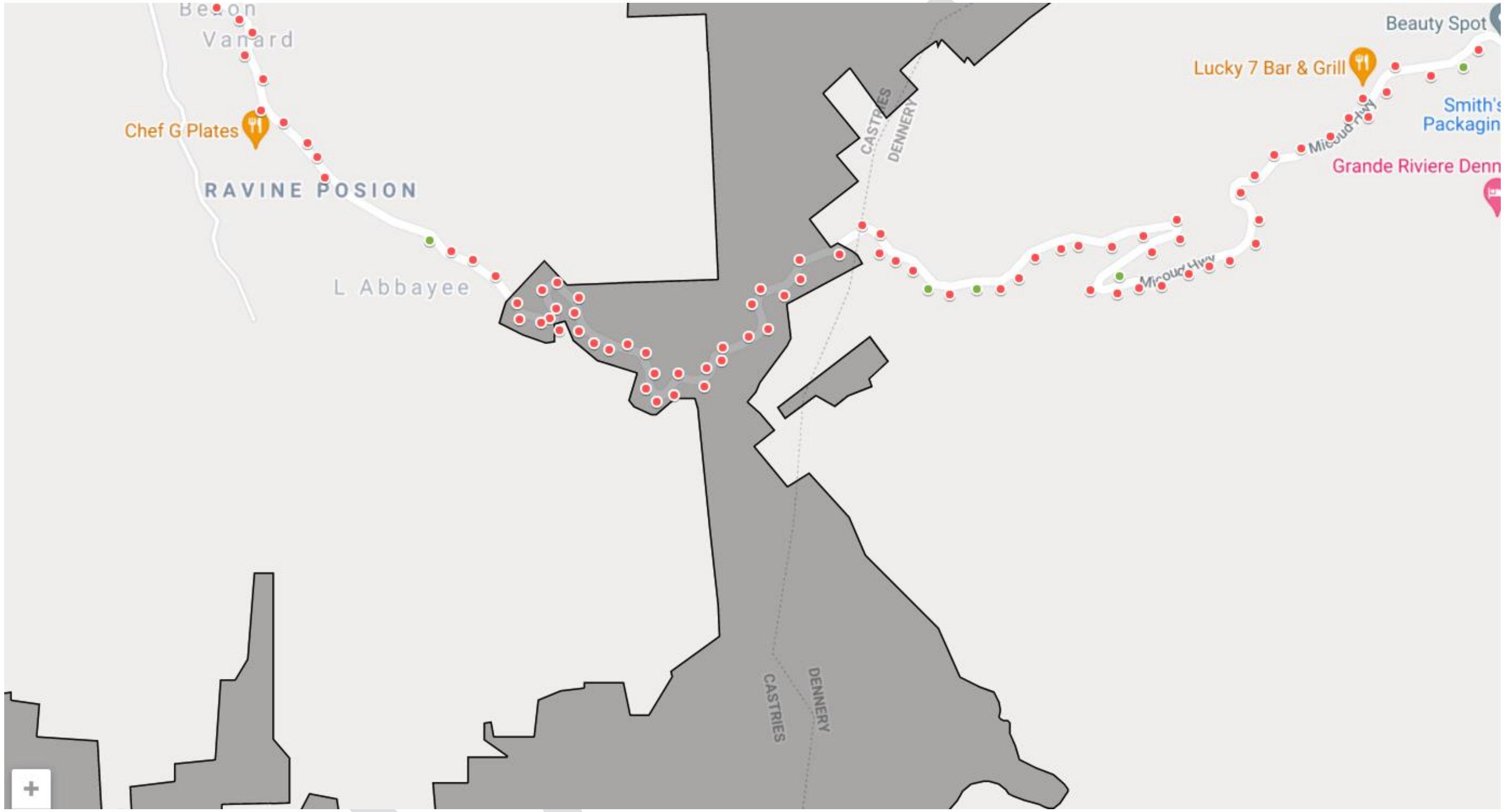

Figure 2: Map Showing Indicative Location of Lighting Along Road Through Castries and Dennery Waterworks Reserve, St Lucia (currently n = 31 x 250 wattage sodium lights)

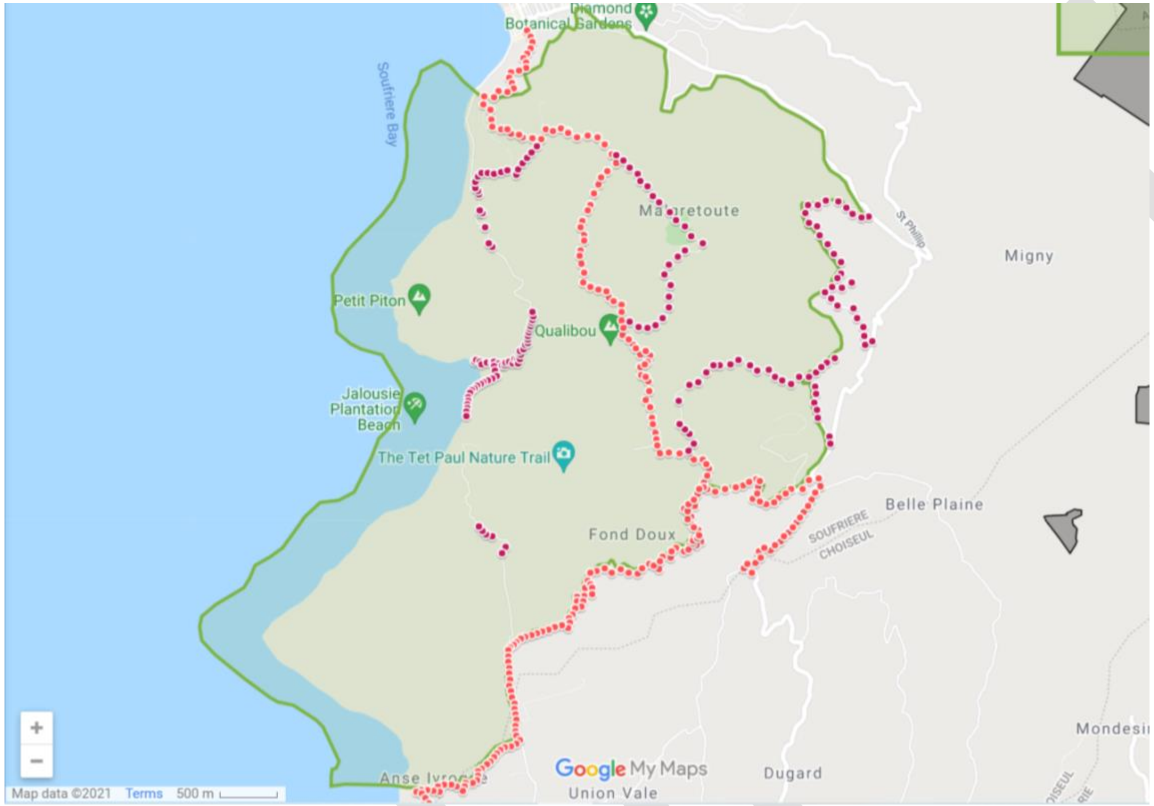

Figure 3: Map Showing Indicative Location of Lighting Through Pitons Management Area, St Lucia (currently n = 77 x 250 wattage sodium lights and n = 120 x 70 wattage sodium lights within the protected area; and n = 127 x 250 wattage sodium lights and n = 34 x 70 wattage sodium lights along the protected area boundary)

