

***Report no. LPP2020/1 v.1***  
***Prepared for: Noble Energy Mediterranean Ltd***  
***December 2020***

# THE EFFECTS OF ARTIFICIAL LIGHT AT NIGHT FROM THE LEVIATHAN PRODUCTION PLATFORM ON THE MARINE ENVIRONMENT

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## Table of Contents

|                                                            |           |
|------------------------------------------------------------|-----------|
| <b>Summary .....</b>                                       | <b>2</b>  |
| <b>Light Pollution and the marine environment .....</b>    | <b>3</b>  |
| <i>1.1 Marine invertebrates.....</i>                       | <i>3</i>  |
| <i>1.2 Plankton.....</i>                                   | <i>3</i>  |
| <i>1.3 Fish .....</i>                                      | <i>3</i>  |
| <i>1.4 Marine mammals.....</i>                             | <i>4</i>  |
| <i>1.5 Sea turtles.....</i>                                | <i>4</i>  |
| <i>1.6 Birds.....</i>                                      | <i>4</i>  |
| <b>Leviathan LPP lighting intensity measurements.....</b>  | <b>6</b>  |
| <b>Effects of LPP ALAN on the marine environment .....</b> | <b>9</b>  |
| <b>Conclusion and Recommendations .....</b>                | <b>12</b> |
| <b>References:.....</b>                                    | <b>13</b> |
| <b>Appendix .....</b>                                      | <b>i</b>  |

## Summary

Light pollution or Artificial Light At Night (ALAN) is a well-documented and globally growing phenomenon in the marine environment. Many of its impacts have been reported including changes in the zooplankton diel vertical migration, bird collisions with ships and offshore platforms, intensified visual predation and foraging in illuminated areas, sessile larvae settlement disruption, desynchronization of reproductive behavior, nesting site displacement, and artificial light-induced disorientation in seaward or long-range migration of several species.

The Leviathan Production Platform (LPP), operated by Noble Energy Mediterranean Ltd., processes the natural gas flow from Leviathan field.

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. The LPP lighting is designed to enable operations to be conducted safely at all hours and to comply with maritime navigation codes and security requirements.

This report analyses the expected effects of the LPP lighting as described in the LPP lighting plan and the lighting intensities measured around the LPP. It is based on the results of marine ALAN research on the effects of light intensities and spectra published in scientific journals and reports.

The environmental effects of LPP lighting on marine invertebrates and plankton are not expected to be significant. The effects on fish community structure, schooling and on the concentration of predators around the LPP

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These effects cannot be assigned to the effects of LPP lighting alone and may also be attributed to the shelter provided by the structure itself.

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Artificial light is known to disrupt female nesting and reduce hatchling seafinding and survival. While there is currently no knowledge of offshore platforms' lighting affecting adult sea turtle navigation and their ability to successfully locate their nesting beaches, this possibility cannot be completely ignored due to the sensitivity of sea turtle populations. Birds are well documented to be affected by the lighting of offshore platforms in the North Sea and in the Gulf of Mexico. Migrating birds could be attracted or disoriented by the LPP lighting. However, since most migrating birds favor overland routes little effect is expected on the migrating population. Due to the fact that the LPP is only 10 km from the shore, if there is lighting attraction it will probably not prevent the birds from reaching the shore if delayed on the LPP.

## Light Pollution and the marine environment

Artificial light at night (ALAN) is globally increasing phenomenon, expected to increase by 6% annually [Gaston 2012]. As most living organisms are sensitive to changes in the intensity and spectrum of light in their environment, light pollution occurs when they are exposed to light in the wrong place, at the wrong time or at the wrong intensity [Depledge 2010]. This has led to increasing concern regarding the ecological consequences of light pollution, now that large areas of the world experience light that differs from natural regimes in timing, intensity and spectrum [Sanders 2020]. Therefore, ALAN is considered to constitute anthropogenic pressure on the marine environment. ALAN has been shown to affect the behavior, reproduction, feeding, orientation and survival of marine invertebrates, amphibians, fish, turtles, mammals and birds.

