



# **Ecological Port Lighting and Biodiversity of the Port Area**

Finlight Group Oy

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## ABSTRACT

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This project aims to develop a comprehensive product-service concept to reduce the negative impact of artificial light on the environment in port areas. Artificial light can have many negative impacts on the ecosystem around the port, including biofouling and disruption of the natural cycle of animals. It may harm the sea transport sector as well. On the other hand, artificial light is an essential condition for the operators to work around the clock, as is necessary for terminal operations. This project aims to find and understand the background information needed to properly balance out the negative impacts of artificial light on nature and the operational needs of the area. Furthermore, part of this study and later pilot project aims to develop a concept that creates an energy-efficient, ecological, and safe entirety.

A system in which the luminaires, spectrum, positioning, and alignment is well planned out and yet dimming is automated ensures a safe environment for the workers and more natural surroundings for the organisms and animals in the area.

Color temperature has been considered from the circadian day–night cycle where **continuous** cold (5000K-6700K) light is not natural while it is the most energy efficient to produce by LED technology. Additional focus is placed on extra warm color temperatures, called Amber tones, around 1800K-2200K. Alignment of luminaires can significantly impact the amount of scattered light in places it is not needed and where it causes disruptions in the behaviour of organisms. Dimming and turning off the lights when not required lessens the amount of light pollution and can save a considerable amount of energy.

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Key words: LED, Biofouling, ALAN

## TABLE OF CONTENTS

1	INTRODUCTION .....	5
2	PORT AREA BIOFOULING .....	8
	2.1 The Formation of Biofilms.....	9
	2.2 Effects of Light and Illumination on Biofouling .....	11
	2.3 Light Factors Which Affect the Process of Biofouling .....	12
	2.3.1 Light Intensity Effect on Biofouling .....	13
	2.3.2 Light Color Effect on Biofouling .....	14
	2.3.3 UV-light Effect on Biofouling .....	14
	2.3.4 Light Exposure Time Effect on Biofouling.....	15
	2.4 Temperature Effect on Biofouling.....	16
	2.5 The complexity of Mitigation Measures Against Biofouling .....	17
3	LIGHT POLLUTION.....	20
	3.1 Light Pollution in Port Areas.....	20
	3.2 Light Pollution Effects .....	22
	3.3 Types of Light Pollution in General .....	24
	3.4 How to Influence the Amount of Light Pollution.....	25
4	BIODIVERSITY MONITORING .....	26
	4.1 Monitoring Methods .....	26
	4.2 Remote Sensing Data Collection.....	27
	4.3 Upward Radiance Remote Sensing .....	29
	4.4 Camera Based Sensors .....	30
	4.5 Citizen Science .....	31
	4.6 Interpolated Single-Channel Detector Maps .....	32
	4.7 Harmful Algae Event Database (HAEDAT).....	32
	4.8 Underwater Visual Surveys.....	33
5	DEVELOPED LIGHT FIXTURES .....	36
	5.1 FL-HM Marine Grade High Mast LED Floodlight .....	37
	5.2 FL-CC Marine Grade LED Floodlight.....	38
	5.2.1 Amber version.....	42
	5.3 FL-TBL-3-PW Marine Grade Passageway Luminaire .....	43
	5.4 FL-TBL-3-UV Marine Grade UV Luminaire .....	45
	5.5 FL-TBL-3-Amber Marine Grade UV Luminaire.....	45
6	LIGHTING PLANNING.....	47
	6.1 Standards, Guidelines, and Regulations.....	49
	6.2 Lighting Level Measurement.....	49

6.3	Beam Angles and Optics .....	50
6.4	Safety .....	51
6.5	Lighting Control .....	52
6.6	Maintenance .....	52
6.7	Security .....	52
7	LIGHTING CONTROL .....	54
7.1	Benefits of Using Automated Lighting Control .....	54
7.2	Circadian Rhythm .....	55
7.3	Wireless Control .....	55
	7.3.1 Casambi .....	56
	7.3.2 Casambi Products with Finlight Solution .....	56
8	Possible negative impacts of RF in port areas .....	58
	8.1.1 Behavioral effect .....	59
	8.1.2 Morphological effect .....	60
	8.1.3 Reproduction effect .....	61
	8.1.4 Thermal effect .....	61
9	THEORETICAL SOLUTION .....	63
	9.1 Solution Framework .....	64
	APPENDICES .....	66
	REFERENCES .....	71

## 1 INTRODUCTION

In the early stages of the project, we conducted extensive research and analysis in several areas, including customer segmentation, location mapping, and identifying equipment suppliers within the port area.

Our customer segmentation analysis allowed us to identify distinct groups with varying needs and preferences, enabling us to tailor our products and services to meet their requirements better. Additionally, our location mapping efforts were crucial in identifying key areas of opportunity and potential challenges within the port area, allowing us to develop a comprehensive understanding of the operating environment.

We also conducted extensive research on the various equipment suppliers operating within the port area, evaluating their lighting needs and how the equipment affects the general lighting of the area. By researching the capabilities and product offerings of equipment suppliers within the port area, we now understand the operating environment better.

The project's overall scope significantly changed from its original plan because the subject area was considerably broader than initially anticipated. In addition, the available relevant information was fragmented and laborious to consolidate, making it challenging to establish a comprehensive framework.

Lighting level measurements and relevant data are hard to acquire from outside sources. Ensuring accurate lighting level measurements is crucial in designing effective lighting solutions for future projects. Relying on third-party measurement data can be risky as it may not accurately reflect each area's specific conditions and requirements. Therefore, we prioritize collecting our lighting level measurements using reliable equipment and validated techniques. We can be confident that our lighting solutions meet or exceed industry standards and regulations by relying on our measurements.

During the project, we realized that to achieve the sustainability goals we wanted, we needed to enhance our products to a level beyond what was previously achieved. For example, incorporating warm tones like amber was particularly effective in achieving our desired ecological outcomes.

This aspect was not initially considered in the original plan, as these product requirements and objectives emerged only during the project's research phase. Nonetheless, we acknowledged the significance of this development and took proactive measures to ensure that our products were modified in an ecologically sustainable and economically viable manner. As a result, product development became a significantly more significant component of the project than initially envisioned. We understood that the success of this kind of project depends on our ability to adapt and respond to the emerging ecological requirements and objectives.

Our focus on new technical solutions in the market aimed to achieve internationalization goals more efficiently. International expansion can be challenging without something new and innovative to offer. By developing and implementing new technical solutions, we aimed to differentiate ourselves in the global market and offer a unique value proposition to potential customers. These efforts are crucial in positioning our company for success in international markets and achieving our goals of expanding our reach beyond domestic markets.

As the project progressed, we fostered a strong working relationship with our team and held bi-weekly meetings to monitor our progress and advance the project's overall objectives.

In conclusion, this project focused on creating ecological and efficient solutions by finding relevant information and developing strategies for planning, measuring, and following up on projects. Through our research and analysis, we gained valuable insights into the needs and requirements of the projects to come, allowing us to design and implement solutions that were both environmentally sustainable, efficient, and cost-effective. In addition, our commitment to collecting accurate measurement data and staying up to date with industry

standards ensures that our solutions meet or exceed regulatory requirements while providing safe and productive working environments for all users. Moving forward, we will continue to apply these principles and strategies to future projects, striving to create solutions that meet the industry's evolving needs while prioritizing environmental sustainability and efficiency.

## 2 PORT AREA BIOFOULING

Biofouling, especially within port areas, has been a subject under scientific research and deliberation for a long time. According to Gu (2005), biofouling describes the undesired accumulation and subsequent adhesion of microbial layers (comprising micro-organisms) on surfaces submerged in or exposed to an aquatic environment. Alternatively, biofouling can be described as the process in which bacteria, algae, and plants stick to and accumulate on wet surfaces. Later, this leads to the establishment of biofilms on the affected surfaces. A biofilm refers to the microbial life which occurs in aggregate. Generally, biofouling must be considered a biofilm-based problem. To comprehend the dynamics and effects of biofouling, the factors which affect the process, and the design of its countermeasures, understanding the natural process of biofilm formation is of immense significance. Naturally, biofilms can manifest at solid-liquid, solid-air, as well as liquid-air interfaces. According to Maddah and Chogle (2017), most microbes can form biofilms; approximately 99% of the earth's living micro-organisms live in such aggregates. A common feature for these microbes is that they are implanted in a medium of microbial origin containing extracellular polymeric substances, commonly made of hydrogel matrices comprising proteins and polysaccharides. It is common knowledge that both artificial and natural surfaces are prone to colonization by bacteria which form a thin layer of microbial biofilms on surfaces. For instance, rocks on seashores have a dicey feeling due to microbial films. The adhesion of microbes on surfaces results from the elaborate interaction between micro-organisms in the natural environment and the chemical, physical, and biological traits of the attachment surfaces, as well as the bacterial cells (Gu, 2005). Various research findings have highlighted the importance of the extracellular polymeric matrix to the survival of biofilm microbes and the ecology of the surrounding in which they occur. Nonetheless, from a human perspective, biofilms can manifest in the wrong places at the wrong time – hence they can cause biofouling.

Biofilms constitute an exciting topic of study due to several reasons. First, they play a critical role in metal corrosion and the degradation of various polymeric and inorganic materials, resulting in severe economic implications for vessels



and underwater structures around their occurrence. Cao *et al.* (2011) emphasize that due to biofilms' accumulation and subsequent adhesion to submerged surfaces, biofouling accelerates the corrosion of the affected surfaces, resulting in the loss of their operative efficiency. Over time the build-up of these fouling organisms can lead to a range of issues for ships, including an increase in drag, fuel consumption, greenhouse gas emissions, the possibility of transporting invasive microbes from one port area to another, and the generally reduced efficiency of the ships and port area vessels (Gu, 2005). Cumulatively, these result in an increase in the cost of ship and port operation, either to recompense for the biofouling on the vessels (e.g., more fuel for ships) or for the physical removal of the biofouling organisms (e.g., scraping, sandblasting, and power washing) from the hull of the vessels. Apart from ships, fouling also causes significant damage to research instruments and aquaculture facilities (such as aquariums, cages, pumps, and canals) in port areas. As a result of the economic damages linked with the formation and establishment of biofilms, especially in port areas, environmentally acceptable ways of preventing their formation (which is the root cause of biofouling) have been extensively investigated. Biofouling significantly undermines ship operational and economic efficiency. According to Magin, Cooper, and Brennan (2010), the presence of a layer(s) beneath ships increases the vessel's resistance to water. Consequently, the friction produced by the dark hull and the sea significantly reduces the ship's speed, thus compromising the vessel's operational efficiency. By reducing the ship's speed, the resistance increases fuel consumption while decreasing its maneuverability, forcing more stops for maintenance and cleaning of the hull and dry dock work and all its additional expenditures.

## **2.1 The Formation of Biofilms**

General microbes form diverse bacterial communities in freshwater and saline environments, which are critical in carbon cycling in natural ecosystems. Ever since their discovery on earth, microbes have demonstrated the tendency to attach and aggregate on surfaces. This attachment ability has significantly improved their success in natural habitats, their minute structure notwithstanding (Maddah & Chogle, 2017). Besides the attachment property,

adhered micro-organisms also demonstrate increased metabolic activities compared to solitary ones. The early stages of bacterial adhesion on surfaces have been a thought-provoking research subject for numerous generations of microbiologists. Various research findings show that microbial adhesion to surfaces can be completed within minutes or even seconds. The difference in attachment completion can be attributed to the difference in physical and chemical traits of the attachment materials. After sticking on surfaces, micro-organisms not only reproduce by producing a three-dimensional structure of biofilms made of gelatinous substances with bacteria entrenched in them but also affects the substratum surfaces, causing corrosion and subsequent deterioration of the attachment material.

According to Maddah and Chogle (2017), for a material or surface to become adulterated by micro-organisms, the single cells or groups of cells must move toward that surface in a process that entails the principle of mass transfer of minute particles. During metabolism, bacteria produce waste products that, on account of mass transfer, move away from the surface. So naturally, bacteria prefer residing on surfaces in aqueous environments rather than "free-floating." Various schools of thought have attempted to explain this phenomenon. Firstly, surfaces could be a source of nutrients drawn from adsorbed matter. Secondly, the constant water flow across such surfaces also ensures the continuous supply of nutrients to the bacteria. Thirdly, the aeration, occasioned by a continuous water flow over such surfaces, provides oxygen for aerobic species. Moreover, the elimination of waste substances from the biofilm is enabled by mass transfer processes. According to Cao *et al.* (2011), the solid surface protects the microbes, enhancing their biofilm survival. Water contains numerous macromolecules that result from the breakdown of previously living matter. These substances tend to be quickly adsorbed onto solid surfaces immersed in aqueous media in preference to the bacteria. It is to this adsorbed stratum that the colonizing micro-organisms attach. Apart from the possible "chemotaxis" to the submerged surface, electrical forces may also play a role in the adhesion process - the charge on a microbe may not be the same as that of the surface, resulting in attraction or repulsion.

Representatives of all the phyla of aquatic biofoulers use sticky substances with either permanent or temporary adhesive capabilities. Nevertheless, the adhesion mechanism and the adhesives' detailed molecular features are unknown. The two main exemptions to this are the adhesives produced by adult marine invertebrates. According to Schmidt *et al.* (2018), the blue mussel's protein glues have been primarily considered to be members of a dihydroxyphenylalanine (DOPA)-rich family of polypeptides. These polypeptides crosslink through an oxidative phenolic tanning-type process. Another exemption is the cement produced by mature adult barnacles, which seems to comprise a complex of hydrophobic proteins dissimilar to blue mussel proteins crosslinked through cysteine residues. Various studies on the establishment and subsequent development of biofilms have suggested that the initial attachment of the microorganisms to the submerged surface is reversible. However, after a period, the bonding becomes more substantial and irreversible.