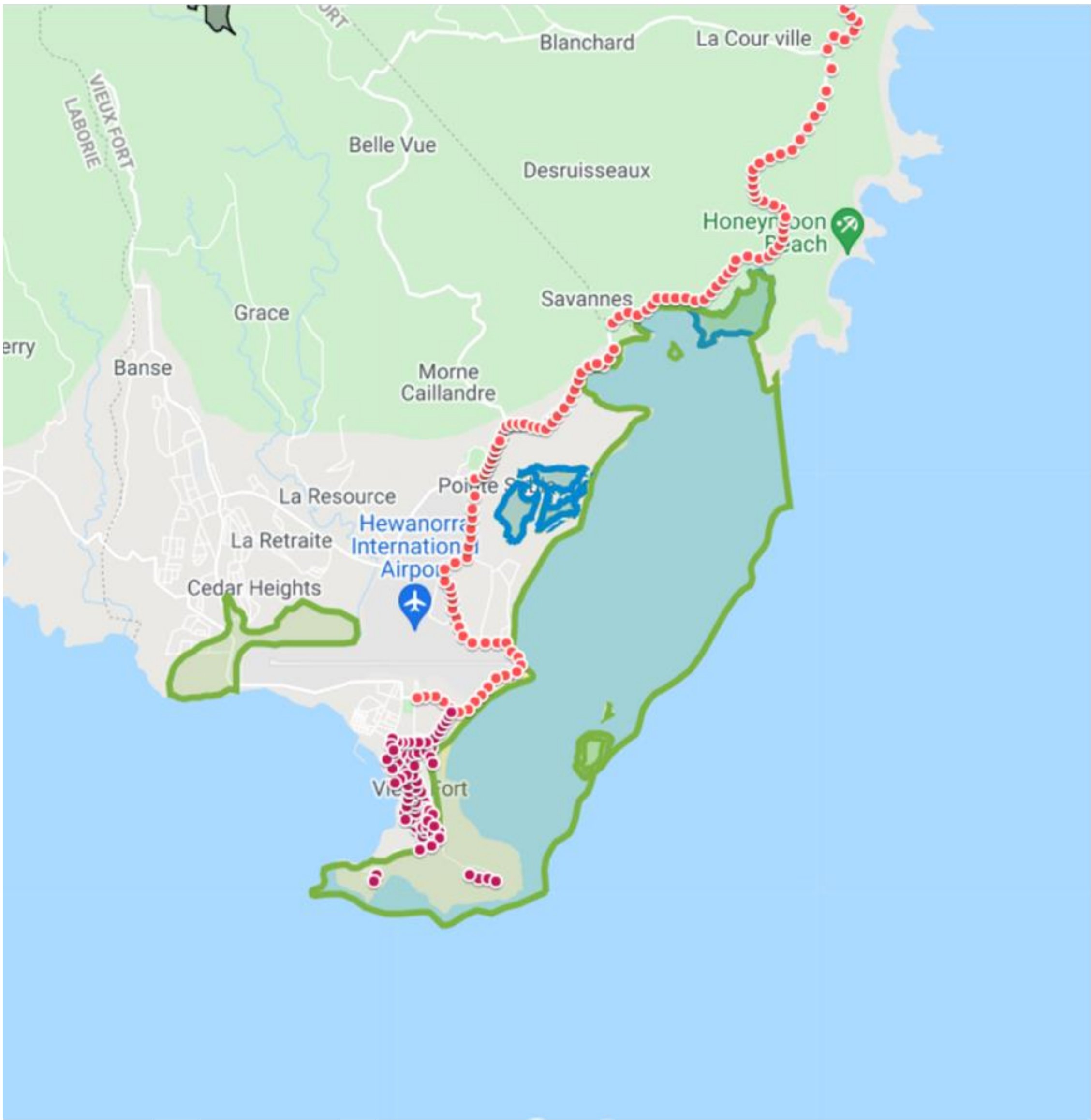

Figure 4: Map Showing Indicative Location of Lighting Bordering Pointe Sables Environmental Protection Area (PSEPA), St Lucia (currently n = 5 x 250 wattage sodium lights within the protected area and n = 3 x 250 wattage sodium lights along the protected area boundary; n = 14 x 70 wattage sodium lights within the protected area)

Figure 5: Map Showing Indicative Location of Lighting Bordering Northern Part of Pointe Sables Environmental Protection Area (PSEPA), St Lucia

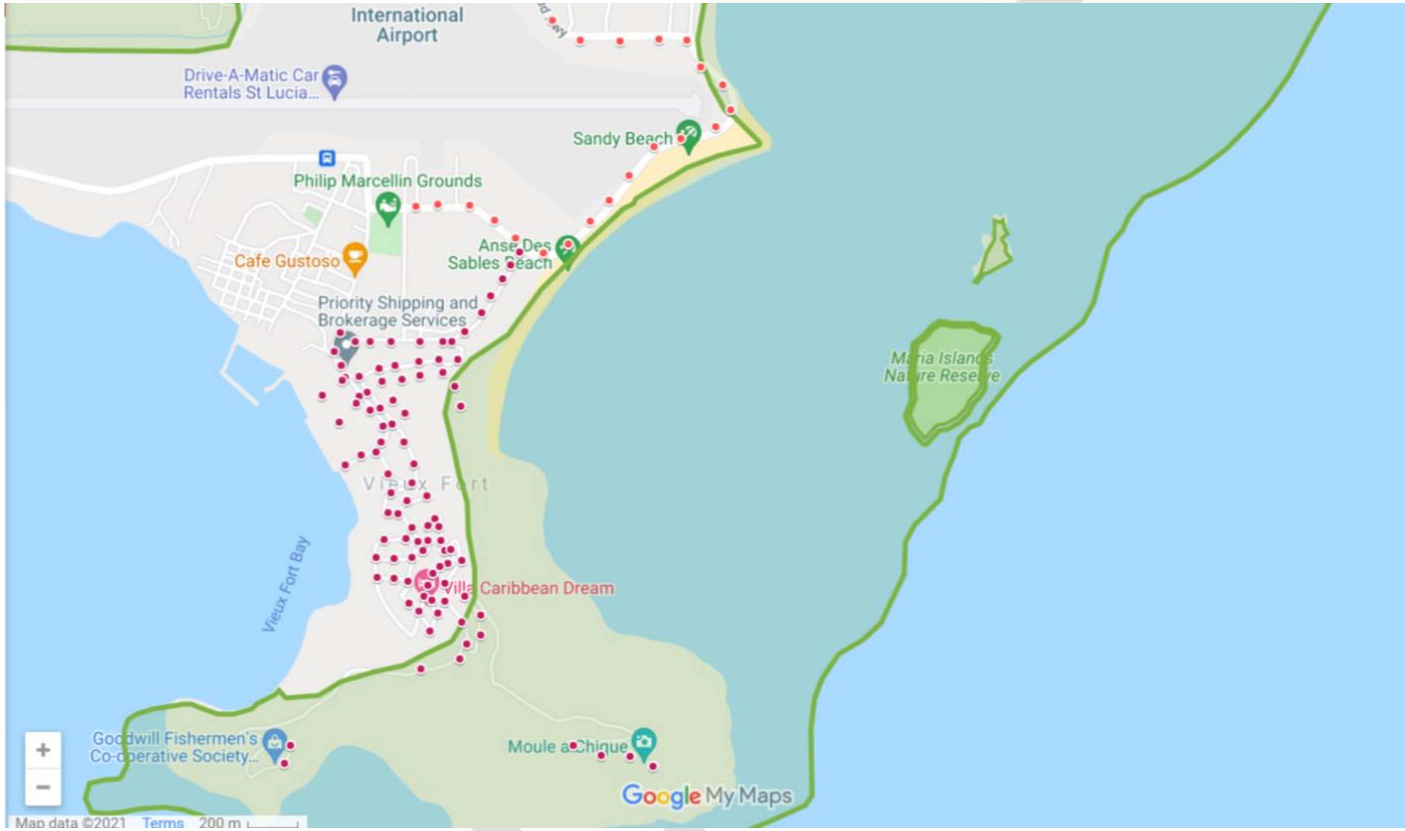

Figure 6: Map Showing Indicative Location of Lighting Bordering Southern Part of Pointe Sables Environmental Protection Area (PSEPA), St Lucia