**1.1 Marine invertebrates** – Species specific and communal effects of ALAN have been shown in marine invertebrates. It resulted in changes in foraging of sandy beach amphipods leading to reduced consumption and growth rates [Luarte 2016]. ALAN induced stress increased the energetic demand of dogwhelks, encouraging foraging whenever food was available, regardless of potential danger [Underwood 2017]. An epifaunal study showed that illuminating settlement surfaces with white lighting at night, affected the colonization of 39% of the taxa analyzed, changing the composition of marine epifaunal communities [Davis 2015].

Several species of corals have been experimentally found to be extremely sensitive to the blue region of the light spectrum [Tamir 2017] and this may be true for more species. Also, corals exposed to ALAN have shown changes in the expression of genes that regulate cell cycle, cell proliferation, cell growth, protein synthesis and display changes in photo physiology [Rosenberg 2019]. *Acropora eurystoma* and *Pocillopora damicornis*, exposed to ALAN face an oxidative stress condition, show lower photosynthesis performances as well as changes in chlorophyll and algae density parameters [Ayalon 2019]. Light pollution is likely to reduce the percentage of *S. pistillata* planulae settling on the substrate. As *S. pistillata* is currently the most common recruited species among the stony corals in the shallow depths in the Gulf of Eilat, this could have a very wide community effect [Tamir 2020]. All these indicate that ALAN may be an important anthropogenic stressor of coral reef ecosystems.

**1.2 Plankton** - One of the most important processes affected by ALAN is the Diel vertical migration of plankton, this global day-night cycle is disturbed by artificial light. Zooplankton response to very low levels of artificial light has also been noted at depths of up to 100 meters [Davis 2020, Ludvigsen 2018]. ALAN also affected the efficiency of photosynthesis in phytoplankton such as *Microcystis aeruginosa* and this may be the case for more phytoplankton species [Poulin 2014].

**1.3 Fish** – Physiologically, light pollution resulted in elevated stress indicators (blood glucose concentrations) in juvenile bonefish (*Albula vulpes*) relative to controls [Szekeres 2017] and

rockfish (*Girella laevis*) individuals exposed to ALAN exhibited increased oxygen consumption and activity [Pulgar 2019]. Behavioral changes are also known, surgeonfish (*Acanthurus triostegus*) larvae collected from rock pools generally avoided illuminated settlement habitats. When lengthy ALAN conditions were experienced, changes in swimming behaviour and higher susceptibility to nocturnal predation were noted [O'Connor 2019]. ALAN was shown to have a dramatic effect on the development of clownfish, *Amphiprion ocellaris* eggs incubated in constant ALAN did not hatch, resulting in zero offspring [Fobert, 2019]. Feeding behaviour is known to be affected: the foraging activity of perch and their attack rates during artificially illuminated nights were significantly higher than under natural conditions [Czarnecka 2019]. These changes also affect fish community structure and interactions. The abundance of small shoaling fish increased when the lights were on followed by an increase of large-bodied predators. These predators also attempted to maintain their position within the illuminated area [Becker 2013]. Blue runners (*Caranx crysos*) around a well-lit petroleum platform were capable of feeding during night and predawn hours at levels comparable to those observed during the day while remaining at a depth where light intensities are sufficiently low to reduce predator encounters (Keenan 2003, Brown 2010). These platforms provide fish an enhanced foraging environment by providing sufficient light to locate and capture prey, and by attracting and concentrating phototactic prey [Keenan 2007]. The effects of ALAN on fish may be species specific and dependent on site and inter-species or community level interactions [Barker 2018].

**1.4 Marine mammals** – In Brazil, dolphins were observed foraging for fish around a gas flare illuminated offshore platform at night. They extended their foraging hours into the night, probably hunting for the large amount of fish attracted by the flare light and for longer hours than by day [Cremer 2009]. Harbor seals extended their salmon fishing hours and concentrated hunting on illuminated areas. Harbor seal predation was experimentally shown to lessen once lights were turned off [Yurk 2000].