Following conditioning and initiation of the biofilm growth, rapid development occurs, and the biofilm increases in attachment and thickness. However, it is essential to note that the morphology of a biofilm observable on a surface depends on the prevailing conditions, including the availability of nutrients, rate of water flow, temperature, pH, and light, among many other determining factors. A biofilm can be made of strands of cells or bands that bulge out from the attachment surface toward the water, or it can be uneven with crevices. The structure and morphology of biofilm change as it ages; an alteration in its morphology is also subject to the prevailing external conditions, predominantly concerning nutrient availability as well as the rate of flow over the biofilm (Havlena *et al.*, 2021). Magin, Cooper, and Brennan (2010). explain that biofilms rarely occur "purely;" they usually manifest together with other fouling mechanisms such as corrosions. The sticky nature of biofilms facilitates the retention of particulate material.

## **2.2 Effects of Light and Illumination on Biofouling**

Over the recent past, various research studies have explored the effect of light and illumination on biofouling. Maltsev *et al.* (2021) explain that the larvae of fouling microbes are sensitive to light. Thus, most of them tend to congregate on

darker surfaces, avoiding direct exposure to light. However, it is essential to note that the fouling organisms' plant forms require light and illumination for their photosynthetic process. Consequently, the plant forms of the fouling organisms accumulate on surfaces exposed to light where illumination is sufficient for their growth. According to Callow and Callow (2002), under normal conditions, the greatest biofouling generally occurs on ship surfaces that are least illuminated or the darker surfaces of the vessels exposed to water.

To begin with, the depth and availability of light significantly impact biofilms' growth and composition. According to Harvenda *et al.* (2019), photosynthetic foulers such as algae are more aggregated in the euphotic sections (0-40m depths). A characteristic feature of this region is that it is considerably warmer, rich in plankton, and highly illuminated. From this point of view, it has been suggested in various studies that response to light and illumination could be exploited to control biofouling in port areas. Whereas dark surfaces (least illuminated) accumulate more biofoulers than light surfaces, it is also true that illumination does not stop biofouling (Zimbelmann *et al.* 2022).

### **2.3 Light Factors Which Affect the Process of Biofouling**

According to Havlena *et al.* (2021), light is among the most common abiotic factors influencing biofouling. Several light factors, especially those associated with cell metabolism, play a critical role in influencing the growth and establishment of biofilms and thus influence the general biofouling process. The main light factors highlighted in various studies to impact biofouling are intensity (quality), ultraviolet (UV) light, temperature, color, and exposure time (duration). Other studies have also included the type of light as a factor that presents significant implications for biofouling. For example, UV light has extensively been used for disinfection and sterilization procedures, with the sole objective of inhibiting bacterial contamination (Hunsucker *et al.* 2019). Over the recent past, numerous studies have focused on exploring the efficiency of using UV in maritime environments, specifically focusing on how UV exposure affects biofouling and how the accumulation of microbes varies with distance from the source of UV light.

### 2.3.1 Light Intensity Effect on Biofouling

The effect of light intensity on biofouling is somewhat complex because light is the primary energy source for autotrophic foulers, such as macroalgae. Their photosynthesis is directly linked to the growth and establishment of biofilms. Braga (2018) emphasizes that light intensity is among the most critical drivers for the growth of the algal communities which constitute biofilms (Schmidt *et al.* 2018). Low light intensity has been associated with a significant reduction in biofilm development, and this can be directly linked with slowing the biofouling process. Under low light intensity, the photosynthetic processes of the macroalgae, which are the most abundant microbes in biofilms, are immensely slowed. As a result, biofouling takes place slowly (Havlena *et al.* 2021). However, it is essential to note that microalgae are not the sole functional contributors to the biofouling community. The complicated interactions between autotrophic and heterotrophic bacteria must be considered, as they play a pivotal role in shaping the overall biofilm system. As already described, the founding microbes may be crucial for settling diatoms in the biofilm.

Port areas are known to be open spaces with limited shade. As a result, light traveling through the atmosphere is less shadowed. Consequently, the high-intensity light reaches the water; thus, photosynthetic foulers use the light energy for photosynthesis (Harvenda *et al.* 2019). This speeds up the build-up and accumulation of microbes on the hulls of ships, thereby speeding up the biofouling process. Other studies have also argued the role of light in hindering the establishment and subsequent accumulation of microbes. According to Maltsev *et al.* (2021), light plays a significant role in inhibiting the settlement of organisms in biofilms. This can be explained by other studies which have shown minimal aggregation of biofilms in well-illuminated areas of the port vessels. This perspective complicates determining the definite role of light intensity in the entire biofouling process. Schmidt *et al.* (2018) also suggested that high-intensity light can also be used to control populations of invasive microbial species at port areas, thereby playing a determinant role in influencing the process of biofouling.

### 2.3.2 Light Color Effect on Biofouling

Just as in the case of light intensity, the role of light color in influencing the process of biofouling is quite intricate. Specific colors (such as white) have been determined to be unattractive to fouling microbes; they influence the recruitment and the subsequent settlement of biofoulers. In as much as white color reflects approximately 50% of light and absorbs the remaining percentage in the form of heat energy (Richard *et al.* 2021). This absorption of light heats the attachment surfaces, thereby inhibiting the settlement of biofoulers, consequently stopping the biofouling process. Conversely, colors like red have been determined to encourage the attachment and settlement of biofoulers such as *Balanus amphitrite*. Additionally, the ability of different colors to reflect light at various frequencies varies significantly, and it is understood that color can influence the settlement of biofoulers during exposure to UV light is limited.

### 2.3.3 UV-light Effect on Biofouling

Ultraviolet radiation describes a non-chemical substitute for control of the biofouling process. Compared with ordinary light, UV light has a much greater penetration rate (Braga, 2018). UV light can eradicate or prevent the growth and aggregation of micro-organisms, especially when applied on an uninterrupted basis (Richard *et al.* 2021). UV light has long been known to kill microbes in bulk water circulation systems. It is a common technique for sterilizing water, especially for medical and food productions. While studies have highlighted the success of UV radiations in killing suspended cells, surface-attaching microbes in biofilms are quite different from their suspended counterparts regarding their metabolism and physiology. As a result, the efficiency with which UV light inactivates suspended microbes may not apply to the organisms in biofilms (Zimbelmann *et al.*, 2022). From this point of view, various studies have suggested that UV light's effect on biofouling is insignificant.

The application of UV light on the biofouled surfaces is determined by the surface area of the target submerged surface. For small surfaces, low-energy UV light is preferred. However, for large surfaces, high-energy UV light works best. The underwater surfaces are irradiated with UV light, and studies have shown that

this strategy effectively prevents marine biofouling. In port areas, fiber optics can convey the UV light from the source to the intended underwater surface. Through this strategy, the attachment of the destructive marine biofoulers to the ship hull can be adequately dealt with. Richard *et al.* (2021) suggest that for small areas where prevention of attachment would be preferred with the port area, a sufficient amount of UV light can be applied to render the target regions unlivable for the microbes. However, higher energy UV light is periodically applied to the biofouled surfaces for large surfaces such as the sides of ships. The high-energy UV light kills the attaching micro-organisms at their larval stages of development, thereby effectively stopping the biofouling process (Hunsucker *et al.* 2019). As a result of its non-toxicity and non-polluting nature both to the local and outlying environment, the application of UV light in the management of biofouling in most port areas has gained prominence over the years (Richard *et al.* 2021). Besides, UV light has demonstrated its ability to inhibit the accumulation of biofoulers in high fouling pressure conditions, as is the case with port areas.

#### **2.3.4 Light Exposure Time Effect on Biofouling**

The duration of microbe exposure to light, concerning the biofouling process, is as complex as with other light parameters such as intensity and color. Macroalgae, the primary inhabitants of biofilms, are known to be autotrophic (Brock & Brock, 1969). As such, they rely on light as their sole energy source for photosynthesis. In this context, their exposure to natural light for more prolonged durations implies increased access to and harnessing light energy for photosynthesis. Consequently, this results in increased availability of food in the biofilms and, thus, increased multiplication of the microbes in the biofilm, which increases the biofouling process on port vessels (Whitworth *et al.* 2022).

On the other hand, Brock and Brock (1969) explain that vessel surfaces that stay exposed to direct light for long periods experience minimal biofouling in port areas. This is primarily associated with the prolonged exposure of biofouling micro-organisms to UV light, resulting in higher mortality of the microbes. This occurrence disrupts the biofouling process. In addition, this phenomenon has been associated with the fact that exposure to light for longer durations has the

potential to initiate photo-inhibition, which lowers the photochemical efficiency of the algal cells due to increased and intense radiations.

## **2.4 Temperature Effect on Biofouling**

Ports are usually located in coastal areas, which are conventionally known for their high temperatures. Water temperature is considered a significant regulating factor in biological fouling, as it directly and indirectly, influences various factors responsible for microbial growth. Seawater temperatures range between -2 and 30<sup>0</sup> C (Farhat *et al.* 2016). This implies that the intensity of biofouling varies between degrees of altitude, nonetheless nearly not on a longitudinal gradient, as a result of the virtually evenly distributed water surface temperature (except when not considering the ocean currents). Furthermore, water temperature influences numerous ecological genes, occasionally resulting in surface bacterial cell alterations and possibly interfering with cell attachment to surfaces. From this point of view, it is pretty clear that some microbes adhere at low temperatures while others adhere at high temperatures. Conversely, other studies have highlighted that water temperature can also modify microbial hydrophobicity and the cells' charge on the microbe's surface.

For this reason, water temperature plays a critical role in facilitating the initial attachment of the foulers to the submerged ship's surface. According to Farhat *et al.* (2016), the rate of biofouling usually increases with temperatures up to 30-40<sup>0</sup>C, above which fouling microbes begin to die. From this perspective, it is equally important to note that the rate of biological fouling decreases with a decrease in temperature. Water temperature also significantly affects the extracellular polymeric matrix secreted by fouling organisms to facilitate their attachment to submerged surfaces in port areas. It is essential to note that water temperatures fluctuate; in port areas, there are times when they are too high and, at times, too low. High temperatures significantly lower the viscosity of the extracellular attachment matrix, thereby reducing the chances of attachment of the fouling microbes to port vessels. The effect of water temperature on the growth and metabolism of microbes is also well documented. At a temperature increase of approximately 10 °C, bacterial cells' enzymatic respiratory activity



almost doubles. Therefore, at high temperatures, an increase in biomass and activity of microbes in the biofilm is always expected (Farhat *et al.* 2016). However, studies have demonstrated that this only happens in the bacterial exponential growth phase when the growth of bacteria is optimum (Farhat *et al.* 2016). As microbes' exponential growth phase approaches, biofilms' development becomes nutrient controlled. Further, the balance between nutrient transportation and maintenance of energy alterations regulates the biofilm growth rate (Farhat *et al.* 2016). According to Callow and Callow (2002), the growth rate of biofilms increases with temperature. However, the efficiency of bacterial growth and the extent of new bacterial biomass production per unit of organic carbon nutrient assimilated may drop, possibly giving rise to less biofilm biomass.

## **2.5 The complexity of Mitigation Measures Against Biofouling**

Biofouling is a natural phenomenon that affects various industries of our society today. In port areas, the corrosion of metals and wear of polymeric materials have become economically significant both for the operations within and without the port, as well as the possible hazards the corruptions resulting from this biological process expose operators of various vessels in ports. A significant economic effect of biofouling on marine vessels relates to the loss of structural integrity and performance triggered, for instance, by the added weight and rugosity to components and obstruction of sensors in marine vessels. Key biofouling organisms, such as mussels, acorn barnacles, bryozoans, calcareous tubeworms, and kelp, are the most frequently referred to in the literature as responsible for those impacts. Over time, the build-up of fouling organisms can result in various issues for ships, including increased drag, emission of greenhouse gases, increased fuel consumption, the possibility of transporting invasive species, and reduced efficiency. These concerns ultimately result in an upsurge in cost either to recompense for the biofouling on the vessel (e.g., more fuel) or the physical removal of the accumulated biofilms (e.g., power washing, scraping, blasting). From this perspective, it is pretty evident that biofouling is a universal problem in aquatic systems.

Many propositions for the inhibition of fouling are grounded on appreciating the distribution and physiology of fouling organisms. While considering any mitigation measures against biofouling, especially in port areas, it is essential to note that microbial attachment on surfaces is a result of the multifaceted communication between the micro-organisms in the natural environment and the physical, biological, and chemical features of the substratum surfaces, and the microbial cells. For this reason, any mitigation measures against the attachment and establishment of these microbes must seek to deal with all aspects of this complex interaction. Such a strategy should be based on an in-depth analysis of the fouling situation in the specific port area or vessel, selecting appropriate anti-fouling mechanisms, and effective and illustrative monitoring of the biofouling process.

The role of light in the biofouling process presents an exciting topic for research studies and future discussions. Various light parameters, including intensity, exposure duration, temperature, and color, play distinct roles in biofouling. Light, especially UV light, can be used as a non-chemical control mechanism against biofouling. It can kill or inhibit the growth of microbes on surfaces, especially when applied continuously. However, it is also worth noting the role of light as an enabling factor in the survival of microbes in biofilms. Light provides the much-needed energy for photosynthesis amongst autotrophic microbes found in biofilms. In this regard, light acts as an enabler in the biofouling process.

Light intensity has a direct impact on the rate of photosynthesis. At lower intensities, any increment in lighting results in a considerable increase in photosynthesis for autotrophs. Nonetheless, at a saturating light intensity, any increase in lighting does not affect the rate of algal photosynthesis. However, excessive lighting can cause photo-oxidative damage to the photosynthetic apparatus of microbe vegetation in biofilms, decreasing their efficiency and rate of photosynthesis, thereby inhibiting the property of light to biofouling. Other light parameters, such as temperature and color, also have distinct effects on biofouling, acting as enablers and inhibitors of biofouling.

Generally, understanding the various factors affecting biofilms' temporal and spatial development, which are the primary indicator of biofouling, is central to formulating effective mitigation strategies against the menace in port areas. Various mitigation measures have been proposed to help deal with biofouling.