Natural and Critical Habitats, and Species in the Protected Areas

4.6 Saint Lucia is home to about 1,300 plant species, 160 birds, 250 reef fish and 50 coral species that are distributed along a wide variety of terrestrial and coastal ecosystems. Three of the island's key sectors to the country's economy and livelihoods, tourism, fisheries and agriculture, rely heavily upon these ecosystems. Further, Saint Lucia is home to a number of endemic plant and animal species: 10 plant, 1 mammal, 5 bird, 7 reptile, 1 amphibian, 19 flies and 144 beetle species. However, the island has also been colonised by more than 280 plant, 18 large animal and 39 insect invasive alien species, some of which are affecting agricultural biodiversity and causing severe losses. At present, habitat modification and destruction and invasive alien species are among the main threats to Saint Lucia's biodiversity and ecosystems. Climate change is another major threat, exacerbating the aforementioned threats, with some already visible impacts on the country's natural resources and associated livelihoods (Government of St Lucia 2020).

4.7 The three protected area which may be subjected to impacts are described below, with the IUCN taxa from IBAT data which may be associated with the areas listed in Table 1.

Castries and Dennery Waterworks

Description: The Government Forest Reserve (GFR) comprise of 7290 hectares of tropical moist forest that straddles the central mountain massif running from north to south of the Island. The GFR is divided into 5 ranges for management purposes. There are no human settlements within the Government Forest Reserve.

IUCN Habitat / Management Category: Forest - Major (>10%); Introduced Vegetation – Minor (<10%).

Threats:

- Non-native predators – especially small Indian mongoose; black, brown rats;
- Hurricaines – June to October;
- Forest fires
- Pests and disease
- Global climate change with the associated sea level rise

Pitons Management Area

Description: Multiple use conservation and management area of 1,134 hectares of land and 875 hectares of sea, respectively, totalling 2,909 hectares. The eponymous Pitons, two forest-clad, towering volcanic spires, are the major iconic landmark of the island. The dominant vegetation is tropical moist forest grading to subtropical wet forest with small areas of dry forest near the coast and on steep slopes, and small areas of wet elfin woodland on the summits. On the Pitons especially, small undisturbed natural forests remain, preserved by the steepness of the land. At least 148 species of plants have been recorded on Gros Piton, and 97 on Petit Piton and the ridge. Many St.Lucia species are found only or mainly there. Many mosses, lichens, orchids and bromeliads thrive in the rainforest conditions. There is a relatively high level of endemic or rare species: the endemic shrubs *Acalypha elizabethae*, and *Bernardia laurentii*, found only on the summit of Petit Piton, also, on the slopes, the rare shrubs *Justicia carthaginensis* and *Piper reticulatum*, the rare vines *Gonolobus coriacea*, *Amphilophium paniculatum* and *Melothria pendula* and a herb, *Eipatorium microstemon.* There are also eight rare species of tree: one found only on the summit of Petit Piton- the pencil cedar *Juniperus barbadensis* (VU) and *Picrasma excelsa* (VU), also *Ocotea coriacea, Guarea kuntheana, Krugiodendron ferreum*, *Forestiera eggersiana*, *Randis nitid* and *Myrcianthus fragrans.*

Twenty-seven bird species have been recorded on Gros Piton, including five endemic birds: the St.Lucia oriole *Icterus laudabilis*, St.Lucia black finch *Melanospiza richardsoni* (EN), St.Lucia flycatcher *Myiarchus oberi sanctae-luceae,* St.Lucia peewee *Contopus oberi* and St.Lucia house wren *Troglodytes aedon sanctae-luceae;* also the white-breasted thrasher

Ramphocinclus brachyurus (EN). There are the indigenous black-eared opossum *Didelphis marsupialis,* 3 species of bat, 3 rodents, 8 reptiles including the endemic St.Lucia anole lizard *Anolis luciae* and 3 amphibians; and many butterflies among the numerous invertebrate species which have not yet been completely surveyed.

The coral reefs are healthy and diverse, comprised of fringing and patch reefs, covering almost 60% of the Marine Management Area. A short survey to a depth of 20 meters revealed 168 species of finfish, 60 species of cnidaria, including corals, 8 molluscs, 14 sponges, 11 echinoderms, 15 arthropods and 8 annelid worms. Hawksbill turtles *Eretmochelys imbricata* (CR) are seen inshore; whale sharks *Rhincodon typus* (VU) and short-finned pilot whales *Globicephala macrorhynchus*, are seen offshore. A comprehensive survey would almost certainly reveal greater diversity (http://www.yichuans.me/datasheet/output/site/pitons-management-area/#:~:text=The%20Pitons%20Management%20Area%20Plan%2C%20approved%20in%202003%2C,Multiple%20Use%20%2853%25%29%20and%20Marine%20Management%20Area%20%2830%25%29).

No-one lives permanently in the PMA. 1,500 people live within the terrestrial multiple use zone of the Management Area.

IUCN Habitat / Management Category: Managed Resource Area. The site lies within a Conservation International-designated Conservation Hotspot and in one of the world's Endemic Bird Areas and in one of the world's Endemic Bird Areas.

Threats: Development pressure associated with tourism and housing. Road construction and associated quarrying, and occasional timber extraction and charcoal burning increase erosion and the transport of sediments into the near shore marine environment. Multiple effects of climate change represent another critical threat facing the PMA.

Pointe Sables Environmental Protection Area (PSEPA)

Description: The Pointe Sable Environmental Protection Area (PSEPA) is a coastal strip in the south of Saint Lucia which extends from Moule-a-Chique to Pointe de Caille, just north of Savannes Bay. This 1038 hectare site was designated an environmental protection area under the Physical Planning and Development Act of 2001 in August 2007. It comprises beaches, rocky shores, rocky, river and freshwater streams. The Maria Islands consist of xeric scubland, with five species of endemic reptiles. The remnants of dry forest vegetation are found on the peninsulas, along the north western edge of the Mankote Mangroves, and on Maria Major. Coral reefs exist as a narrow band of patch reefs extending from Saltibus Pointe to Maria Islands. The Mankote mangroves are the largest mangrove forest on the island.

IUCN Habitat / Management Category: Protected Area.