**1.5 Sea turtles** – Sea turtle populations are threatened worldwide and therefore the effects of ALAN on sea turtles are well documented. Female loggerhead turtle nesting attempts are shown to decrease in the presence of ALAN [Silva 2017]. This is also known in other turtle species as is reduced site orientation and nesting success [Mazor 2013]. Another major issue is hatchling orientation towards the sea after hatching – “seafinding”. Hatchlings emerge from nest at night and use visual cues to direct towards the brightest and lowest horizon, which should lead them to the sea. However, coastal night time illumination reduces seafinding ability of loggerheads (*Caretta caretta*), flatback turtle (*Natator depressus*) and green turtle (*Chelonia mydas*) leading to lower survival rates of hatchlings affecting the whole turtle population [Dimitriadis 2018, Pendoley 2016].

**1.6 Birds** – Seabirds rely mainly on visual cues and a well-lit large vertical structure at a dark night or in a dark environment represents a very powerful visual cue. Many nocturnally

migrating birds are therefore affected by ALAN. In the North Sea large numbers of birds are attracted and disoriented by light from the numerous offshore platforms [Poot 2008]. As a result seabirds have been known to crash into platform lights or to circle platforms for days until exhaustion [Wiese 2001]. Flocks of migratory birds were also observed to be attracted and even occasionally entering the gas flare. These effects are thought to be a result of general attraction of lighting combined with the disturbance of their internal compass by the red light emitted from the offshore platforms [Marquenie 2013, Ronconi 2015].

## Leviathan Production Platform lighting intensity measurements

The Leviathan Production Platform (LPP) processes natural gas from the Leviathan Field. The LPP is located approximately 10 km off the coast of Dor, Israel, and is operated by Noble Energy Mediterranean Ltd. (Noble Energy).

[מידע אודות מתקני האסדה]

. The LPP lighting is designed to enable and support the safe operations of the facility and to comply with maritime navigation codes and security requirements. Navigational lighting was designed according to United States Federal Regulation Title 33 Part 67 Aids to Navigation on Artificial Islands and Fixed Structures.

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. To assess the impact of the LPP nighttime lighting the “LPP Lighting Intensity Measurement Plan (LPP-OP-NEM-EHS-PLN-0001)” was formulated by Nobel Energy and approved by the Ministry for Environmental Protection. Lighting intensity measurements were performed using a “testo 545 light lux-meter” by an accredited surveyor, [שם ספק חיצוני], on 16.9.20 and the results were reported in “Leviathan Production Platform Lighting Intensity Measurement Operation and routine ON” (ISR-N2-9-20 02.11.2020). The light intensities presented in this report include vertical and horizontal measurements taken at each sampling point around the LPP. The measurements performed in the field were oriented towards finding the range of the LPP lighting impact and therefore measurement locations were adjusted accordingly (see Figure 2).

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## Effects of LPP ALAN on the marine environment

As presented in the previous section, almost all marine organisms are sensitive to changes in light regime and therefore would be affected by ALAN. However, in many cases it appears that these effects are species specific and vary from one environment or ecosystem to another. Therefore, when trying to determine the possible environmental effects of ALAN from the LPP it is important to examine the data from studies conducted on offshore platforms, the Mediterranean environment and local species.

The platform is an offshore artificial structure likely to function as an artificial reef and support the settlement of various epibionts, which would not necessarily mirror the natural rock reef species or community structure. As such, ALAN effects on the survivorship of these organisms would not reflect on the wellbeing of local natural reefs. The most critically affected invertebrate species mentioned in ALAN research, hermatypic corals, are not found in the Levant. Therefore, the expected ALAN effects on local invertebrate species and on the epifauna community structure do not appear to be environmentally significant.

Plankton is known to be sensitive to lunar light levels (less than 0.3 lux) and in recent research is shown to react even to very low levels of artificial light [Davis 2020, Ludvigsen 2018].

“Biologically important light” has been defined for plankton as detectable red ( $0.0135 \text{ lux m}^{-2}$ ), blue ( $0.00017 \text{ lux m}^{-2}$ ) and green ( $0.0006 \text{ lux m}^{-2}$ ) [Davis 2020]. According to the lighting intensities measured in the lighting intensity survey near the platform (Figure 3) the expected reaction ranges from phototaxis and aggregation of certain species in illuminated layers to disruption of diel migration of plankton

The extent of this reaction to “biologically important light” will depend on the actual depth of light penetration from perimeter lighting into the water.