However, most of them do not include inhibition against the algal activity. Therefore, future studies should explore non-chemical mitigation measures against biofouling to solve the problem while protecting port area biodiversity.

Biofouling is a complex subject and requires a lot of study and sampling in the actual location where it occurs. There seems to be no simple solution to prevent biofouling with, e.g., specific light color temperature or even the light amount in the port area general lighting. However, it is possible to reduce the amount with these factors. More specified solutions, like UV lights near the hulls, need to be further studied in the target area, considering the biodiversity and nature's state as a whole.

FL-TBL-3-UV Marine Grade LED Luminaire was designed as a possible solution near the hulls. However, using UV lights on a larger scale in the dock area has to be studied more deeply with actual testing and measuring in the target port.

### **3 LIGHT POLLUTION**

Light pollution is a severe problem in today's world. It is defined as "any adverse effect of artificial light including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste." It can also be defined as the introduction by humans, directly or indirectly, of artificial light into the environment. Scientists have found that light pollution can negatively affect humans and the environment. For example, it has been linked to increased stress levels, fatigue, anxiety, and even cancer, and it can also disrupt food webs and affect entire ecosystems. Furthermore, it has also been linked to smog and can be classified as annoying or excessive light pollution. Fortunately, there are ways to reduce light pollution. One is to use lighting fixtures more efficiently. Another is to promote "dark time," which is the night period when artificial lighting is unnecessary. This can save energy, improve visibility, and protect wildlife. We need to be aware of light pollution and take action to reduce its harmful effects.

To better understand the effects of light pollution, we need first to understand what causes it. Excessive amounts of artificial light can cause it. This can be from improperly shielded lights or inefficient lighting fixtures. Light pollution comes not only from streetlights and headlights but also from signs and advertisements, office building lights at night, security lighting, and even car lights inside buildings. In the United States, about 11 million streetlights and 3 million parking lots have lights on all night.

In addition to the effect on humans and animals, light pollution also impacts the environment. It has been found that light pollution not only causes ecosystem disruption but can cause species extinction.

#### **3.1 Light Pollution in Port Areas**

Light pollution can significantly impact the environment, particularly in Mediterranean ports. It has been found to disrupt the natural migrations, feeding, and breeding of birds and zooplankton, cephalopods, fish, and other marine species. In addition, brightly lit cruise ships moving through dark waters can disorient these creatures, leading to collisions and an increased risk of predation

due to the permanent 'moonlight' created by their lights. Here, the lights can be grouped into three major components: exterior and interior lighting, mobile lights on boats and ships, and illumination from advertising signs. Exterior lighting is typically directed downwards to illuminate the port area from overhead light fixtures, such as street lights or spotlights. Exterior lighting includes lighting used to illuminate equipment and machinery on the dock. Interior lighting includes artificial indoor lighting in buildings. Mobile lights refer to those used by boats, ships, ferries, and other vessels in port as well as mobile cranes and the like. Finally, advertising signs are illuminated billboards and digital displays advertising businesses or events in ports.

In a recent study, researchers examined the effects of light pollution on the seafloor off the coast of Plymouth, UK. The study using radiative transfer modeling and mapping and accounting for in situ measured optical seawater properties found that green and blue light could penetrate depths greater than 80 meters. Furthermore, on cloudy nights, significant levels of green and blue light, biologically significant light pollution, were observed in 76% seafloor. However, the red light was largely absent from the seafloor (Davies, T. W. (2020). These results demonstrate the potentially harmful effects of artificial lighting on marine ecosystems. For example, copepods and other organisms rely more on green and blue light, while red light is mainly undetectable. Furthermore, seafloor sediment and phytoplankton blooms can further reduce the amount of light reaching deeper water levels.

The findings from this study have global implications, especially in port areas with increased human settlement and upcoming infrastructure. Port areas are complex environments in which human activities are widely developed. They are considered hot spots of light pollution due to the concentration and mix of artificial lights. In addition, lights in port areas have specific characteristics, such as tall masts and bright anchor lights. As a new study led by the University of Plymouth in the UK found out (Davies, T. W. (2020) that neighboring sea floors to the human residence are being affected by artificial light coming from coastal cities. This type of light from coastal urban centers disrupts the natural biological cycles of marine life on sea floors. These creatures rely on the moon's light to

regulate behaviors such as reproduction, sleep, and food choices, but this light pollution makes it increasingly difficult for them to survive.

### **3.2 Light Pollution Effects**

Light pollution researcher believes that similar or worse results could be expected in Southern Europe, facing increased offshore development and coastal urbanization, whose impact extends to coral reef systems (Peregrym, M. 2020). It is acknowledged that light is critical for coral reefs to survive and flourish. However, light pollution due to increasing coastal development in tropical areas can damage corals and their habitats. Artificial Light at Night (ALAN) affects the reef environment through sky glow caused by scattered particles and direct light from lights such as streetlights and floodlight that shines on the water. This light pollution can cause oxidative stress in corals and disrupt their natural circadian rhythm, affecting essential behaviors such as spawning, hunting, feeding, and diurnal migrations; this ultimately has negative repercussions for the ecological function of reefs (Tamir, R. 2017).

Light pollution is becoming a more common global issue, with coastal areas in tropical regions particularly affected. For example, a recent study conducted Northern Gulf of Aqaba showed that around the shoreline, the intensity of light penetrating the water at night was two orders of magnitude higher than in the middle of a nearby gulf (Tamir, R. 2017). The study also revealed artificial light signals up to 30 meters deep, displaying the far-reaching effects of ALAN. Not only has coastal light pollution increased, but it is also transforming the light spectra on reefs. This shift in spectra has direct implications for reef organisms as their behavior patterns are tied to the overlap between artificial light and cryptochromes (light-sensing proteins).

Coral reefs are particularly vulnerable to the adverse effects of ALAN. This is mainly due to their dependence on light cues for vital behavioral and physiological functions, including coral spawning. Spawning involves the release of eggs and sperm from corals into the water column and requires moonlight to succeed. Artificial light can disrupt this process, resulting in a decreased chance of egg fertilization. In one example, pillar coral *Dendrogyra cylindrus* had a spawning period that lasted seven days in an aquarium with artificial light compared to just three days naturally on the reef (Neely, K. L. 2020).

Similarly, larvae exposed to artificial light treatments displayed a 30% reduction in recruitment success. The study, which compared the impact of light pollution in situ and ex-situ Pillar Corals, concluded that proximity to artificial light resulted in delayed spawn times. The study proposes that artificial lights are red, shifting the twilight spectrum and affecting corals' perception of lighting cues that trigger spawning (Neely, K. L. 2020). Light pollution, therefore, poses an additional threat to coral reproduction which is already under stress from climate change. What this means for the Mediterranean coastline is an increased risk of coral bleaching, as well as reduced reproductive success and population growth. This study brings to light the importance of controlling light pollution in order to protect fragile coral ecosystems.

Introducing ALAN can harm photosynthetic processes in coral symbionts, decreasing coral energy reserves and increasing oxidative stress. This is because ALAN can cause photoinhibition and damage the photosynthetic machinery of corals, resulting in the production of reactive oxygen species and subsequent oxidative damage to lipids (Levy O., 2020). ALAN has added to the existing adverse effects of climate change on coral reefs, compounding a difficult situation for these delicate ecosystems. As human populations grow, coastal development will become more widespread, and we must consider its potential ecological consequences. Clearly, reefs face various threats globally, and ALAN is yet another factor that must be considered. By doing so, we can work towards conserving these vital marine ecosystems.

To mitigate human impacts on these species, coastal managers should consider regulations on artificial lighting near reefs, such as using LED lights that are less disruptive to marine life. Additionally, further research should be conducted to

understand better the mechanisms behind coral spawning and how artificial light affects this process.

Artificial lighting in harbors can harm marine life, but not only the ecosystem suffers. For example, a study showed that this light could increase the presence of fouling species, which attach and settle to ships' hulls and oil rigs structure. This is particularly concerning for vessels in tropical conditions or shallow coastal waters because of higher light exposure and more heat and nutrients. These fouling species can cause damage to the vessels, resulting in increased drag, higher fuel consumption, structural damage, and decreased maneuverability. Additionally, artificial light may affect larvae biology depending on where they settle. These findings indicate that harbor lighting should be monitored carefully to avoid potential adverse effects.

### 3.3 Types of Light Pollution in General

- Glare
  - Glare is caused by too bright lights that are misdirected. As a result, glare can cause light pollution. In addition, big contrast between dark and bright areas can obscure vision, and glare can cause blindness in the users of the area, causing serious safety issues.
- Over-illumination
  - Over-illumination means that an area is unnecessarily brightly lit.
- Light trespass
  - For example, the area's lights are shining on the neighboring lot.
- Sky glow
  - The brightening of the night sky due to artificial lighting cause light pollution. It means the overall amount of light reflected in the sky from the area lighting. Incorrectly directed and unnecessarily bright lights are the main cause of the sky's glow. (Rajkhowa, 2014)



### **3.4 How to Influence the Amount of Light Pollution**

Light pollution can be minimized by carefully planning, selecting the right light fixtures, and efficiently controlling the area's luminaires. Correct beam angles and light shields with the fixtures make it possible to efficiently control the amount of scattered light. Beam angles, lighting fixture orientation, and mechanical shields help to direct the light where needed and reduce the amount of light scattered in the water and up to the sky.

The lighting fixtures' orientation and direction are critical in influencing light pollution in port areas. Improperly oriented or directed fixtures can result in excess light spillover, negatively impacting the environment and nearby communities.

To address this issue, we prioritize carefully placing and orienting our lighting fixtures, considering each area's specific needs and requirements within the port. By ensuring that our fixtures are adequately oriented and directed, we can minimize light spillover and reduce the overall impact of light pollution.

Versatile control and dimming of the luminaires are also crucial because, with these, it is possible to reduce the overall light to a minimum when the operators and personnel do not need it. Lighting control is discussed in more detail in a separate paragraph.

## **4 BIODIVERSITY MONITORING**

Recognizing the threats posed to marine biodiversity and its importance to human society has caused experts to call for international initiatives to monitor ecosystem changes. To this end, we have reviewed methods of collecting and managing biodiversity-related data. Knowing what species are present in different locations at different times is a fundamental factor when it comes to biodiversity, but monitoring methods have inherent limitations when it comes to the taxa, ecological guilds, and body sizes they can register. In addition, this data must be organized or mapped within its respective environment to make sense of it.

### **4.1 Monitoring Methods**

Monitoring refers to regular or irregular surveillance to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm (Hellawell, J. M. 1997). The formulation of this standard requires information on the baseline structure and variation in the system to be monitored. However, establishing a natural baseline may be difficult because long-term data sets on most taxonomic groups from undisturbed sites are not available to provide information about natural variation in species assemblages. Humans have affected most of the world's ecosystems, making it difficult to find undisturbed sites that can provide baseline information about natural variations (Arcese, P., 1997). Nevertheless, fairly natural areas still exist in the surroundings of many urban centers, and an urban-to-rural gradient of decreasing human influence could be used to assess the effect of human-caused landscape changes on biota (McDonnell, M. J., 1990). These gradients provide a framework in which ecologists can examine human-induced landscape changes and compare the global findings to unravel generalities in community structure related to the disturbance.

Through consistent monitoring efforts, these landscapes can be treated as field experiments for addressing basic ecological questions and issues related to humans' impact on their environment (Niemelä et al., 2000). The Convention on

Biological Diversity defines biodiversity as the variability among living organisms from all sources, i.e., terrestrial, marine, and other aquatic ecosystems, and the ecological complexes they are part of, e.g., diversity within species, between species and species of ecosystems. Therefore, biodiversity monitoring can encompass a variety of biological entities and levels. Generally, biodiversity monitoring uses the distribution and abundance of organisms and their associations with the physical environment to determine the status of biodiversity or changes over time and space. The main goal of biodiversity monitoring is to detect incipient change or assess the effectiveness of a policy.

Tracking and maintaining biodiversity requires quantification over time, which can be done through Marine Protected Areas (MPAs). This monitoring should include inventories of species and habitats and regular surveillance activities. Counting all species and mapping habitats is ideal but often unrealistic; hence, measuring investigation efforts for species inventories and using suitable spatial modeling for habitat inventory is recommended (Bianchi, C. N., 2022). Regarding surveillance activities, the focus should be on conspicuous species and priority habitats along with efficient descriptor taxa and ecological indices to assess the environment's status. Although the importance of regular monitoring, diachronic inventories and mapping are rarely done (Bianchi, C. N., 2022). Therefore, keeping track of long-term changes in marine ecosystems is vital for detecting even subtle human impacts.

## **4.2 Remote Sensing Data Collection**

Remote sensing data collection via satellite imagery is a powerful tool for monitoring light amount, temperature, and wavelengths across the Mediterranean region. This data can be used to detect hotspots of light pollution and areas that experience higher levels of illumination than others. Additionally, remote sensing can be used to investigate changes in species composition due to different lighting regimes. Several marine and landscape pattern quantification have been developed, including various methods that link the spatial arrangement of features in the landscape to ecosystem functions and biodiversity. Both fieldwork and aerial photography can provide mapping data,

but satellite-borne sensors automatically collect and store such data in a digital grid-cell format. (El Mahrad, B., 2020)

Remote sensing (RS) technology has become widely used to fill the data gaps and provide efficient access to existing information needed for coastal and marine management. Some of the potential RS technologies include Satellite-based Remote Sensing, Aerial Remote Sensing, Unmanned Aerial Vehicles, Unmanned Surface Vehicles, Unmanned Underwater Vehicles, and Static Sensors, to be incorporated into the DAPSI(W)R(M) framework (Drivers–Activities–Pressures–State changes–Impacts (on Welfare)–Responses (as Measures), a holistic approach to biodiversity monitoring. Remotely sensed data is used as input for these approaches, allowing for the quantification of landscape pattern metrics over large areas in a repeatable and non-destructive fashion. In addition, integrating this data with geographic information systems (GIS) and simulation models can provide powerful spatial tools for assessing and predicting changes in landscape patterns over time.