Threats: Inappropriate agricultural practices; feral livestock; pollution; inappropriate fishing practices; inappropriate development practices; inadequate enforcement; inappropriate extractive practices.

Table 1 summarises the Red List taxa found within 50 km of the three protected areas potentially to be impacted by the proposed lighting scheme – the effects of nocturnal lighting (and LED lighting, where known, are included within the Biodiversity Impact Assessment section).

		Protected Area Name		
IUCN Red List Species – CR, EN and VU		Castries and Dennery Waterworks Reserve	Pitons Management Area	Pointe Sables Environmental Protection Area (PSEPA)
Bird Species		7*	8*	7*
	Black-capped Petrel	?	?	?
	White-breasted Thrasher	Possibly present in east of	Absent	Absent

		protected area but not where replacement LED lighting is proposed		
	St Lucia Black Finch	Present	Absent	Possibly Present
	St Lucia Oriole	Present	Present	Absent
	St Lucia Amazon	Present	Absent	Absent
	Black Swift	Present	?	?
Turtle Species		5	5	5
Reptiles (Snakes and Lizards)		6	6	6
American Crocodile		1	1	1
Amphibians (St Vincent Frog)		0	1**	0
Trees		2	2	2
Flowering Plants		3	3	3
Cartilaginous Fish (e.g. Sharks and Rays)		24	24	24
Other Fish / Sea Horses / Eels		20	20	20
Corals		10	10	10
Hydrozoa		1	1	1
Total		**79**	**81**	**79**

Table 1: Summary of IUCN Red List Species Likely to be Associated With Each Protected Area

* Sempers warbler considered likely to be extinct; Whistling warbler confined to St Vincent.
** St Vincent frog confined to St Vincent.

4.8 As the IBAT search covers a 50 km buffer from the protected area, due to the size of the island, the species list is replicated for all three protected areas, with the exception of the inclusion of the St Vincent Frog and Whistling Warbler, both of which fall within the buffer data search range of the Pitons Management Area, but both of which are endemic to St Vincent to the south.

5. BIODIVERSITY IMPACT ASSESSMENT

5.1 The following impacts have been identified due to the replacement of sodium wattage bulbs with LED lighting from the ESDD:

- The potential benefits associated with light impacts as a result of the replacement of sodium wattage bulbs with LED bulbs; and
- Potential habitat loss.

Effects of Nightime Lighting on Species and Habitats

Ecological light pollution includes direct glare, chronically increased illumination, and temporary, unexpected fluctuations in lighting (Rich and Longcore, 2006). Illumination is the amount of light incident per unit area and is the most commonly used measurement relevant to ecological light pollution. Light varies in its intensity (the number of photons per unit area) and in its spectral content (expressed by wavelength). Illumination is regularly measured in lux which expresses the intensity of light incident on a surface weighted for the spectral sensitivity of the human eye.

The key differences between the effects of sodium and LED lighting are:

- The primary visual difference between them is that metal halide light is white and the light emitted from a High Pressure Sodium (HPS) bulb is amber orange.
- HPS lights have a very narrow colour spectrum, limited to warm deep yellow light. LEDs are available in a wide range of colour temperatures, generally from 2700K-6000K (ranging from 'warm white' to 'daylight')
- HPS Lights have the worst CRI of any light source. Typically, they fall around 25. LEDs are available in the full range of CRI values. Typically, above 70 CRI.
- The main benefit of using HPS is that they are the only light source with a similar efficiency to LEDs and maintain luminescence quite well. The losses associated with Omnidirectional light output rates them below LED. LEDs are very efficient relative to

> every lighting type on the market. Typical source efficiency ranges from 80 - 130 lumens/watt. Where LEDs really shine, however, is in their system efficiency (the amount of light that actually reaches the target area after all losses are accounted for).

The differences in the light splay (and thus the lighting impacting on surrounding vegetation and any other species which may be present, e.g. roosting and feeding birds, invertebrates, bats and reptiles such as snakes, as well as on the vegetation is illustrated in the figures below. Essentially, it can be seen that the lux figure is reduced in LED systems compared to the use of sodium lights both within the vicinity of the light sources and on the adjacent vegetation (to 5 m distant); lux levels are measured at a height of 1 m above ground level.

Modelled lux differences on their surroundings are illustrated in Figures 7 – 10 below.

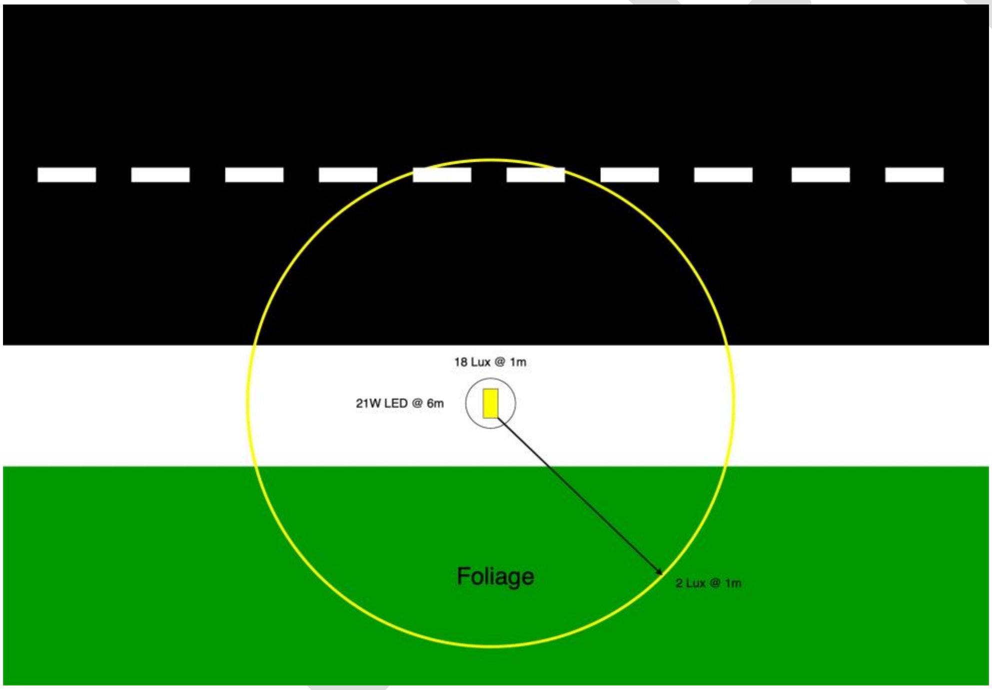

Figure 7: LED 21W Bulb Showing Lux Levels of 2 Lux onto Vegetation at 1m from Light Source