Current research shows both physiological and behavioral effects of exposure to ALAN in fish. However, the physiological effects reported were all described at illumination intensities much higher than those measured around the LPP [Szekeres 2017, Pulgar 2019, O'Connor 2019, Czarnecka 2019]. All these experiments were conducted at lighting intensities of at least 20 lux,

Therefore, we expect very little, if any, physiological effects on the fish community

When assessing the effect of LPP lighting on the fish behaviour and the fish community structure in the surrounding environment we need to take into account the attraction of fish to the vertical structure of platform. The availability of shelter and food provided by the structure and the epibionts that will settle on it is expected to attract fish regardless of the effects of ALAN. ALAN will be one of the factors that will determine the make-up of the fish community that develops around the LPP. It is expected to contribute to the aggregation of

planktivorous fish and thereby also attract larger predators as is known from platforms in the North Sea and Gulf of Mexico [Keenan 2003, Keenan 2007, Brown 2010, Barker 2018]. Foraging and feeding by both planktivorous fish and predators are expected to be extended by the artificial light.

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Increased fish schooling or shoaling around the LPP may lead to increased dolphin foraging at night around the illuminated area as reported on platforms in Brazil. This is not necessarily a negative effect as they will forage according to prey availability.

Sea turtles are known to be affected by ALAN in female nesting behaviour and success and in hatchling “seafinding” and survival. There is currently no knowledge of offshore platforms’ lighting affecting sea turtle navigation and their ability to successfully locate their nesting beaches. However, the possibility of offshore ALAN affecting sea turtles cannot be completely ignored

Birds are known to be affected by the lighting of offshore platforms in the North Sea and in the Gulf of Mexico [Montevecchi 2012]. Migrating birds could be attracted or disoriented by the LPP lighting, though probably more by the platform lighting than the security perimeter lighting. Migrating soaring birds favor overland routes and are therefore not expected to be effected by the LPP lighting [Frumkin 1995, Leshem 1998]. Migrating flapping birds are more likely to use oversea routes. However, due to the fact that the LPP is only 10 km from the shore the effects will probably not prevent the birds from reaching the shore after delaying at the LPP.

## Conclusion and Recommendations

This report is based on the results of the measurements performed by <sup>(ספק חיצוני)</sup> Sustainability and Light Design. Analysis of the expected environmental effects of the LPP lighting was done by comparing these measurements to the effects of light intensities and spectra published in scientific journals and reports. <sup>[מידע סודי]</sup>

The environmental effects of LPP lighting on marine invertebrates and plankton are not expected to be significant. The effects on fish community structure, schooling and on the concentration of predators around the LPP <sup>[מידע סודי]</sup>

. These effects cannot be assigned to the effects of lighting alone and may also be attributed to the shelter provided by the structure itself. These effects are mainly the results of the perimeter security lighting plan, which is mandated for security reasons.