These methods enable ecologists to assess and monitor the composition and arrangement of features in a landscape, such as vegetation, hydrology, and elevation. The data collected can then be used to drive spatially explicit simulation models that project changes in spatial cover under various scenarios. Furthermore, existing biodiversity data can be stored as one of the layers or inferred from other layers (e.g., fauna biodiversity may be associated with the structural diversity of the vegetation layer). This approach allows for a more comprehensive understanding of how changes in landscape patterns affect biodiversity and ecosystem functions. With these advances, landscape pattern quantification is becoming invaluable for resource management, conservation planning, and natural resource monitoring.

Remote sensing measurements via satellite imagery can be used to monitor the changes in light pollution in different areas. By examining the night-time visible and near-infrared emissions from the earth, scientists use a combination of passive remote sensing instruments and active sensors to track changes in light pollution. Meteorological conditions and cloud cover must be considered for a

complete analysis of radiation changes and atmospheric effects on them. This requires local conditions to be carefully analyzed and compared to those at a reference site. Ground-based remotely sensed data can be analyzed more accurately than satellites because of the absolute specializations in radiometry and radiometric, as well as the spatial resolution. The improvement of colorimetric sensors can also cause issues in terms of spectral resolution because of spectral similarities between three-wavelength bands.

### **4.3 Upward Radiance Remote Sensing**

From astronauts aboard the ISS, photographs of the earth's night side have provided a third source of quantitative information about nights in and around conservation sites. These images taken with consumer-grade digital single-reflex cameras show excellent quality, even though they may not provide global coverage and are not taken at nadir angles. Furthermore, the photos must be corrected due to the oblique viewing angles. An example can be seen in a 2015 image of Calgary, Canada (Figure 1). The photograph clearly shows the significant waterways and municipal parks against the light from the city. Such visuals are invaluable for conservationists to accurately assess light levels near protected places and study the spectral power distribution of its sources.



Figure 1. Barentine, J. C. (2019). Methods for assessment and monitoring of light pollution around ecologically sensitive sites. *Journal of Imaging*, 5(5), 54.

#### 4.4 Camera Based Sensors

Several camera-based sensors that can be mounted on a camera to increase the accuracy and precision of the collected data have been developed. These units include photosensitive devices that correct for sensor-specific characteristics

(e.g., response curves) and mechanisms for reducing noise and resolving the light detected by the sensor into color channels. In addition, some of these devices are designed to detect specific wavelengths outside the detection range by off-the-shelf cameras. One example of a device that can be mounted directly on a compact sensor is the Xenon mGPS-Lite, an overpressure gas sensor. A xenon lamp is used to illuminate the device and continuously measure the light's intensity from nearby buildings' lamps. Again, these sensors' signals, including color channels, can be acquired and further processed to improve accuracy and precision.

#### **4.5 Citizen Science**

Citizen Science is described as a diverse range of approaches that involve people in science and monitoring in a noncontracted or voluntary capacity (Bonney, R., 2009).

Citizen Science involves different approach categories. Broadly categorized as a contributory approach where participants are primarily involved as data collectors. Collaborative/co-created approaches involve participants in additional stages of the scientific process, including identifying the question of interest, designing methodologies, analyzing data, and using the results (Bonney, R., 2009).

On the other hand, participatory monitoring/community-based monitoring is focused on participation by local people with a vital stake in their local environment, aiming that local people rather than scientist-led activities define the monitoring. It is mainly found in developing countries and the Arctic, where community members depend on living resources for their livelihood and cultural identity. Nevertheless, the information collected occasionally offers a baseline for monitoring changes in biodiversity distribution and abundance under the influence of light pollution.

#### **4.6 Interpolated Single-Channel Detector Maps**

The primary requirement for sites to be accredited in the certification programs is a characteristic night sky brightness measured at the zenith that does not surpass a set threshold. Both single-channel detectors, such as SQM and all-sky imagery, are utilized to perform sky-quality surveys. However, these surveys typically only observe a few locations in enormous dark skies. Areal maps of zenithal night sky brightness estimates can be generated from remote sensing measurements. However, the accuracy of these estimates is model-dependent. It tends to not accurately match ground measurements due to variable conditions like turbid weather, artificial sources, and natural sources like airglow.

Single-channel detectors offer limited spatial information on the night sky, though they can be used to interpolate measurements taken at multiple points and yield more straightforward maps of sky brightness (Barentine, J. C. 2019). However, interpreting these results is difficult when a sampling frequency of one sample per square kilometer is necessary to keep the uncertainty in zenithal night sky brightness measurements within ten percent.

#### **4.7 Harmful Algae Event Database (HAEDAT)**

HAEDAT is a database containing records of harmful algal events worldwide, including those in the Mediterranean Sea. These records are collected and collated through an international network of monitoring programs, making it one of the most comprehensive global databases for tracking changes in HABs. The information provided by HAEDAT allows scientists to monitor and compare harmful algal populations in different locations, providing insight into the environmental and human impacts on marine biodiversity (Marampouti, C., 2020).

The HAEDAT database is an invaluable tool for scientists and managers working to conserve the Mediterranean Sea and its biodiversity. Gathering data from various sources provides a detailed picture of how HABs affect the region, allowing us to make informed decisions about how best to protect this important marine environment.



The HAEDAT database is essential for understanding the dynamics of harmful algal populations in the Mediterranean Sea. It records continuous data on HABs, allowing scientists to evaluate changes in biodiversity over time and space and the effects of human activities such as climate change, fishing, and nutrient enrichment. The information provided by this database enables us to analyze the impacts of human activities on biodiversity in this important marine environment.

The data from HAEDAT can also be used to understand better the ecology of HABs and how their populations are influenced by environmental factors such as salinity, temperature, turbidity, and nutrients (IOC-UNESCO 2022). This information can help us make more informed decisions about managing the Mediterranean Sea in a way that promotes biodiversity.

By using HAEDAT, we can also assess the potential impacts of HABs on other species and habitats in the Mediterranean Basin. This could inform management plans for sustainable fisheries, aquaculture, and conservation programs. By understanding how these populations are affected by environmental change, we can make better decisions about how to protect the marine environment.

#### **4.8 Underwater Visual Surveys**

The rapid growth of innovative techniques in assessing marine biodiversity has made specimen sampling and observation using photos and video less necessary (Bianchi, C. N., 2022). Environmental DNA (eDNA) is one technique that can be used to survey the entire marine biota, from microscopic organisms to vertebrates, without collecting them (Eble, J. A., 2020, Rees, H. C. 2014). The advantages of this method include its speed and ease of use on a large scale. Studies on fish have demonstrated that eDNA can detect species often missed by visual surveys, including cryptobenthic, pelagic, and rare species (Stat, M., 2017). Although the method is not yet reliable enough to identify all species in a given area, it provides an essential complementary tool to traditional methods. The effectiveness of biodiversity assessments based on eDNA is limited by the availability of barcoding reference databases.

Remote acoustic sensors can be used to capture the various sounds in the aquatic environment, and these noises stem from both natural and artificial sources (Stowell, D., 2020). This array of sounds created by living organisms is called acoustic biodiversity, which encompasses a wide range of levels of an organization, such as individual species, populations, communities, and entire ecosystems. These distinct audio signatures can provide insights into many ecological aspects, including species presence or absence, population density and structure, migration patterns, and interactions between species (Duarte, C. M., 2021). For example, research studies in the Mediterranean Sea have focused on examining the circadian rhythms of snapping shrimps and fish (Pieretti, N, 2017), the behavior of dolphins (Brunoldi, M., 2016), the relationship between fish and coral reefs, and comparing fish population sizes determined through passive acoustics and traditional visual census surveys (Pieretti, N. 2020). Acoustic indices can be used to better understand marine biodiversity and human activity's impact. However, more studies are needed to confirm their accuracy. Besides, further research is required for acoustic indices to be reliably used for assessing marine ecology and biodiversity in Mediterranean Marine Protected Areas. In the meantime, traditional observer-based methods should also be utilized to complement the acoustic indices.

Baited remote underwater video (BRUV) systems involve using one or two cameras for filming to attract fish and other invertebrates. This method can be used as an alternative to traditional sampling methods. Although, results may be biased toward predatory species due to their inability to detect herbivorous and omnivorous species (Cappo, M., 2006). Despite this limitation, BRUV has been used in the Mediterranean Sea with results consistent with visual census surveys and detect high-level predators more effectively (La Manna, G., 2021).

An essential aspect of the monitoring is that the number of species observed in marine protected areas must be considered when studying biodiversity. The amount of effort required to take a census, such as a cost or time, the number of samples, or the area investigated, is an essential factor that must be considered. A species-area relationship curve is commonly used for this purpose, as it considers the effort required to take a census of species in certain areas. This is

done by considering factors such as time or the number of samples instead of just the area alone.

## 5 DEVELOPED LIGHT FIXTURES

This section describes the products which have been developed during this project. These lights can be used as an initial measurement during the pilot project and modified or fine-tuned based on the measured data.

The information we gathered and analyzed during this project was crucial in developing and optimizing our products to meet the specific needs of these kinds of projects. By identifying the key factors that contribute to ecological and efficient solutions, we were able to fine-tune our products and make them more effective in meeting those needs.

We explored different design possibilities during the project to incorporate amber tones into our luminaires. By experimenting with different materials and color temperature settings, we were able to fine-tune our products and develop solutions that effectively incorporate warm tones into the lighting design.

We recognized the importance of warm tones in achieving the desired ecological outcomes in port areas, and therefore, we prioritized incorporating them into our products. Our design efforts included everything from modifying existing products to developing new solutions that could effectively incorporate warm tones.

Overall, our commitment to acquiring and utilizing relevant information allowed us to develop tailored products to meet the specific needs of these kinds of projects. Moving forward, we will continue prioritizing research and analysis in our product development process to ensure that our products remain at the forefront of ecological and efficient solutions in the industry.

## **5.1 FL-HM Marine Grade High Mast LED Floodlight**

FL-HM LED floodlights are designed to be used in the general lighting of the port areas. High mast installations with multiple beam angles enable precise illumination of the areas. Furthermore, different beam angles and lighting planning enable us to control the area's light pollution.

FL-HM product family has the highest lumen output from the selection with up to 225 000 lumens, ensuring that it can meet the requirements of even the tallest masts. Minimal light pollution and glare can be achieved with precise beam angles and the possibility of adding mechanical shields to limit the angles further.

Because of the modular design, the possibilities for control are versatile. One of the baselines in product development was the possibility of using different LED chips and lenses, for example, to allow the usage of amber lenses.



Figure 2. High-mast floodlight

## 5.2 FL-CC Marine Grade LED Floodlight

FL-CC-MG series has been developed for usage in the port area. It can be used in general lighting the masts or equipment used in the ports, such as cranes. During the development, special care was taken in the materials chosen to withstand the harsh environment. Another important part was the vibration resistance, as the cranes cause much vibration to the equipment installed. This can cause problems with the mounting equipment of the luminaires or the electrical components of the drivers used in the luminaire.

The product family has multiple beam angle options to match the need for different installation heights. Combined with lighting planning, these beam angle options can direct the light only where needed, so we can significantly reduce light pollution.

As a modular light fixture, it is possible to use, for example, amber lenses in half of the modules and regular lenses in the other half. This allows the same luminaire to be used as a general light luminaire giving amber light and a powerful work light giving colder light where humans can see and perceive things better.



Figure 3. High-mast floodlight

**Technical data:**

**MATERIALS**

Frame material: Aluminum (grey)

Reflector/Diffuser: Opal Polycarbonate Diffuser

Bracket: AISI 316

Hardware: AISI 316

**DEGREE OF PROTECTION (IP)**

IP66

IK10

**CERTIFICATES**

ETL US Listed (5020028)

Suitable for wet locations

CE

### **INFORMATION/INSTALLATION**

Installation: Surface mounting with U, Z or SD bracket

U bracket: 40W, 100W, 135W, 240W, 400W and 480W

U or Z bracket: 240W, 400W and 480W

SD Bracket: 400W and 480W

Operating environment: -40 °C – +55 °C (10 % – 90 % RH)

LED-driver: Meanwell HLG / Sosen

Lighting Control: On/Off

Warranty: 5–8 years

Polycarbonate Junction box with 2 pcs cable glands

### **LIGHT SOURCE**

Ra/CRI (Color Rendering Index): >70

Lifespan: > 100 000 h (L70B10)

SDCM: < 4

Power Factor: > 0,95

LED Chips: LUMILEDS

Beam Angles: (30°, 60°, 90°, 120°, 40°x120°)