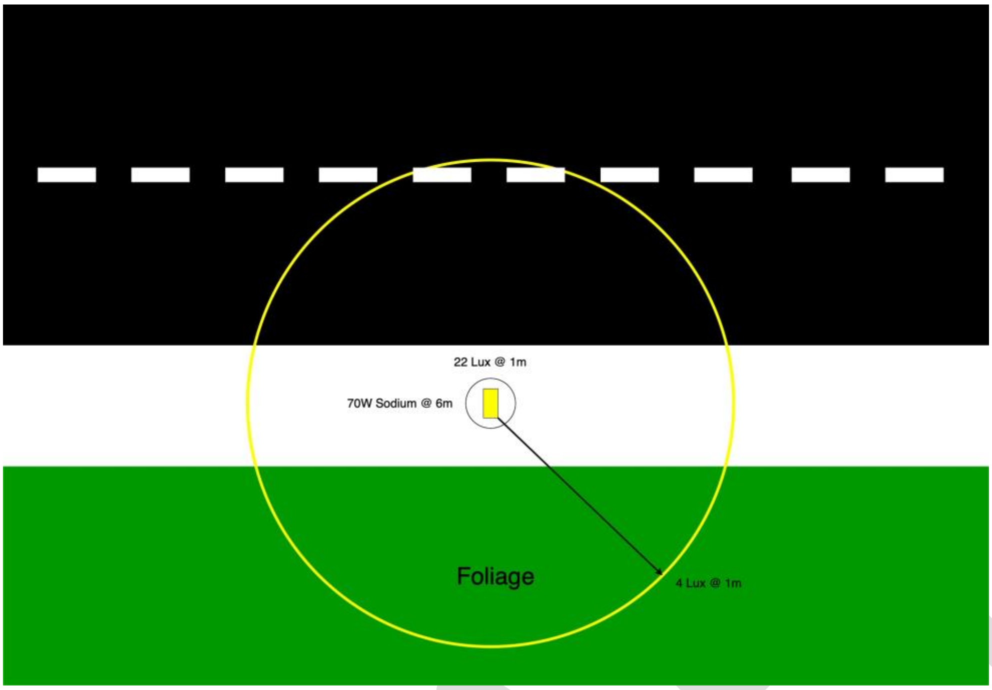

Figure 8: Sodium 70W Bulb Showing Lux Levels of 4 Lux onto Vegetation at 1m from Light Source

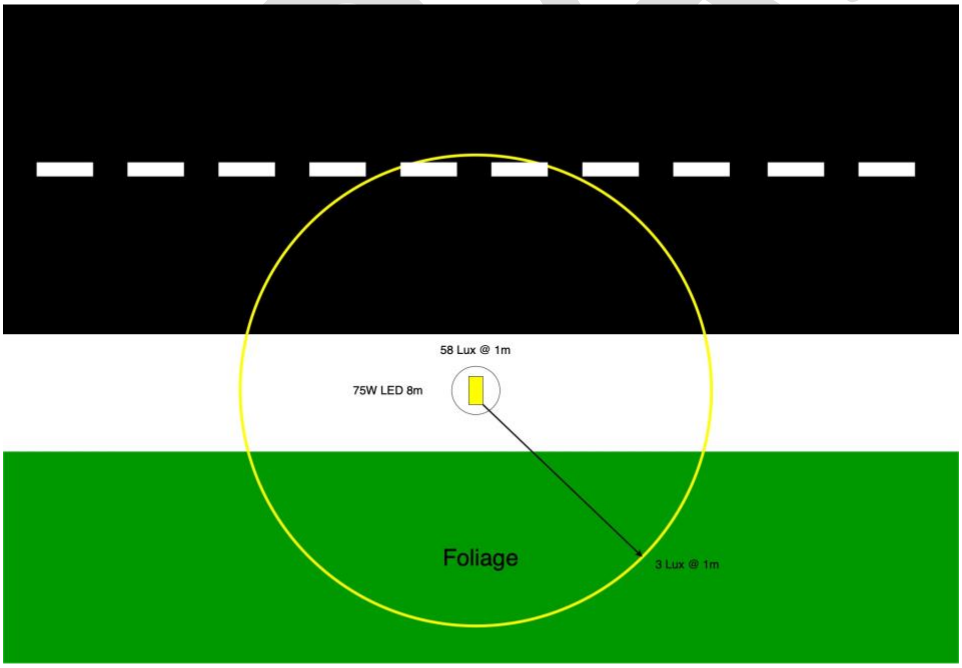

Figure 9: LED 75W Bulb Showing Lux Levels of 3 Lux onto Vegetation at 1m from Light Source

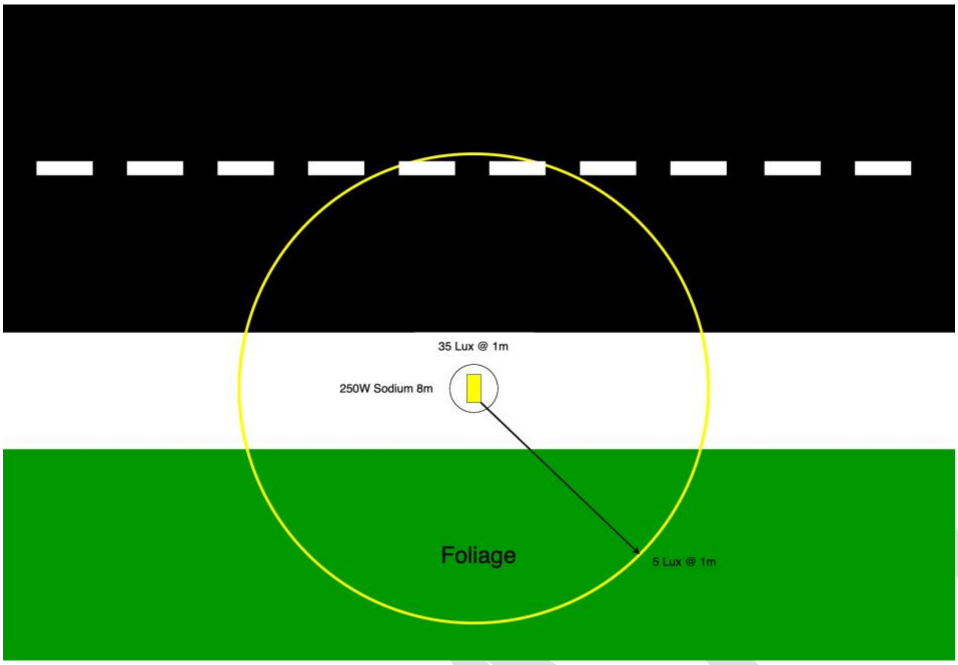

Figure 10: Sodium 250W Bulb Showing Lux Levels of 5 Lux onto Vegetation at 1m from Light Source

Artificial lighting is considered to have the following effect on the species groups likeliest to be encountered within the three protected areas.

Bats

The behaviour of bats is altered by artificial lighting. Artificial lighting is thought to increase the chances of predation, and therefore bats may modify their behaviour to respond to this threat (Speakman et al 1991 , Jones et al 1994). Many avian predators will hunt bats which may be one reason why bats avoid flying in the day (ILP 2018). Illuminating a bat roost can cause disturbance (Downs et al 2003) and this may result in the bats deserting the roost or even becoming entombed within it (Packman et al 2015). Light falling on a roost access point will at least delay bats from emerging and this shortens the amount of time available to them for foraging (Boldogh et al 2007). As the main peak of nocturnal insect abundance occurs at and soon after dusk, a delay in emergence means this vital time for feeding is missed. This has been shown to have direct impacts on bats' reproductive ecology, such as slower growth rates and starvation of young (Duverge et al 2000).

In addition, the associated flightpath to and from the access point is just as valuable and vulnerable as the roost itself. Severing a key flightpath some distance from the roost could cause desertion in its own right.

In addition to causing disturbance to bats at the roost, artificial lighting can also affect the feeding behaviour of bats. There are two aspects to this. One is the attraction that light from certain types of light sources has to a range of insects; the other is the presence of lit conditions posing a barrier to movement.