## References:

- Ayalon, I., de Barros Marangoni, L.F., Benichou, J.I., Avisar, D. and Levy, O., 2019. Red Sea corals under Artificial Light Pollution at Night (ALAN) undergo oxidative stress and photosynthetic impairment. *Global change biology*, 25(12), pp.4194-4207.
- Barker, V.A. and Cowan, J.H., 2018. The effect of artificial light on the community structure of reef-associated fishes at oil and gas platforms in the northern Gulf of Mexico. *Environmental biology of fishes*, 101(1), pp.153-166.
- Becker, A., Whitfield, A.K., Cowley, P.D., Järnegren, J. and Næsje, T.F., 2013. Potential effects of artificial light associated with anthropogenic infrastructure on the abundance and foraging behaviour of estuary-associated fishes. *Journal of Applied Ecology*, 50(1), pp.43-50.
- Brown, H., Benfield, M.C., Keenan, S.F. and Powers, S.P., 2010. Movement patterns and home ranges of a pelagic carangid fish, *Caranx crysos*, around a petroleum platform complex. *Marine Ecology Progress Series*, 403, pp.205-218.
- Cremer, M.J., Barreto, A.S., Hardt, F.A.S., Júnior, A.J.T. and Mounayer, R., 2009. Cetacean occurrence near an offshore oil platform in southern Brazil. *Biotemas*, 22(3), pp.247-251.
- Czarnecka, M., Kakareko, T., Jermacz, Ł., Pawlak, R. and Kobak, J., 2019. Combined effects of nocturnal exposure to artificial light and habitat complexity on fish foraging. *Science of The Total Environment*, 684, pp.14-22.
- Davies, T.W., Coleman, M., Griffith, K.M. and Jenkins, S.R., 2015. Night-time lighting alters the composition of marine epifaunal communities. *Biology letters*, 11(4), p.20150080.
- Davies, T.W., McKee, D., Fishwick, J., Tidau, S. and Smyth, T., 2020. Biologically important artificial light at night on the seafloor. *Scientific reports*, 10(1), pp.1-10.
- Depledge, M.H., Godard-Codding, C.A. and Bowen, R.E., 2010. Light pollution in the sea. *Marine pollution bulletin*, 9(60), pp.1383-1385.
- Dimitriadis, C., Fournari-Konstantinidou, I., Sourbès, L., Koutsoubas, D. and Mazaris, A.D., 2018. Reduction of sea turtle population recruitment caused by nightlight: evidence from the Mediterranean region. *Ocean & Coastal Management*, 153, pp.108-115.
- Fobert, E.K., Burke da Silva, K. and Swearer, S.E., 2019. Artificial light at night causes reproductive failure in clownfish. *Biology letters*, 15(7), p.20190272.
- Frumkin, R., Pinshow, B. and Kleinhaus, S., 1995. A review of bird migration over Israel. *Journal für Ornithologie*, 136(2), pp.127-147.
- Gaston, K.J., Davies, T.W., Bennie, J. and Hopkins, J., 2012. Reducing the ecological consequences of night-time light pollution: options and developments. *Journal of Applied Ecology*, 49(6), pp.1256-1266.
- Keenan, S.F., Benfield, M.C. and Shaw, R.F., 2003. Zooplanktivory by blue runner *Caranx crysos*: a potential energetic subsidy to Gulf of Mexico fish populations at petroleum platforms. In *American Fisheries Society Symposium* (pp. 167-180). American Fisheries Society.

- Keenan, S.F., Benfield, M.C. and Blackburn, J.K., 2007. Importance of the artificial light field around offshore petroleum platforms for the associated fish community. *Marine Ecology Progress Series*, 331, pp.219-231.
- Leshem, Y. and Yom-Tov, Yoram, 1998. Routes of migrating soaring birds. *Ibis*, 140(1), pp.41-52.
- Longcore, T., Rodríguez, A., Witherington, B., Penniman, J.F., Herf, L. and Herf, M., 2018. Rapid assessment of lamp spectrum to quantify ecological effects of light at night. *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology*, 329(8-9), pp.511-521.
- Luarte, T., Bonta, C.C., Silva-Rodriguez, E.A., Quijón, P.A., Miranda, C., Farias, A.A. and Duarte, C., 2016. Light pollution reduces activity, food consumption and growth rates in a sandy beach invertebrate. *Environmental Pollution*, 218, pp.1147-1153.
- Ludvigsen, M., Berge, J., Geoffroy, M., Cohen, J.H., Pedro, R., Nornes, S.M., Singh, H., Sørensen, A.J., Daase, M. and Johnsen, G., 2018. Use of an autonomous surface vehicle reveals small-scale diel vertical migrations of zooplankton and susceptibility to light pollution under low solar irradiance. *Science advances*, 4(1), p.eaap9887.
- Marquenie, J., Donners, M., Poot, H., Steckel, W. and de Wit, B., 2013. Bird-friendly light sources: adapting the spectral composition of artificial lighting. *IEEE Industry Applications Magazine*, 19(2), pp.56-62.
- Mazor, T., Levin, N., Possingham, H.P., Levy, Y., Rocchini, D., Richardson, A.J. and Kark, S., 2013. Can satellite-based night lights be used for conservation? The case of nesting sea turtles in the Mediterranean. *Biological Conservation*, 159, pp.63-72.
- O'Connor, J.J., Fobert, E.K., Besson, M., Jacob, H. and Lecchini, D., 2019. Live fast, die young: Behavioural and physiological impacts of light pollution on a marine fish during larval recruitment. *Marine Pollution Bulletin*, 146, pp.908-914.
- Pendoley, K. and Kamrowski, R.L., 2016. Sea-finding in marine turtle hatchlings: What is an appropriate exclusion zone to limit disruptive impacts of industrial light at night?. *Journal for Nature Conservation*, 30, pp.1-11.
- Poot, H., Ens, B.J., de Vries, H., Donners, M.A., Wernand, M.R. and Marquenie, J.M., 2008. Green light for nocturnally migrating birds. *Ecology and society*, 13(2).
- Poulin, C., Bruyant, F., Laprise, M.H., Cockshutt, A.M., Marie-Rose Vandenhecke, J. and Huot, Y., 2014. The impact of light pollution on diel changes in the photophysiology of *Microcystis aeruginosa*. *Journal of plankton research*, 36(1), pp.286-291.
- Pulgar, J., Zeballos, D., Vargas, J., Aldana, M., Manriquez, P.H., Manriquez, K., Quijón, P.A., Widdicombe, S., Anguita, C., Quintanilla, D. and Duarte, C., 2019. Endogenous cycles, activity patterns and energy expenditure of an intertidal fish is modified by artificial light pollution at night (ALAN). *Environmental Pollution*, 244, pp.361-366.
- Ronconi, R.A., Allard, K.A. and Taylor, P.D., 2015. Bird interactions with offshore oil and gas platforms: review of impacts and monitoring techniques. *Journal of Environmental Management*, 147, pp.34-45.