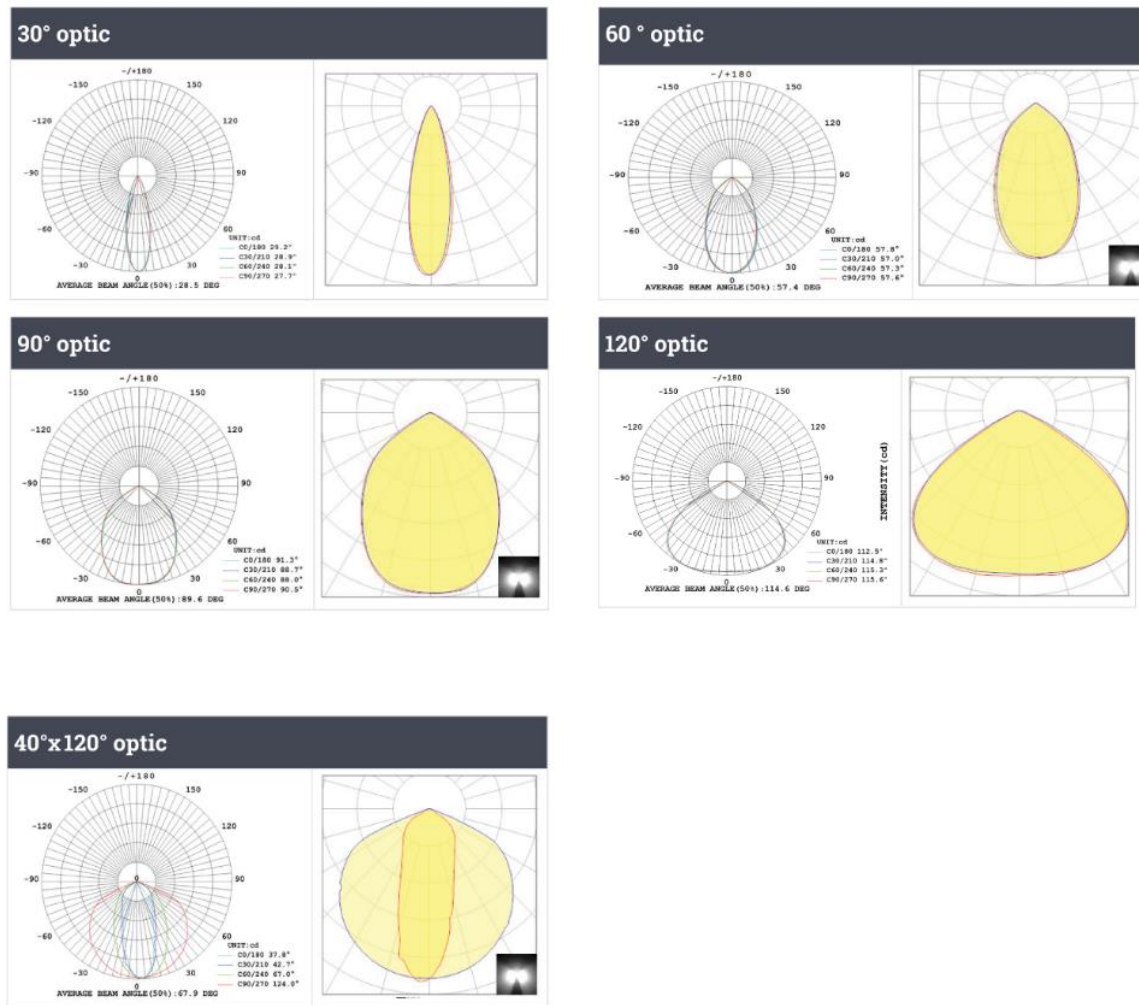


Figure 4. Lights distribution charts

## TEHNICAL PRODUCT INFORMATION

Color Temperature Options: 4000 K / 5000 K

Input Voltage:

100–277VAC 50/60Hz (standard) = L

180–528VAC = H

## MARINE GRADE FEATURES

- Silicone seals (IP66)
- Breather valves (IP68)
- Adjustable RST brackets (316)
- RST Safety Pendant
- Double anti-corrosion painting and powder coating
- The product range meets even the strictest corrosion

resistance classes and is certified to the following standards:  
BIS, DIN 50 021-1998, DIN 50 021-SS and DIN EN ISO  
12944-2:2017 according to CX class

### **ACCESSORIES/OPTIONS**

- L (Driver for the input voltage range 100–277VAC 50/60Hz)
- H (Driver for the input voltage range 180–528VAC 50/60Hz)
- UBR (U bracket)
- ZBR (Z bracket)
- SD (SD bracket)
- SS (sunshade)
- 740 (CRI 70, 4000K)
- 750 (CRI 70, 5000K)

#### **5.2.1 Amber version**

We explored various technical solutions to achieve the desired warm amber tones in our lighting fixtures. These included experimenting with different materials, such as amber-tinted lenses and filters, and utilizing specific color-temperature LED chips to achieve the desired effect. Additionally, we worked on optimizing our products' reflective surfaces and lens designs to ensure that the amber tones were distributed evenly and effectively. Through these efforts, we were able to fine-tune our products and develop effective technical solutions for incorporating warm amber tones into our lighting fixtures.

### 5.3 FL-TBL-3-PW Marine Grade Passageway Luminaire

FL-TBL-3 tubular LED-luminaire was designed as a flexible lighting solution for general lighting in the port area and a passageway luminaire. In addition, this surface-mountable luminaire can withstand harsh environments and vibration.

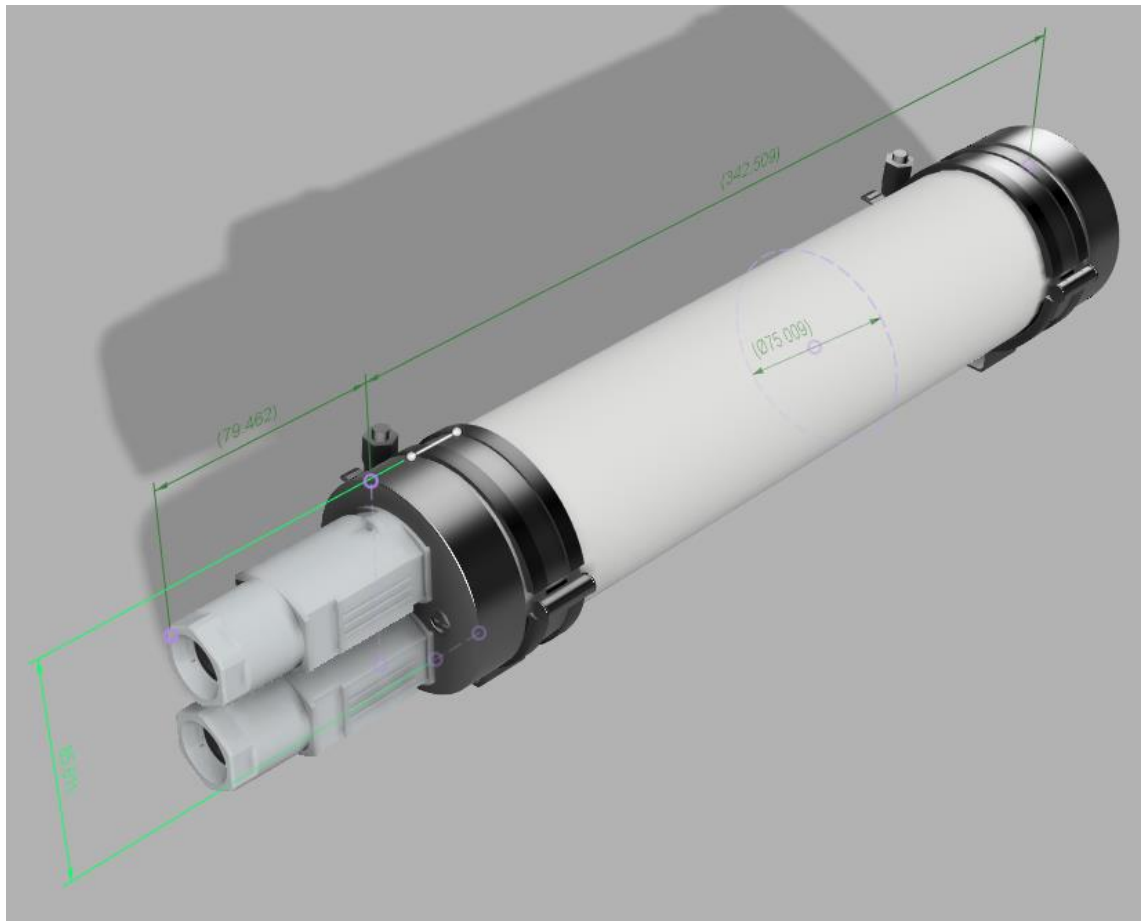


Figure 5. TBL-3-PW luminaire

#### Technical data:

#### MATERIALS

Reflector/Diffuser (tube): Opal polycarbonate

End caps: Stainless steel (316)

Mounting accessories: Stainless steel (316)

#### DEGREE OF PROTECTION (IP)

IP66

IK10 (PC)

### **INFORMATION/INSTALLATION**

Mounting: Surface / suspended with accessory SK  
(Suspension Kit)

Operating Temperature: -30–+50°C

Direct sun impact: +55°C

### **LIGHT SOURCE**

CRI (Color Rendering Index): >80

SDCM: <3

CCT (Color Temperature): 4000 K (3000 K)

Lifespan: 72 000 h (L70B50)

### **DRIVER**

Input Voltage: AC120–277V 50/60Hz

Driver lifespan: 100 000h

### **ACCESSORIES / OPTIONS**

SK – Suspension mounting kit

Phoenix Contact IPD -series connectors for 5 x 1,5–2,5 mm<sup>2</sup>  
cables. 1 connector (1IPD) / 2 connectors + through wiring  
(2IPD). Connector length 86 mm.

1IPD – 1 IPD connector without through wiring (connector at  
one end only)

2IPD – 2 IPD connectors + through wiring (connector at both ends)

#### 5.4 FL-TBL-3-UV Marine Grade UV Luminaire

The same housing can be used to produce a UV fixture using LED UV Zhaga modules. Depending on the panel feed-through connectors, an IP rating can be achieved so the fixture can be used underwater in the dock area.



Figure 6. TBL-3-PW luminaire

#### 5.5 FL-TBL-3-Amber Marine Grade Luminaire

FL-TBL-3 tubular housing can also be used with amber lenses because of its modular design. The same luminaire can produce amber and colder work lights with different control options and LED modules. It can also be used as a regular tunable white fixture for approximately 2700K – 6000K color temperatures. Amber color temperature (1800K – 2200K) can be achieved using a polymethyl methacrylate tube with the correct color instead of amber tone modules or LED chips or by using Amber LED chips.