Studies from temperate regions suggest that, among aerial insectivorous bats, fast-flying species that forage in the open are attracted to artificial lights, whereas slow-flying species that forage in cluttered environments avoid those lights, but little work has been conducted in the Tropics. The measurement of aerial insectivore responses to light pollution was undertaken in a tropical cloud forest in Monteverde, Costa Rica (Frank *et al*. 2019). Bat echolocation was recorded at 20 pairs of light and dark sites. Foraging activity was higher at artificially lighted sites than dark sites near the new moon, especially around blue-white fluorescent lighting. Most recorded bat species showed increased or unchanged activity in response to light, including some slow-flying and edge-foraging bats. This finding suggests that, contrary to the evaluated hypothesis, flight speed and foraging mode are not sufficient to determine bat responses to artificial lights in the tropics. Two bat species showed decreased activity at light sites, and a low species evenness was recorded around lights, particularly fluorescent lights, compared with dark sites. As in the temperate zone, light pollution in the tropics seems to concentrate certain bat species around human-inhabited areas, potentially shifting community structure. However there does not seem to be readily comparable studies between sodium and LED lights in tropical environments.

Birds

Birds align their activities to the appropriate time of the day and year through the stimulation of photoreceptors by daylight, which synchronizes their internal circadian and circannual clocks (Dawson et. al., 2001). Within Europe, recent studies on bird populations of common species in the wild have shown that artificial light at night can affect many aspects of a bird's life: the foraging activity of blackbirds (*Turdus merula*) is extended (Russ *et. al.*, 2015); the timing of dawn singing of the common songbird is altered (Kempenaers *et. al.*, 2010; Da Silva *et. al.*, 2014); and the timing of reproduction in blue tits (*Cyanistes caeruleus*) and great tits (*Parus major*) is advanced (Kempenaers *et. al.*, 2010; de Jong *et. al.*, 2015). It is likely that some of these changes at least are similarly applicable to bird species in the Tropics, and thus relevant in this context. Artificial lighting is also known to disorientate migrating birds, and may lead to increase in disease transmission in birds.

Invertebrates

There is a growing concern that artificial light might affect local insect populations and disrupt their dispersal across the landscape. Widespread nocturnal artificial illumination radically disrupts the habitats of night-active species. Nocturnal and crepuscular insects are abundant and important components of these ecosystems. Thus, the impact of ALAN on insect fitness and abundance can provide a useful metric of overall ecosystem disturbance. The potential effects of ALAN on insects can be categorized as temporal disorientation, spatial disorientation, attraction, desensitization, and recognition (Owens, A. C. S 2018).

Plants

In many cases, artificial light in the night-time environment is sufficiently bright to induce a physiological response in plants, affecting their phenology, growth form and resource allocation. The physiology, behaviour and ecology of herbivores and pollinators are also likely to be impacted by artificial light (Bennie et al. 2016). In a UK study, scientists took a 13-year record of the timing of bud opening in trees, and matched it up with satellite imagery of night-time lighting. After controlling for urban heat, they found that artificial lighting was linked with trees bursting their buds more than a week earlier — a magnitude similar to that predicted for 2 °C of global warming. A study of soya-bean farms in Illinois found that the light from adjacent roads and passing cars could be delaying the maturation of crops by up to seven weeks, as well as reducing yield.

Reptiles: Snakes and Lizards

Studies on the impacts of artificial lighting on snakes and lizards are lacking.

Turtles

Artificial lighting is known to disorientate turtles. The development of coasts brings an increase in artificial light, which can be quite the problem for nesting sea turtles. The development and increase in artificial light has contributed greatly to the decline of populations in recent years (Conserve Sea Turtles). Artificial lighting has a detrimental effect on sea turtle reproduction in many different ways. For instance, lighting can cause the turtles to avoid nesting in the area because they consider it bad habitat. Even if they decide to nest there, there is still the chance that their nests may potentially fail (Salmon 2003). Nestlings will often deter their emergence from the nest in the presence of artificial lighting (Salmon). If the nestlings hatch, they begin the process of locating the ocean from the nest, called “seafinding”. This task is accomplished mostly visually. An effect called "hatchling disorientation" occurs when hatchlings become disoriented and wander the opposite direction and inland, which then often leads to them to die of dehydration or predation (Witherington 2003). According to scientists, hatchlings have “an innate instinct that leads them in the brightest direction”, which is usually moon light.

Potential Lighting Impacts on Red List Taxa

Table 2 (below) identifies the risk of impact upon IUCN Red List species taxa within each protected area.

IUCN Red List Species Taxa		**Protected Area Name**		
		Castries and Dennery Waterworks Reserve	Pitons Management Area	Pointe Sables Environmental Protection Area (PSEPA)
Bird Species (6)*:				
	Black-capped Petrel	Unknown if and where breeds ?	Unknown if and where breeds ?	Unknown if and where breeds ?
	White-breasted Thrasher	Not applicable as range further to the east within protected area	Not applicable as not present	Not applicable as not present
	St Lucia Black Finch	Potentially occurs at project site	Not applicable as not present	Potentially occurs at project site
	St Lucia Oriole	Potentially occurs at project site	Potentially occurs at project site	Not applicable as not present
	St Lucia Amazon	Potentially occurs at project site	Not applicable as not present	Not applicable as not present
	Black Swift	Potentially occurs at project site	Not certain if species is present	Not certain if species is present
Turtle Species (5)		Coastal and marine species, protected area is in the centre of the island – no impact on coastal and marine areas	Coastal and Marine species – no lighting changes proposed adjacent to potential nesting beaches	Coastal and Marine species – no lighting changes proposed adjacent to potential nesting beaches
Reptile Species (Snakes and Lizards)		Unknown which species occur at project site	Unknown which species occur at project site	Unknown which species occur at project site

American Crocodile		Coastal species, protected area is in the centre of the island – no impact on coastal areas	Coastal and Marine species – no lighting changes proposed immediately adjacent to coast	Coastal and Marine species – no lighting changes proposed immediately adjacent to coast
Amphibians (St Vincent Frog)		N/A	N/A	N/A
Tree Species (2)	Lansan	Local distribution not known; relatively abundant rainforest tree in St Lucia, which is the species' stronghold	Local distribution not known; relatively abundant rainforest tree in St Lucia, which is the species' stronghold	Local distribution not known; relatively abundant rainforest tree in St Lucia, which is the species' stronghold
	Spanish cedar	Local distribution not known; generally occurs < 1200m scattered in moist and seasonally dry sub-tropical or tropical mixed semi-evergreen or semi-deciduous forests on the American mainland, also roadsides, pastures and disturbed areas in the Caribbean	Local distribution not known; generally occurs < 1200m scattered in moist and seasonally dry sub-tropical or tropical mixed semi-evergreen or semi-deciduous forests on the American mainland, also roadsides, pastures and disturbed areas in the Caribbean	Local distribution not known; generally occurs < 1200m scattered in moist and seasonally dry sub-tropical or tropical mixed semi-evergreen or semi-deciduous forests on the American mainland, also roadsides, pastures and disturbed areas in the Caribbean
Flowering Plants (3)	Wild soursop	Local distribution not known;	Local distribution not known;	Local distribution not known;
	Red sweetwood (*Aniba bracteata*)	Local distribution not known; Indigenous common tree of lower montane rainforest, especially in	Local distribution not known; Indigenous common tree of lower montane rainforest, especially in	Local distribution not known; Indigenous common tree of lower montane rainforest, especially in disturbed areas such as small landslips.