- Rosenberg, Y., Doniger, T. and Levy, O., 2019. Sustainability of coral reefs are affected by ecological light pollution in the Gulf of Aqaba/Eilat. *Communications biology*, 2(1), pp.1-9.
- Sanders, D., Frago, E., Kehoe, R., Patterson, C. and Gaston, K.J., 2020. A meta-analysis of biological impacts of artificial light at night. *Nature Ecology & Evolution*, pp.1-8.
- Silva, E., Marco, A., da Graça, J., Pérez, H., Abella, E., Patino-Martinez, J., Martins, S. and Almeida, C., 2017. Light pollution affects nesting behavior of loggerhead turtles and predation risk of nests and hatchlings. *Journal of Photochemistry and Photobiology B: Biology*, 173, pp.240-249.
- Szekeres, P., Wilson, A.D., Haak, C.R., Danylchuk, A.J., Brownscombe, J.W., Elvidge, C.K., Shultz, A.D., Birnie-Gauvin, K. and Cooke, S.J., 2017. Does coastal light pollution alter the nocturnal behavior and blood physiology of juvenile bonefish (*Albula vulpes*)?. *Bulletin of Marine Science*, 93(2), pp.491-505.
- Tamir, R., Lerner, A., Haspel, C., Dubinsky, Z. and Iluz, D., 2017. The spectral and spatial distribution of light pollution in the waters of the northern Gulf of Aqaba (Eilat). *Scientific reports*, 7, p.42329.
- Tamir, R., Eyal, G., Cohen, I. and Loya, Y., 2020. Effects of light pollution on the early life stages of the most abundant northern red sea coral. *Microorganisms*, 8(2), p.193.
- Underwood, C.N., Davies, T.W. and Queirós, A.M., 2017. Artificial light at night alters trophic interactions of intertidal invertebrates. *Journal of Animal Ecology*, 86(4), pp.781-789.
- Wiese, F.K., Montevecchi, W.A., Davoren, G.K., Huettmann, F., Diamond, A.W. and Linke, J., 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. *Marine Pollution Bulletin*, 42(12), pp.1285-1290.
- Yurk, H., Trites, A.W., 2000. Experimental attempts to reduce predation by harbor seals on out-migrating juvenile salmonids. *Trans. Am. Fish Soc.* 129, pp.1360–1366.



## Appendix

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