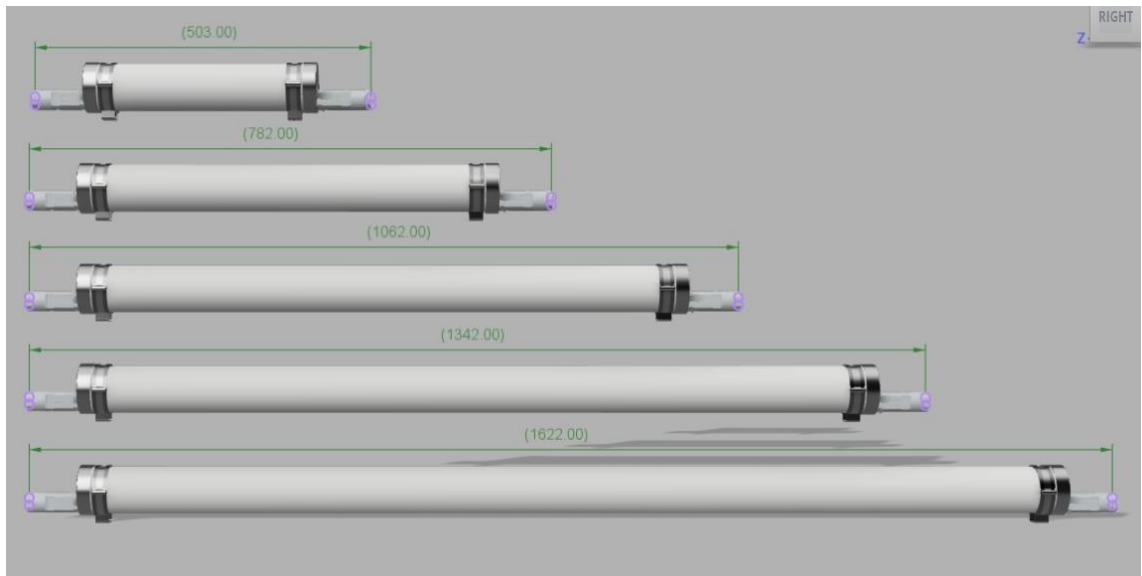
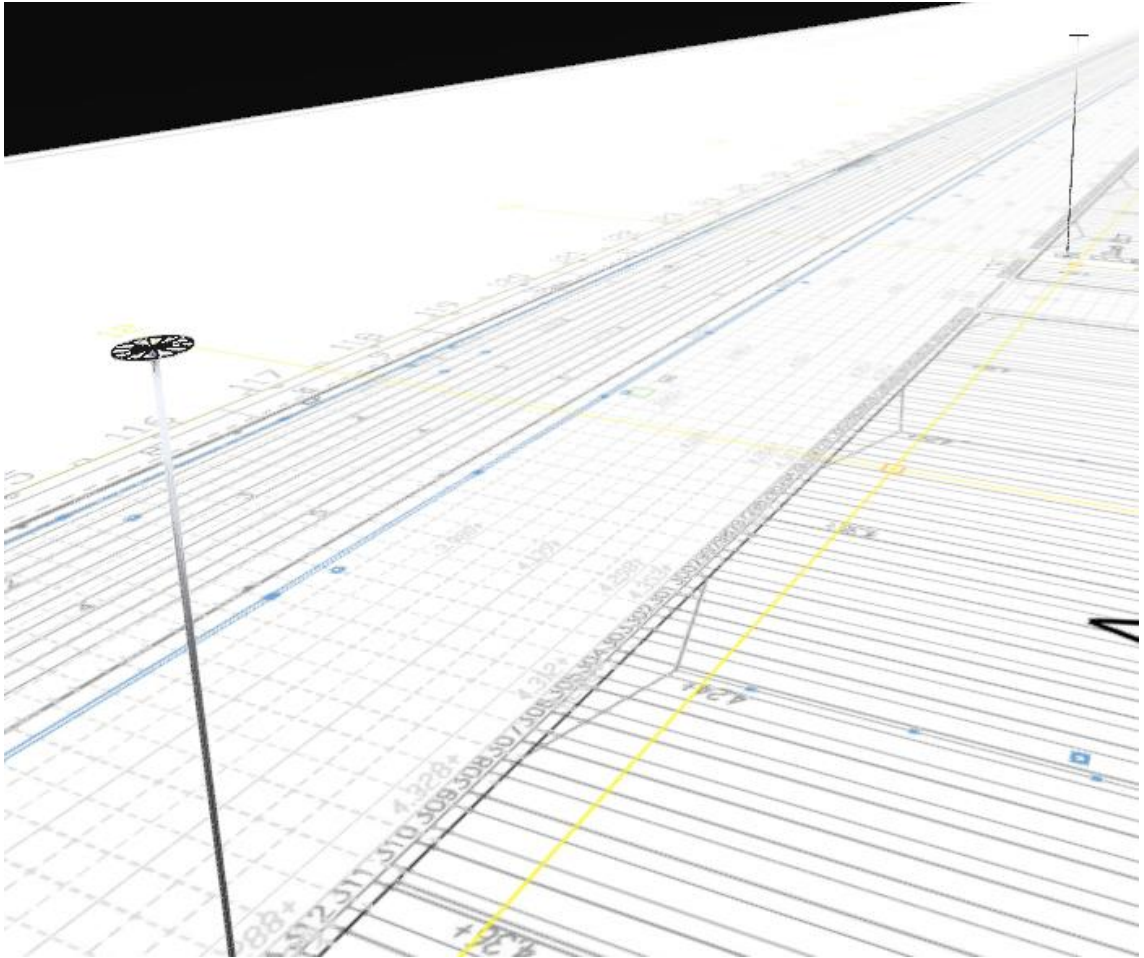
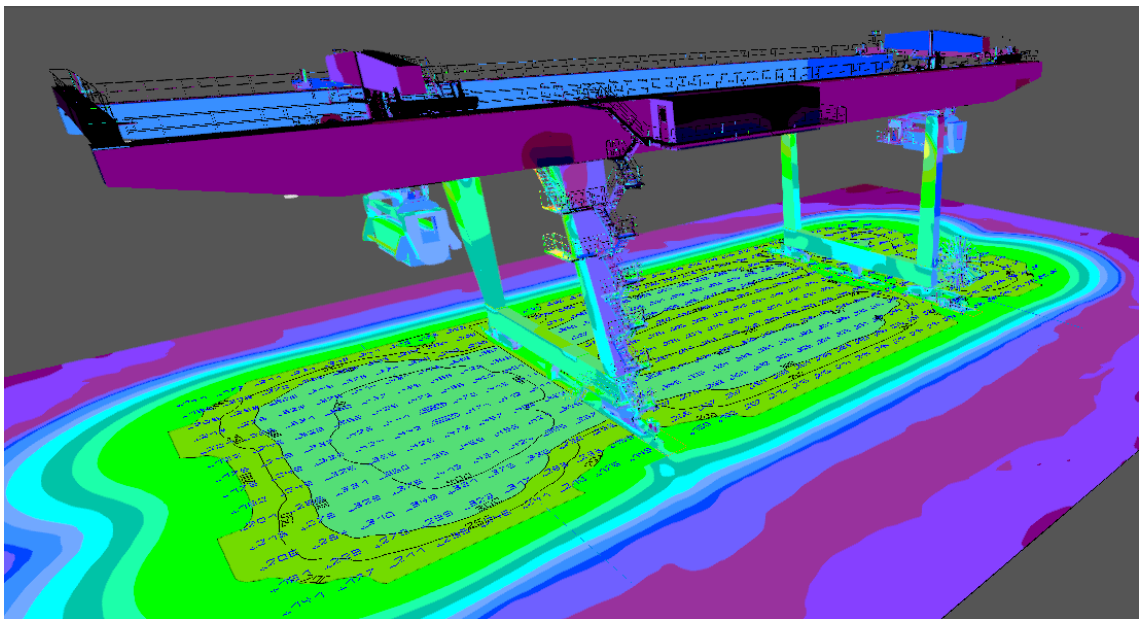
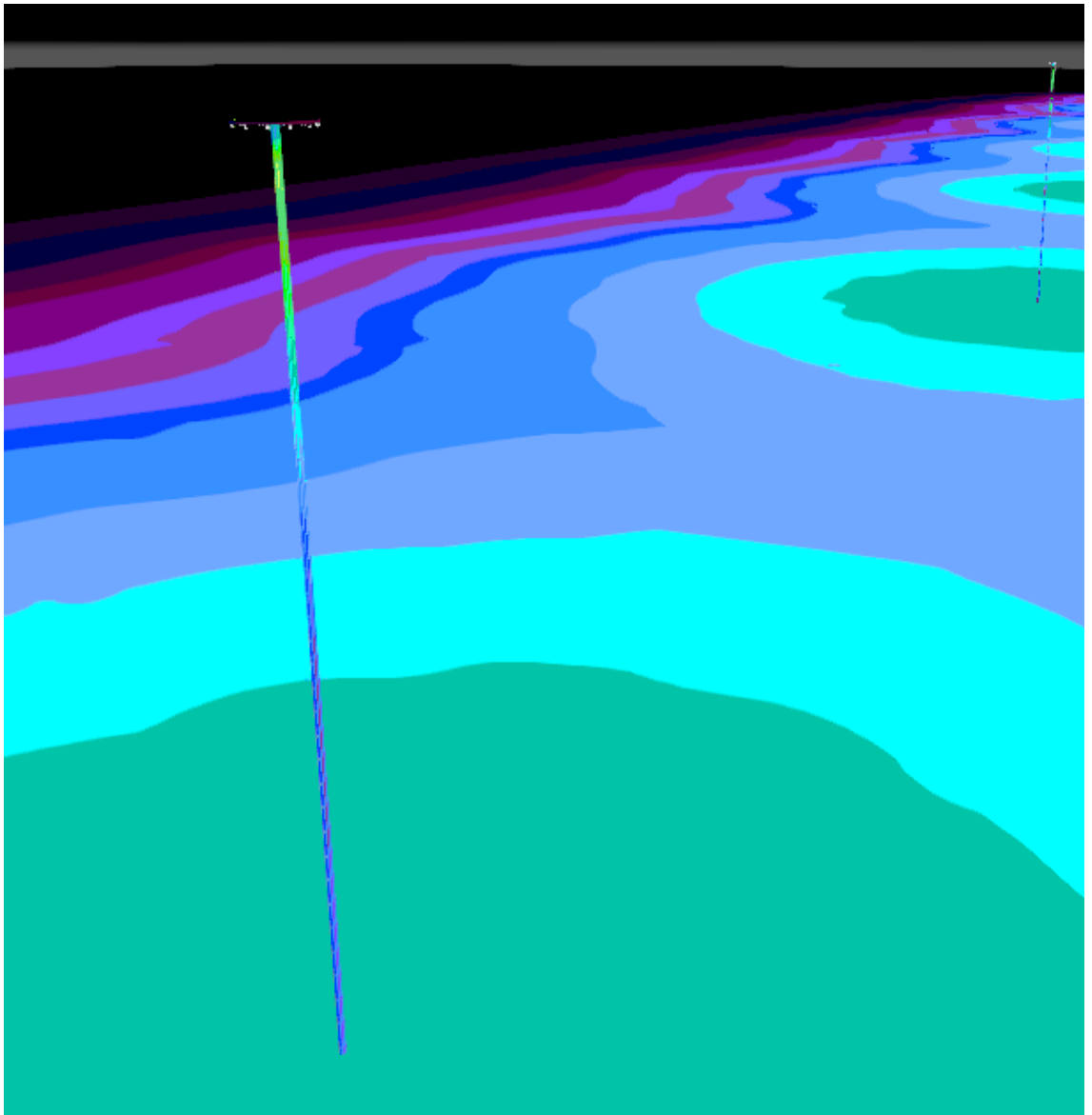


Figure 7. TBL-3-PW luminaire

## 6 LIGHTING PLANNING

This section reviews the most critical factors to consider when planning lighting in the port areas. As with all lighting planning, the planning must consider what the area is used for and how. When it is clear how the area is used, it is possible to plan where the light is necessary and when.







## **6.1 Standards, Guidelines, and Regulations**

Different national and local regulations cover issues like visibility, safety, placement of light fixtures, control of light pollution, and wildlife protection that must be considered when planning the lighting and overall system of the port area. These must be considered case by case as they differ vastly in different locations. In addition, these regulations, standards, and guidelines are constantly being updated, so the information can have significant changes quickly as the technology involved receives major upgrades continuously.

## **6.2 Lighting Level Measurement**

Accurate measurement data is essential when designing lighting solutions for ports, as it forms the basis for determining the appropriate lighting levels and selecting the right lighting fixtures. However, obtaining accurate measurement data can be a challenging and complex process.

One of the primary difficulties in obtaining accurate measurement data is the wide variation in lighting conditions within a port area. Different port areas can have vastly different lighting requirements, depending on factors such as the type of cargo being handled, the size and layout of the area, and the specific tasks being performed. Additionally, weather conditions such as fog or rain can significantly affect the lighting requirements, further complicating the gathering of accurate measurement data.

To address these challenges, we must collect our confirmed measurement data about the light amounts at the ports. This data must be gathered using reliable measurement equipment and validated by experts in the field. By relying on our measurement data, we can be confident that the lighting solutions we design will meet the specific needs of each port area and provide safe and efficient working conditions for those who rely on the port for their livelihoods.

In addition to collecting accurate measurement data, staying updated with the latest industry standards and guidelines for lighting in port areas is essential.

These standards help ensure that lighting solutions are safe, efficient, and environmentally responsible. By following these standards, we can be confident that our lighting solutions will meet or exceed the necessary regulations and provide a sustainable environment for all stakeholders in the port community.

In conclusion, while obtaining accurate measurement data can be challenging, it is crucial for designing effective lighting solutions for ports. By relying on our confirmed measurement data and staying up to date with industry standards, we can provide the lighting necessary to meet the specific needs of each port area while ensuring the safety and productivity of those who work and operate within it.

### **6.3 Beam Angles and Optics**

Choosing the right beam angles and the availability of different beam angles with the fixtures are essential when making the lighting calculations and planning the overall solution. With smaller beam angles, fewer collective lumens are used to illuminate the area needed as less light is scattered where it is not needed, directly affecting the amount of light pollution caused by the solution. This also decreases the fixtures' unwanted glare, making the area a more pleasant and safe workplace.

With more control over the beam angles, we can consider the container handling equipment and their operators more as we can better control the glare factors.

Various beam angles have always been an essential factor in product development. Thus, all our products come with the possibility to adjust the beam angles when ordering luminaires.

Mechanical glare shields can be and should be used to limit further the area where the majority of overall light is directed. In addition, reflectors and shields help minimize the light pollution caused by high-powered floodlights and the glare to operators.

These mechanical shields can also minimize the amount of light directed at the sky, helping prevent the effects of ALAN.

## 6.4 Safety

Safety is one of the most important parts of the regulations referencing port areas, and with good reason. The number of enormous objects handled in these locations are huge and can cause many safety issues related to visibility. Glare from lighting, too brightly lit areas, and shadowy areas can cause safety issues when personnel moves around the area. These must be taken into account with the lighting and operating planning.

Factors to consider about the safety aspect of lighting:

- Lighting levels must be correct, considering the task done in the location.
- Shadows can cause personnel not to be visible to moving equipment operators, causing safety issues. In addition, shadows can conceal obstacles causing navigation issues for the operators.
- Lighting must be adequate to ensure the visibility of personnel, vehicles, ships, and obstacles.
- Emergency lighting must be considered in case of power outages or other emergencies that can take place in the area.
- Glare from lighting can be dangerous for vehicle operators and ships using the port area. Even a short period of blindness for the operators caused by glare can cause serious safety issues, so glare should be eliminated already in the planning phase.

## **6.5 Lighting Control**

Lighting control is also an essential part of lighting planning. This is covered in a separate section below as it is entirely but closely related to the lighting plan.

## **6.6 Maintenance**

Product maintenance is necessary to ensure the highest possible lifetime of the products and must also be part of the lighting planning. Some standards and regulations give some guidelines for the maintenance cycles, maintenance factors, and lighting level coefficients, which can be used when calculating the luminous amounts. However, the fact is that these do not consider the differences between fixtures and are more of a universal value and cannot be used in all situations as they are. Therefore, the lighting planner must consider this when presenting the plans to the customer.

The plan must include at least the following points about maintenance:

- Product inspection schedule for the announced lifecycle of the system.
- Cleaning instructions and schedule.
- Availability of spare parts and the instructions for mechanical maintenance.
- Control system inspection schedule to ensure the controls work correctly on the site.

## **6.7 Security**

Lighting planning should also consider the security of the area. Port areas are generally off-limits to the public, and the lighting system should enable security and personnel to guard the area effectively. In addition, it should cover the entire area to deter unauthorized entry.

With tunable white light fixtures, it is possible to have a more ecological warmer color temperature light for continuous security light level. With sensors and control, this can be changed if there is activity on the site.

## **7 LIGHTING CONTROL**

Lighting control in port areas significantly affects the amount of light pollution produced. Light is an important resource in these around-the-clock workplaces as it affects safety and work efficiency. When we can reduce the amount of light that is not needed at particular times, we can drastically reduce the amount of light pollution and energy consumption. With motion sensors, we can increase the lighting to the required levels locally when the area is used, and with constant light sensors, the amount of light is continually monitored.

Our solution includes explicitly individual control and dimming of the area's luminaires, lighting level monitoring, and motion sensors. In addition, we plan to include the container handling equipment and the mobile harbor cranes in the lighting control system of the area, including area lighting. When we get feedback from this equipment, the lighting control will be more precise and automated.

### **7.1 Benefits of Using Automated Lighting Control**

"Traditional" control includes switching the lights on and off with constant light sensors and different timers. These already offer some energy savings if the settings are done well, and the area has no constant changes.

In the most basic settings, these systems would keep even lighting levels, offer no energy savings, and cause large amounts of light pollution as the lights would be at 100% even when there is no need at specific locations.

With LED lighting, the luminaires can be individually dimmed by 0-100% as the lighting control system requires. Dimming combined with constant light monitoring can offer energy savings and less light pollution during dusk and dawn and when there are other light sources in the area, e.g., container handling equipment (CHE).