		disturbed areas such as small landslips.	disturbed areas such as small landslips.	
	Ariba ramageana	Local distribution unknown; Rare tree of lower montane rainforest	Local distribution unknown; Rare tree of lower montane rainforest	Not present; Rare tree of lower montane rainforest
Cartilaginous Fish (e.g. Sharks and Rays)		Marine species, protected area is in the centre of the island – no impact on marine areas	Marine species – no changes to lighting regime on marine areas	Marine species – no changes to lighting regime on marine areas
Other Fish / Sea Horses / Eels		Marine species, protected area is in the centre of the island – no impact on marine areas	Marine species – no changes to lighting regime on marine areas	Marine species – no changes to lighting regime on marine areas
Corals		Marine species, protected area is in the centre of the island – no impact on marine areas	Marine species – no changes to lighting regime on marine areas	Marine species – no changes to lighting regime on marine areas
Hydrozoa		Marine species, protected area is in the centre of the island – no impact on marine areas	Marine species – no changes to lighting regime on marine areas	Marine species – no changes to lighting regime on marine areas

Table 2: Impact Risk to IUCN Red List Species Within Each Protected Area

* Sempers warbler considered to be extinct.

Performance Standard 6 IFC

Performance Standard 6 (IFC 2012) recognizes that protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development.

PS6 Targets

Under PS6, the targets are as follows: a net gain for Critical Habitat and no net loss for Natural Habitat. In practice, defining Critical Habitat and demonstrating net gain with the appropriate level of confidence may be challenging.

The key steps in aligning with PS6 are as follows:

Critical Habitat Assessment (PS6, Paragraph 16): assessing the biodiversity importance of an area (e.g. threatened and restricted-range species and ecosystems, protected areas) in comparison to their global distributions or population sizes;

Mitigation Design (PS6, Paragraph 17): described within a Biodiversity Action Plan, for impacts on Critical Habitat and Natural Habitat;

Offset Design (PS6, Paragraphs 10 and 18): design of compensatory offsets for significant residual adverse impacts, 'after appropriate avoidance, minimisation and restoration measures have been applied';

Protected Area assessment (PS6, Paragraph 20): meeting the requirements for Critical Habitat and Natural Habitat where appropriate; and

Monitoring and Evaluation Design (PS6, Paragraphs 17-18); a long-term programme sufficient to assess the status of Critical Habitat and demonstrate biodiversity gains.

Application of PS6 is very site-specific, depending on the species, ecosystems, quality of baseline data and existing biodiversity management. Fulfilling the requirements of PS6 is a significant undertaking, hence alignment is best initiated at the very start of project planning, and integrated with the development of an Environmental Impact Assessment.

5.3 Maintaining and increasing natural unlit areas is likely to be the most effective option for reducing the ecological effects of lighting. However, this will often conflict with other social and economic objectives. Decreasing the duration of lighting will reduce energy costs and carbon emissions, but is unlikely to alleviate many impacts on nocturnal and crepuscular animals, as peak times of demand for lighting frequently coincide with those in the activities of these species. Reducing the trespass of lighting will maintain heterogeneity even in otherwise well-lit areas, providing dark refuges that mobile animals can exploit. Decreasing the intensity of lighting will reduce energy consumption and limit both skyglow and the area impacted by high-intensity direct light (Gaston *et al.*, 2012).

5.6 Recent decades have seen changes in the street lighting (and other lighting) technologies deployed, often with narrow spectrum light sources such as low-pressure sodium (LPS) and high-pressure sodium (HPS) lamps, which emit primarily yellow or amber light, being replaced with broader spectrum 'white' sources that enable better colour rendering for human vision; although broad-spectrum fluorescent lighting has been used locally in street lighting since the 1930s. The development of central management systems (CMS) allows lighting operators to adjust times of operation remotely as required. Broader spectrum lighting technologies such as metal halide and light emitting diode (LED) lamps are becoming increasingly cost-effective to use, and the perceived amenity value of 'whiter' light is resulting in increasing numbers of these being introduced. Meanwhile, reductions in the duration and intensity of lighting, along with reducing the trespass of light into unwanted areas, are additional options currently being explored to cut street lighting costs, carbon emissions and light pollution. LED lamps are particularly suited to operating at variable brightness and/or being switched off at times of low demand, as they operate at full efficiency with no 'warm-up' time. One consequence of these changes is likely to be that in the future artificially lit environments will exhibit more complex patterns of spatial and temporal variation at both local and regional scales.

Table 3. Selected major outdoor electrical lighting types, and some of their characteristics, based on data from Elvidge *et al*. (2010). CCT – Correlated Colour Temperature (Kelvin) – colour appearance of light emitted by a lamp, with lower values being regarded as 'warm' and higher as 'cool' in appearance; CRI – Colour Rendering Index – ability of a lamp to reproduce colours compared with a natural source (assigned a value of 100); LE – Luminous Efficacy (dimensionless) – efficiency with which a lamp produces visible light. Values (and ranges) reflect representative examples of the different types.

	CCT	CRI	LE
Low-pressure sodium	1807		87
High-pressure sodium	2005-2108	7-32	90-126
Fluorescent	2766-5193	5-82	61-92
Metal halide	2874-4160	64-100	62-100
Light emitting diodes (LED)	1739-8357	65-100	28-66

5.3 According to the study conducted by Mayta (2018), LED luminaires, being a monochromatic light source that does not generate ultraviolet or infrared light, avoid causing risk to flora and fauna, as stated by Baños Sarco & Pizarro Bustamante (2019) indicating that LED luminaires offer better colour rendering, being able to observe the real colour of the illuminated objects, do not generate ultraviolet or infrared light, avoiding risks to human health as well as flora and fauna. LEDs tend to emit a broad-spectrum white light that includes most of the frequencies important to the natural world.

Current Evidence for Impacts of Switching to LED Street Lights

Costs

Research focusing on the costs and opportunities surrounding adoption of LED lights has already revealed substantial complexity in the responses of ecosystems to this new technology, especially when compared to the impacts of artificial light at night (ALAN) from other types of light source.

A key risk associated with transitioning to LED lighting is that, because LEDs are more versatile and cheaper to run than existing technologies, their adoption directly leads to the use of ALAN over greater geographic areas and at higher radiance, thereby exposing a larger number of ecosystems to the disruptive influence of light pollution, and to a larger extent. In addition to simply increasing the rate at which additional lighting is installed (because of savings made elsewhere by increased energy efficiency), LEDs may also encourage the use of lighting in novel settings, such as for solar-powered ornamental garden lighting, where species may be exposed to ALAN in environments where they previously experienced natural darkness, leading to direct impacts on their behaviour. LEDs may also contribute to increasing sky-glow, because they typically contain a greater proportion of short wavelengths. However, with careful design (e.g. proper shielding), LEDs can enable lighting installations that are less wasteful and produce lower sky-glow.

Beyond the potential impacts of increasing ALAN as a whole, some studies have identified ways in which switching to LED from other lighting technologies directly increases disruption to the ecosystem, for example by decreasing the quantity (biomass) of periphyton (the layer of algae and other photosynthetic microorganisms that grows underwater, coating the surface of objects that project above the sediment) compared to high-pressure sodium lights, but as none of the project LEDs are immediately adjacent to water this is not considered a negative impact for the project. At the opposite end of the food chain, LEDs can increase the night-time activity and/or hunting success of visual predators (such as ground-beetles) compared to non-LED lighting, leading to greater predation, and consequently reduced abundance, of herbivores such as slugs and aphids. The wider impacts of such "top-down effects" on different species as they cascade through a food web can be difficult to predict.

Opportunities

By contrast, the effects of LEDs on the growth and flowering of terrestrial plants may be lower than other light sources; an effect which may also be linked to the spectral composition of LEDs, because blue wavelengths are less important to plant photosynthesis. In the same way that effects on predators can lead to top-down effects in ecosystems, effects on plants (and other primary producers) can lead to cascading "bottom-up effects" which are equally unpredictable. Therefore, LEDs may cause less severe bottom-up effects than other lighting technologies in some settings.

Indeed, several studies appear to show that LEDs are less disruptive - or at least, no more disruptive - to certain elements of ecosystems than the incumbent lighting technologies. Commercially available LED street lights are significantly less attractive to nocturnal insects (including flies, beetles, moths, and other groups) than metal halide lights, and no more attractive than high-pressure sodium (HPS) lights. This effect is the same when comparing domestic lights, with LEDs being less attractive than traditional tungsten filament bulbs and novel compact fluorescent bulbs, regardless of colour temperature. Similarly, LEDs had no more impact upon seed set in a nocturnally pollinated plant than HPS lights. Many European bat species are also sensitive to ALAN: some (such as the greater and lesser horseshoe bats, *Rhinolophus ferrumequinum* and *R. hipposideros*) will avoid light sources, whereas others (such as the common pipistrelle Pipistrellus pipistrellus) are tolerant to lights and may even preferentially hunt in their vicinity (probably responding to the high attracted densities of their insect prey). LEDs caused less disruption to the activity of both light averse and light-tolerant groups than mercury vapor lights in some studies (but not all), although there was no change to the activity of light-tolerant bats following a switch from low-pressure sodium lights to LEDs. On the whole, these results do not support the widely held expectation that blue-rich LED lighting will increase the disruptive effects of ALAN on insects and other nocturnal wildlife, but more research is necessary.

Very few studies have looked at the impacts of LED lighting versus HPS sodium on biodiversity. One such study in the UK monitored timing of dawn and dusk bird song; frequency of owl vocalisations; avian diversity, relative abundance and community composition; small invasive mammal and ground insect activity; and invertebrate relative abundance at 26 residential properties over an 18-month period that coincided with a retrofit from high-pressure sodium (HPS) to white light-emitting diode (LED) streetlights. Initiation time of dawn song was advanced or delayed for two bird species following the retrofit and backyard avian community composition was altered. Avian species richness, relative abundances of three bird species and ground insect activity increased in the presence of LED streetlights. No other retrofit effects were found. Our study suggests that retrofitting streetlights with white LEDs may lead to both positive and negative conservation outcomes for urban wildlife, **but direct impacts are relatively small and may be mitigated by changes in lighting characteristics, such as dimming. Streetlight retrofits could provide an opportunity to reduce the impacts of ALAN on urban wildlife if intentionally designed with conservation benefits in mind** (McNaughton *et al*. 2021).

6. Mitigation Measures to Achieve No Net Loss or Net Gain of Biodiversity Values

6.1 In respect of mitigation measures in relation to LEDS, the following measures are proposed.

- prevent areas from being artificially lit are far as possible, so limit light splay which LEDs are more effective at than the existing sodium lights;
- limit the duration of lighting, and avoid periods close to dusk and dawn so that light-induced disturbance to species emerging / returning at these times will be limited;
- reduce the 'trespass' of lighting into areas that are not intended to be lit (including the night sky), again the directional nature of LED lighting makes such 'light trespass' less likely than from sodium lights – cowelling could be used to limit excess light spillage;
- change the intensity of lighting; and
- change the spectral composition of lighting - a warm white spectrum (ideally <2700Kelvin) should be adopted where possible to reduce the blue light component.

6.2 Although the activities do not consider the direct impact to habitat within these areas, it is advisable to establish measures and/or restrictions during the development of the activities to prevent and/or mitigate the possible impacts that could affect the flora and fauna surrounding the access roads, or that is developed near or on the poles already installed, such as:

- Speed control;
- Restrictions on disturbance and extraction of wild flora and fauna by personnel carrying out the work;
- Prohibition of open fires near natural vegetation; and
- Noise control (car horns and machinery) when work is carried out near or in protected areas, as well as others that may be considered appropriate.

7. CONCLUSIONS

7.1 A desktop study has been undertaken looking at the potential effects of the replacement of high pressure sodium lighting (HPS) with LED lighting in the context of three protected areas on the island of St Lucia.

7.2 Very limited research has been undertaken on the impacts of LEDs versus the impacts of HPS lights. Most of the research undertaken relates to bats in the UK. Studies from the Tropics were not located.

7.3 Negative effects of artificial lighting at night (ALAN) on wildlife species include disorientation, fragmentation of habitats, fragmentation of commuting corridors, and induced behavioural changes in bats and birds or example.

7.4 Positive effects of using LEDS include the light being more focussed and more readily controllable; however there is also some evidence of negative effects of LEDS, such as certain slower-flting bat species in the UK avoiding white light sources, but this may well vary from species to species.

7.5 The most comprehensive piece of research undertaken on the impacts of LEDs on wildlife was in the UK (McNaughton *et al*. 2021) and identified that direct impacts are relatively limited and may be mitigated by changes in lighting characteristics, such as dimming.

7.6 The LEDs to be used on this project involve replacing x with y. This will result in a more focussed, directional light source (focussed on the road surface) and will result in lower lux levels on any surrounding vegetation (3 lux at 5 m distance from the light source for a 70W LED compared with 5 lux at 5 m distance from a light source from a 250W HPS; and 2 lux at 5 m distance from the light source for a 21W LED compared with 4 lux at 5 m distance from a light source from a 70W HPS).

7.7 In addition, within one of the protected areas (Pointes Sables Environmental Protection Area - PSEPA), only 3-4 lights fall within the protected area boundary, and within the other two protected areas, only limited areas will be affected, with replacement lights only being fitted, and all works undertaken from the existing highway.

7.8 Additionally, it is not anticipated that there will be any loss of habitat within any of the three protected areas, as the installation and/or retrofitting of streetlights and CCTV cameras will be done on public roads and existing poles. Excavation or trenching activities are not expected to be undertaken (RINA 2021).

7.9 It is concluded on the basis of this brief study that there are unlikely to be overall adverse impacts of LED bulb replacement over and above the impacts currently experienced as a result of HPS lighting, and indeed there might be benefits such as a reduction of light splay, resulting in overall darker areas for nocturnal species.

8. RECOMMENDATIONS

8.1 As there are no apparent significant adverse effects from using LED lights compared to HPS lights, it is recommended that these can be fitted within / adjacent to the three protected areas in the low numbers envisaged.

8.2 It is recommended that any LED lights fitted are fitted with cowlings as far as possible to further reduce light splay onto vegetation along the roadside verge.

8.3 It is further recommended that the use of artificial lighting is minimised in the hour after dusk and the hour before dawn so that nocturnal species can emerge to feed / return to day resting places.

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