Motion sensors can dim the lights to certain levels when no motion is detected and eventually switch the lights off after a specified time.

## **7.2 Circadian Rhythm**

Circadian rhythm is the natural physical, mental, and behavioral changes that follow a 24-hour cycle, influenced by light and darkness in an organism's environment. It regulates sleep patterns, hormone production, metabolism, and other physiological processes in humans and many other living beings. The term "circadian" comes from the Latin words "circa," meaning "around," and "diem," meaning "day."

A correctly set up lighting control system and the correct tunable white light fixtures can create a setting in the area that follows the circadian rhythm. However, because it is impossible to have the correct light and dark cycles in port areas, the lighting should be as close as possible to this natural cycle. This means as warm color temperature and as little light as possible at night.

Wildlife can be protected from these disturbances by following a circadian rhythm in outdoor lighting. This is particularly important for nocturnal species, which rely on natural patterns of light and dark to survive. Circadian-friendly lighting can help reduce light pollution and maintain a healthy balance of light and dark. This is crucial for the preservation of natural habitats and the conservation of biodiversity. Investing in circadian-friendly outdoor lighting is an investment in our environment and the future of our planet.

## **7.3 Wireless Control**

Our solution includes a wireless lighting control system because of its vast benefits compared to wired solutions. The distances between light fixtures in port areas are generally long, so the amount of cables needed for wired systems is enormous. Therefore, a wireless control system is much easier to set up and maintain.

Reconfiguration and changes to the lighting system are flexible after introducing a wireless system, as there is no need to run new wires when adding fixtures or

if the usage of a particular area changes. If a new fixture is needed, the installation process is simple, and the reconfiguration of the control system takes only minutes. This makes the system scalable as it can quickly expand to match the area's possible growth or changes.

### **7.3.1 Casambi**

The Casambi lighting control system offers all the necessary components and control options required for the solution we created. It is robust, scalable, cost-effective, and flexible. The communication between Casambi devices is done via Bluetooth Low Energy or BLE. In short, making it a future-proof and robust solution.

There is no central control unit which would cause the whole system to fail if the control unit failed. Instead, Casambi uses a wireless Bluetooth mesh network where all the intelligence is replicated in every node, which means the system's intelligence is decentralized, offering a system without a single point of failure.

Remote control or reconfiguration of the system can be done with a mobile device from anywhere in the area, as no central control unit is involved. The system does not require an internet connection for regular operation. The whole system can be controlled from a single point, and the software updates are distributed over the air for all the nodes.

Casambi products offered by different manufacturers are fully compatible, ensuring customers can choose the provider freely. Furthermore, it is open to all lighting industry companies offering an entire Ecosystem of products from different manufacturers and component providers.

### **7.3.2 Casambi Products with Finlight Solution**

Light fixtures offered by Finlight are fully compatible with Casambi control system components. We have considered the control options with product development, ensuring that control units can be added to our products as needed.



FL-CC

FL-HM

FL-TBL-3

FL-TBL-3-PW

FL-TBL-3-UV

## 8 Possible negative impacts of RF in port areas

Radio frequencies (RF) and electromagnetic fields (EMF) form part of the natural environment since sources such as the sun and the ionosphere emit them. These frequencies do not affect the natural environment and have low diversity. However, due to technological advancements, artificial RF and EMF are the main contributors to overexposure to these frequencies. These artificial RF and EMF come from sources such as satellite transmissions, the radio and television broadcasting, mobile telephony, and many wireless communications invented, such as Wi-Fi. Our over-dependency (from communication to security to agriculture to technologies that use RF and EMF) has increased its presence in the environment. Anthropogenic Radio frequency (RF) exposure is a significant and fast-increasing threat to terrestrial and marine environments. With the current rollout of the 5G network, the impacts of these frequencies on biodiversity are expected to intensify. This rapid increase in RF waves causes interferences in plants' and animals' biological and physiological processes. These impacts will be not only felt by humans but also by terrestrial and aquatic species. Migratory species respond to specific RF and EMF types, thus affecting their pattern. This is similar to pollinators.

Pulsed waves of RF and EMF (those that have low-frequency modulations) have a more significant biological effect that depends on the duration of exposure to an organism. It also depends on the organism's intensity and susceptibility to such fields. Several studies and experiments have provided strong evidence of the athermal microwave effects of RF and EMF waves in the natural environment. These studies have been discussed in depth herein and explain how we can measure the impacts of RF and EMF in natural environments.

Radio frequencies in the wild affect the populations of animals. Birds are affected since they develop their nests in trees where the atmosphere is highly contaminated by RF and EMF waves. In a monitoring study done in Spain, the number of nests for the white stork (*Ciconia ciconia*) recorded near a cellular base station emitting radio waves was less. This was compared to the number observed away from the cellular station in a difference of 100m away. This can be attributed to the effects of the RF and EMF on several reproductive stages, i.e.,

during the construction of nests, in the number of eggs, during the development stage of the embryos, during the hatching stage, and by the mortality of chicks during their first development stages. This has also been observed in other bird species. In amphibians, population declines are usually a result of synergies between environmental degradation and exposure to RF. This makes amphibians reduce their ability to respond to environmental stressors due to the presence of another stressor. Abnormal deformation of amphibians in the wild can directly affect the survival and mortality of amphibian embryos leading to population declines.

### **8.1.1 Behavioral effect**

In a study on the effect of mobile phones on reproduction and development in *Drosophila melanogaster*, it was observed that after exposure of fruit flies to RF and EMF from mobile phones, the individuals were reported to have elevated stress protein levels (Hsp70). The presence of these stress proteins means that an organism has been exposed to adverse environmental conditions. Generally, exposure to pulsed waves of RF and EMF in mammals makes them alarmed, and in cases where avoidance is possible, they tend to avoid the areas, e.g., in bats.

RF and EMF affect the nervous system of both humans and animals. In a study done on rats, it was discovered that prolonged exposure to these frequencies made them have derogatory behavior. They could not distinguish between familiar and unfamiliar objectives. This was also observed in regions around Skrunda Radio Station Latvia, northern Europe, where children have less developed memory. Their response and attention time were much slower compared to non-exposed children. In addition, their neuromuscular apparatus endurance levels were much reduced.

Plants display a broad spectrum of biochemical and developmental responses in cases of stressful occurrences. This is because they are sessile organisms and thus cannot have similar responses as animals. The most common stress response in plants is the high production of Reactive Oxygen Species (ROS) molecules. If unchecked, the build-up of ROS in plant cells may result in cell

damage by oxidizing proteins, photosynthetic pigments, lipids, and nucleic acids (DNA and RNA). This may, in turn, lead to cell death. To counteract this action, plants have ROS-scavenging enzymes.

On the contrary, ROS acts as signaling molecules that trigger plant stress tolerance responses. Therefore, exposure to RF and EMF affects the activities of ROS-scavenging enzymes. For example, in duckweed (*Lemna minor*), the activity of ROS scavenging enzymes increases significantly after exposure to RF and EMF. This shows that exposure triggered secondary stress defense responses in the plant. This, however, would ultimately affect *Lemna minor*'s growth.

### **8.1.2 Morphological effect**

Insects and amphibians exposed to experimental RF and EMF waves were reported to form deformities. Abnormalities were also recorded during their developmental process and, in some instances, led to the mortality of individuals. In an earlier study in Northern Europe, plants exposed to RF and EMF frequencies were observed to have abnormal branching. Many of the plants developed new branches from buds suggesting the effects of cell proliferation in cases of short-term exposure. For long-term exposure, the results are vice versa, with cases of plant deformities and shorter life spans observed: a case study of *Spirodela polyrhiza*.

Chlorophyll in *Robinia pseudoacacia* (black locust plant) is affected by RF and EMF waves. The most sensitive of the two was chlorophyll-b. It usually gets enhanced in the first stages of exposure/first vegetative stages but later on diminishes as exposure continues. The ratio between chlorophyll-a and chlorophyll-b becomes decreases as exposure increases. This ratio is much dependent on the Light Harvesting protein complex (LHC II), which is affected by exposure to RF and EMF during the early developmental stages of vegetative plants. LHC II is known to have structural flexibility in slight changes in environmental conditions. Thus, LHC II will inhibit a plant's capacity to harvest light and regulate non-photochemical quenching in long-term exposure to RF and EMF. It is noticed that *Zea mays* (Maize) seedling growth was affected by the decline in root and coleoptile lengths when exposed to RF and EMF waves over

a long period. This will later affect the plant's growth, leading to a shortage of food production as it forms the primary source of carbohydrates in many parts of Mediterranean countries.

### **8.1.3 Reproduction effect**

With the increase in the use of radio frequencies, the effects have been documented to affect even humans. Studies have shown that these electromagnetic frequencies emitted from mobile phones have a relation with the increased levels of male infertility and increase in cancer risks by disruption of chromosomes. Similarly, in a study experimented on rats, it was recorded that there was sperm reduction in rats that were exposed to electromagnetic radio frequencies. Electromagnetic frequencies have been recorded to stimulate NADH oxidase in mammalian cells, thus resulting in oxidative stress, which affects sperm motility. Also, in invertebrates, electromagnetic frequencies negatively affect reproductive success due to DNA fragmentation and the death of reproductive cells. The effects on invertebrates are massively causing developmental delays. These RF and EMF frequencies affect the gonadal development in insects through the non-thermal process.

In Mediterranean countries, white stork (*Ciconia ciconia*) species were reported unable to produce young ones. Their reproduction was affected by the presence of Radio waves frequencies from a cellular station. As the nests furthered away from the source of the RF, more chicks were counted in the nests.

On the contrary, exposure to RF and EMF frequencies in *Drosophila melanogaster* increased ovulation in females. Also, there was an increase in cell divisions at the chromosomes. At the chromosomal level, there was an increase in transcriptional activity. This study concluded that exposure to the RF in *D. melanogaster* increased in offspring.

### **8.1.4 Thermal effect**

RF and EMF wave is classified as nonionizing radiation due to their characteristics of not having enough energy to break chemical bonds. They, however, can increase surface temperatures in biological materials. In biological

entities, exposure to RF results in either absorption or reflection of some of the energy. As organisms get exposed to higher frequencies, above 6 GHz, absorption occurs at relatively shorter depths; thus, most of the energy is contained on the surface. This absorption causes movement of the molecules and electrical charging of particles, resulting in surface heating. If this persists for long periods or the intensity of these frequencies increases, then potential tissue damage will occur.

## 9 THEORETICAL SOLUTION

Finlight solution for ecological port lighting consists of multiple parts that act as a whole depending on the geographical location. The simplest and most cost-effective way to reduce artificial lighting's impact on the environment is to reduce the amount of light in the area when it is unnecessary. This can be achieved using a modern lighting control system in the area. While this lessens the impact, more can be achieved by carefully choosing the luminaires used in the area, applying correct beam angles, and using shields to block unwanted glare, directly affecting the amount of light pollution.

Accurately measuring lighting data is critical in designing effective lighting solutions for port areas. However, the wide variation in lighting conditions within a port area, including factors such as weather conditions and specific tasks being performed, makes gathering accurate measurement data challenging. To overcome these difficulties, it is essential to collect our confirmed measurement data using reliable equipment and validated by experts in the field. In addition, staying up to date with industry standards and guidelines is also crucial for ensuring that lighting solutions are safe, efficient, and environmentally responsible. Ultimately, designing effective lighting solutions for ports requires a comprehensive understanding of the specific needs of each area within the port, as well as a commitment to using accurate measurement data and adhering to industry standards.

The control of the color temperature of the artificial lighting can further decrease the impact on nature. This can be achieved by using tunable white LEDs in the luminaires or parts of the luminaires. Different wavelengths affect species in the area in different ways. This is an essential factor to consider when doing the initial mapping of the area and the complete lighting system planning of a specific port.

When the project considers these factors, the products can be chosen and built with the correct components to the area. Using amber LEDs or amber lenses in

the products can have a massive advantage in conserving biodiversity as it allows further adjustment options for the wavelengths used.

The final part is the control of unwanted fouling organisms through UV light in the dock area. This final part requires careful study of the specific port and extensive sampling from which the organisms present can be mapped. After the mapping, a study of the biological effects of UV wavelength light on the present organisms must be done to ensure the solution can benefit the location. It is possible to reduce the amount of biofilm accumulation on the ships staying in the port using UV light. Again, however, it requires careful study of the specific area as the organisms present, and the ecological conditions are vastly different from location to location.

## **9.1 Solution Framework**

- Initial mapping of the area.
  - Light pollution levels.
  - Luminaires and the wavelengths used.
  - Species present in the area.
  - Control system and how it is used.
- A decision on which species and habitats to monitor.
  - Planning of the monitoring.
  - Initial surveys via partners in the area.
  - Organization and mapping of the initial data.
- Making a lighting plan for the area.
  - Deciding the correct luminaires and wavelengths suitable for the specific area.
- Lighting control planning.
  - Making a plan for the lighting control of the whole area as an aggregate.
- Monitoring after the solution is implemented.
  - Timeline of the monitoring process.
  - Monitoring methods





## APPENDICES

### Report on Trip to TOC Europe

### Appendix 1

#### Introduction:

Our company's owners, Mr. Samuli Sainio (CEO) and Mr. Petri Salminen (COO), attended Terminal Operator's Conference (TOC) Europe in Rotterdam, the Netherlands, last summer intending to search for potential clients and partners for our innovative lighting concept that improves biodiversity in port areas. We participated in the event as a visitor and conducted several meetings with different stakeholders in the port industry.

#### Approach:

During the event, we approached several European port operators, terminal managers, and logistics companies to discuss the benefits of our new lighting concept. We emphasized the positive impact of our lighting system on the environment and the potential savings that could be made by implementing our solution. We also highlighted the positive image that companies could achieve by investing in sustainable technologies.

#### Results:

We had a positive response from several port operators who were interested in our lighting concept. Some of them, such as Terminal Investment Limited (TiL), showed great interest in our solution and requested further information. In contrast, others expressed willingness to negotiate about participating in a pilot project if the study succeeds. We also had several discussions with logistics companies interested in our solution's positive environmental impact and its potential to reduce their carbon footprint.

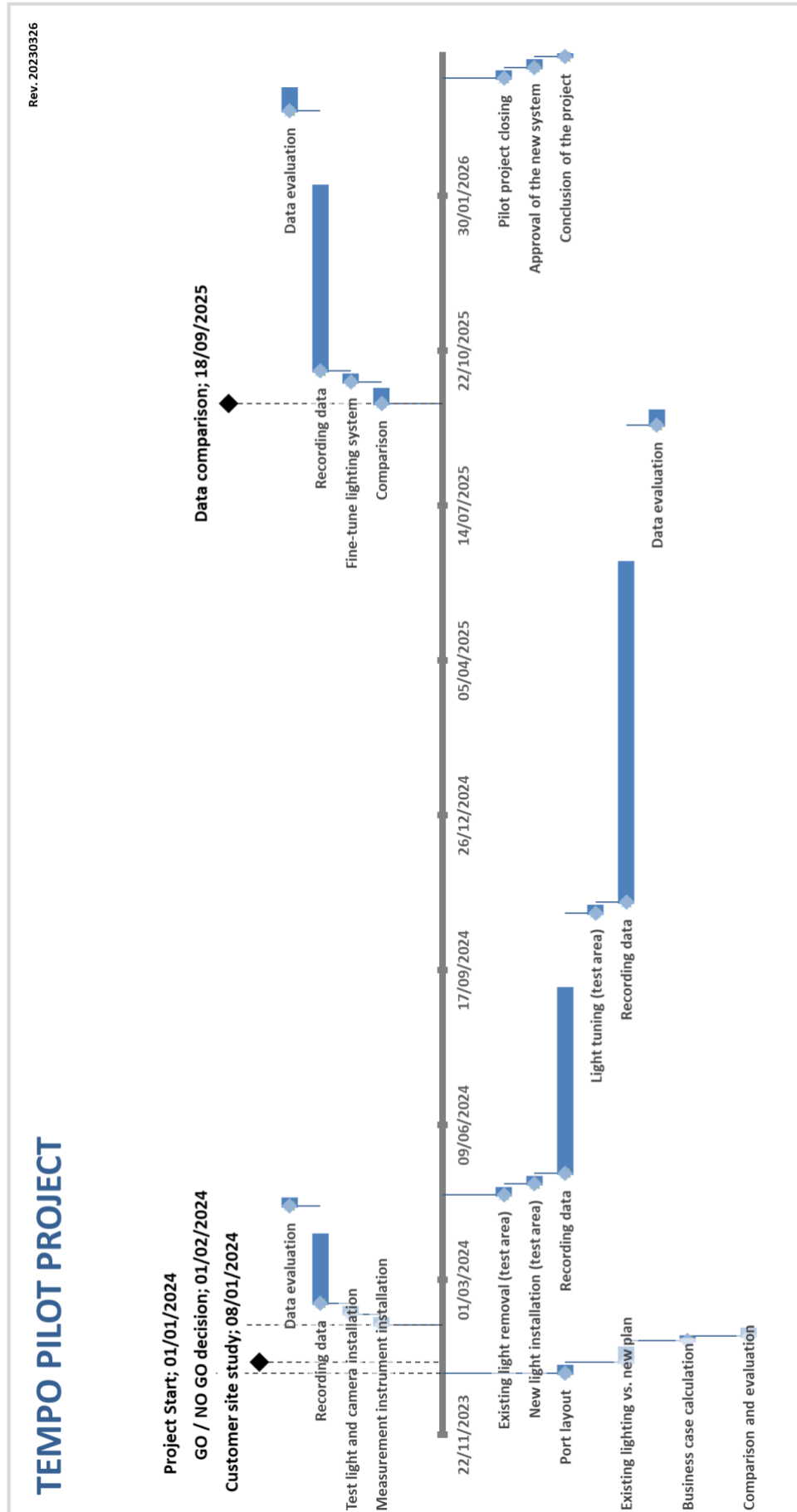
However, we also noticed that some of the companies we approached were not so open to the concept, and we suspect that the war in Ukraine may have played a role in their reluctance. Some of these companies expressed concerns about the geopolitical situation and hesitated to invest in new technologies or projects. We understood their concerns and did our best to provide them with reassurance and information about the potential benefits of our solution.

Furthermore, one of the reasons for hesitation could be that the study of the project was not yet that far, that we could demonstrate concrete actions and detailed examples of the upcoming pilot project during the TOC event.

### Conclusion:

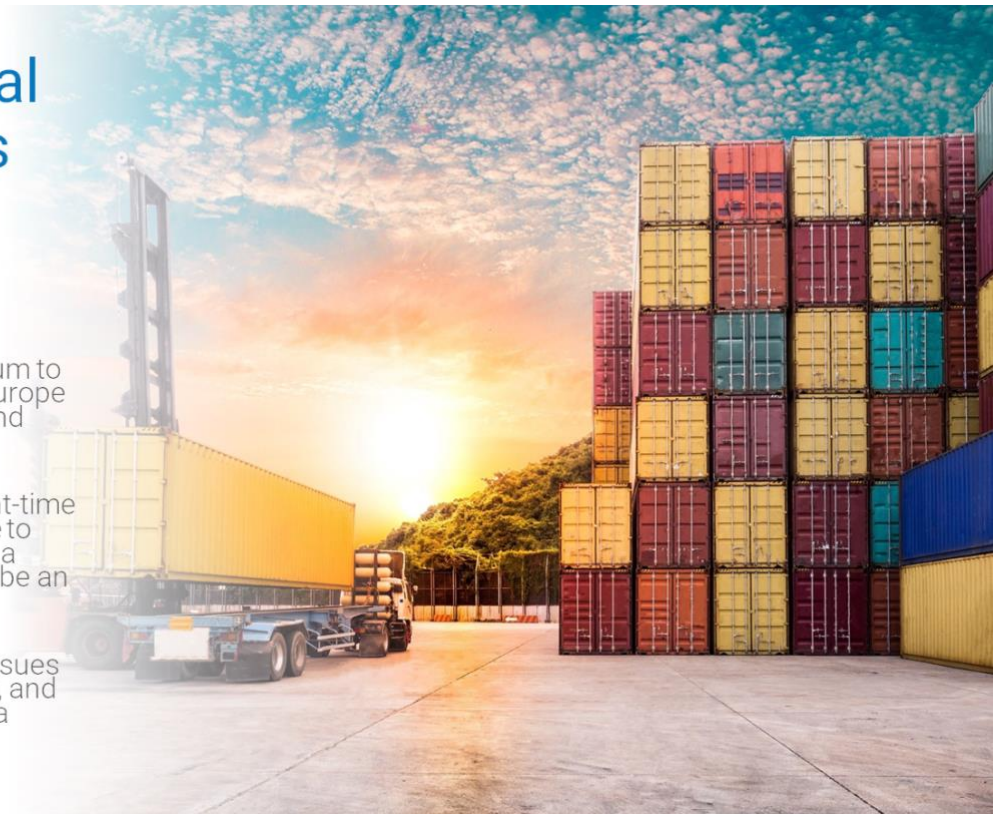
Overall, our participation and market research in TOC Europe was a success. We approached and searched potential clients and cooperators for our lighting concept that improves biodiversity in port areas. As a result, we received a positive response from several stakeholders in the port industry. We are confident that our solution will gain more recognition and acceptance in the future.

At the same time, we recognize that the war in Ukraine has created an uncertain environment for some companies, which may have impacted their willingness to invest in new technologies or projects. We believe that it is essential to remain aware of the geopolitical context in which we operate and to address any concerns that companies may have. We plan to follow up with the contacts we made during the event and continue to promote our sustainable solution to the port industry after the TEMPO project is over while acknowledging and respecting the challenges that some companies may be facing.



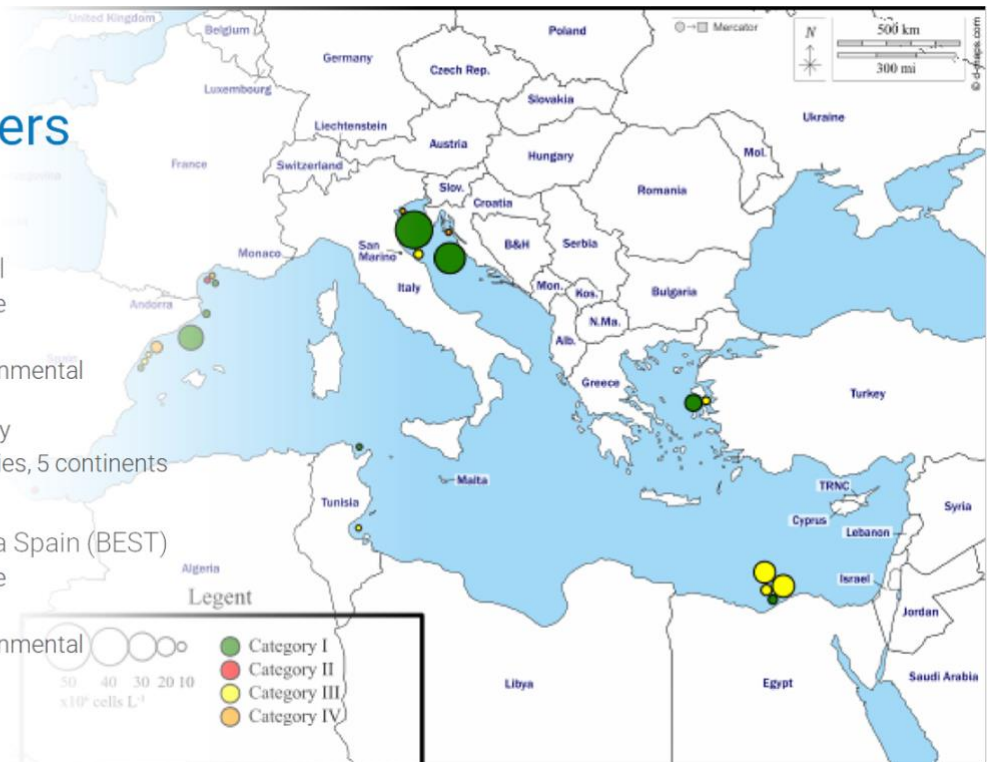
# Environmental requirements

- Relatively warm water temperature
- Water salinity level medium to high (areas in northern Europe have low salinity levels and therefore lower alga and biofouling occurrence)
- Location with longer night-time (dark hours) is preferable to gain more information in a shorter time frame - Can be an EU country, but it is not necessary
- Destination has known issues with water pollution, alga, and biofouling at the port area



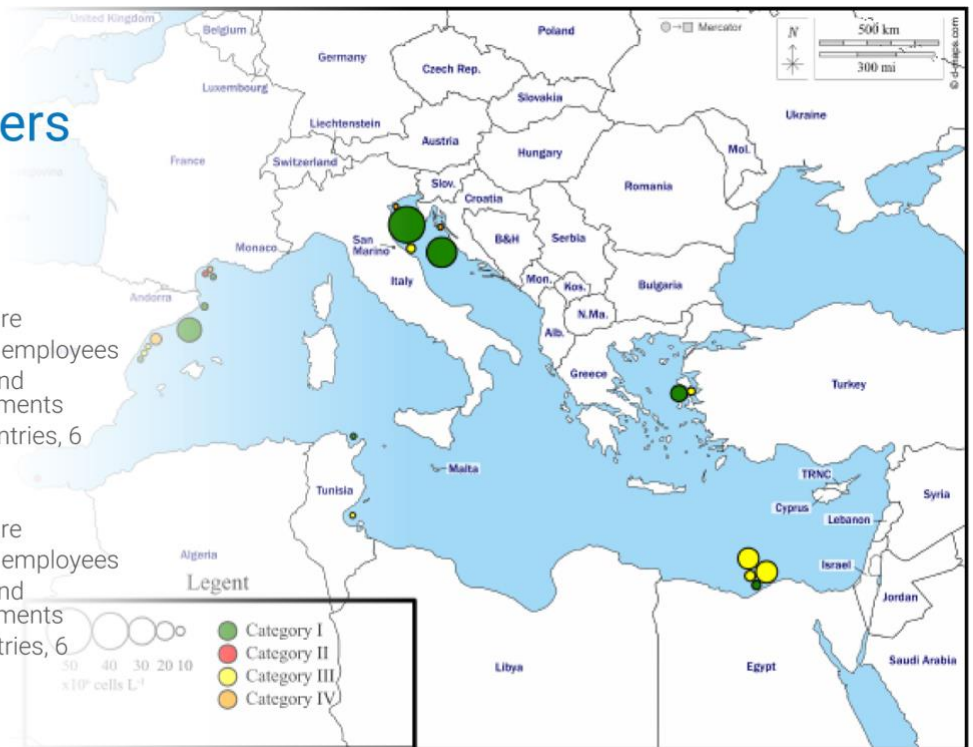
# Pilot project target customers and locations

- TiL – HCT, Hadarom, Israel
  - Warm water temperature
  - Global operator
  - Sustainability and environmental commitments
  - MSC is a parent company
  - 70+ terminals, 31 countries, 5 continents
- Hutchison Ports, Barcelona Spain (BEST)
  - Warm water temperature
  - Global operator
  - Sustainability and environmental commitments



## Pilot project target customers and locations

- DP World, Tarragona, Spain
  - Warm water temperature
  - Global operator, 71000 employees
  - Sustainability, people and environmental commitments
  - 100+ terminals, 46 countries, 6 continents
- PSA Genova PRA, Italy
  - Warm water temperature
  - Global operator, 49000 employees
  - Sustainability, people and environmental commitments
  - 66+ terminals, 42 countries, 6 continents



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