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# MARLAN: Plymouth Marine Laboratory's Marine Artificial Light at Night Research Facility

Ana M Queirós, Liz Talbot, Chris Pascoe, Anthony Staff and Steve Widdicombe

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# MARLAN: Plymouth Marine Laboratory's Marine Artificial Light at Night Research Facility

**Contributors:** Ana M Queirós[1], Liz Talbot[1], Chris Pascoe[1], Anthony Staff[1] and Steve Widdicombe[1]

[1]Plymouth Marine Laboratory, Plymouth, United Kingdom

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Cover image: Joana Nunes in the MARLAN. Photo by Ana Queirós.

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## Executive Summary

This document provides technical guidance about, and design description of, the Plymouth Marine Laboratory's Marine Artificial Light At Night Research Facility (MARLAN), a bespoke seawater aquarium facility dedicated to the study of light pollution in the marine environment.

## 1.Introduction

This document describes the technical design and infrastructure of Plymouth Marine Laboratory's (PML) Marine Artificial Light At Night Research Facility (MARLAN). This is a bespoke light insulated seawater aquarium facility dedicated to the study of light pollution effects on marine life, embedded within PML's mesocosm laboratory. The latter is a temperature-controlled seawater laboratory, which includes a number of additional environmental controls, previously described in Findlay, Kendall et al. (2008), Queirós, Fernandes et al. (2015), and Ravaglioli, Bulleri et al. (2019).

MARLAN is separated from the rest of the mesocosm laboratory *via* a black polyester fabric partition to eliminate the seepage of ambient light into the working area. This darker environment (Fig.1a) is further maintained by researchers' use of dimmer red LED headtorches during all interactions with the setup. Marine organisms are generally less sensitive to red light, and its propagation through the water will be more quickly attenuated than other light currently deployed in the system. This precaution limits the imposition of any substantial level of additional light to the MARLAN treatments experienced by animals, during experiments. Environmental temperature control within the MARLAN facility is operated in tandem with the rest of the mesocosm.

MARLAN has three main components: the Holding System (Section 2), the Lighting System (Section 3) and the Tidal Lightscape Simulator (Section 4).

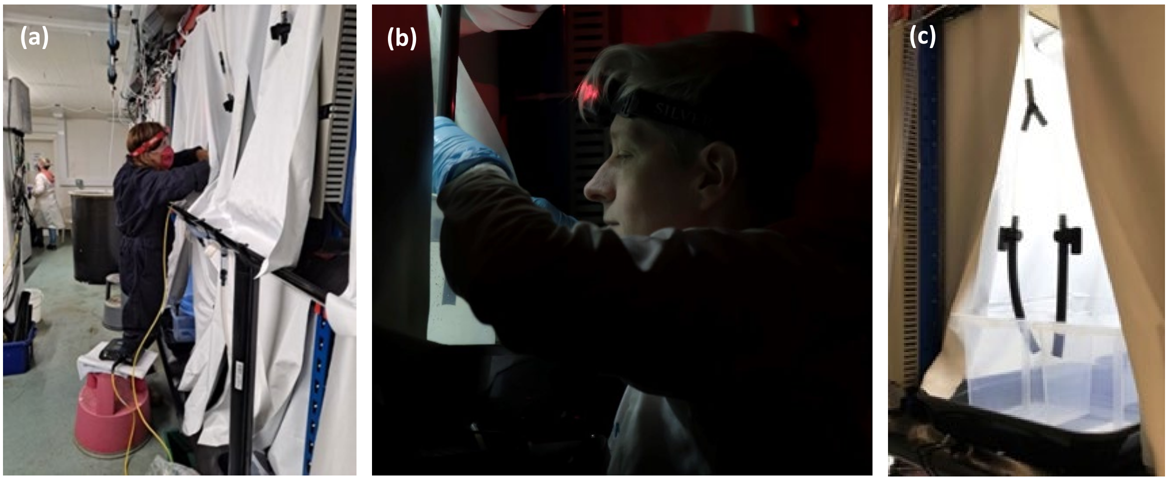

**Fig. 1**. The MARLAN: (a) View along one of the 920 cm sides of the holding system during light calibration by Pascoe, with individual holding cells and header tanks in view (main mesocosm lighting on). White, light cancelling fabric is visible. (b) a close up of the system during experiments, with the user (Talbot) employing a red LED torch against the darkened environment. The cell's light cancelling partition has been opened to allow the user to interact with the system; (c) an individual cell, where light cancelling partition is open, exposing aquaria and seawater tubing.

## 2. The Holding System

The holding system is distributed over two 920cm long shelves, with a 90cm headspace, the lowest level just above the mesocosm floor. Each level houses 15 individual light treatment cells (30 overall), the whole system having a capacity to house up to 90 5-12L marine aquaria. These, in turn, are appropriate to the housing of ~500 adult intertidal animals (Fig. 1).

Each cell is light insulated *via* the use of light cancelling fabric partitioning, which allows for the deployment of individual light regimes and treatment levels in each separate cell (see Section 3 for a description of the lighting set-up), without changing the overall environmental temperature control provided by the main mesocosm's facilities

Up to 1500L of seawater are re-circulated within the system, and housed across four 450L PVC header tanks, all connected to each other *via* a lower-level clear silicone tubing system. Water from each header tank is circulated to top hose lines located at the outer top edge of shelves, *via* head pumps (Eheim CompactON 1000 for aquaria on bottom shelves, Eheim CompactON 2100 for aquaria on top shelves). Each pump provides water to about half of the aquaria located along each of the 920cm sides of the holding system, supplying water to tanks positioned in both the top and the lower shelf. In each of these four units, water enters the circulation system first *via* the top line (industry standard PVC push fit tubing) from which "T" connectors supply PVC pipes located adjacent to individual cells (Fig.1). This tubing is in turn connected to industry standard black flow valves *via* clear silicone tubing, the valves controlling the water flow to one or two aquaria within that side of each individual cell. Industry standard black silicone tubing is attached to each valve, connecting it to an individual aquarium, with the use of "Y" connectors in cases when one valve supplies two aquaria. The use of black tubing limits the intrusion of any ambient light into cells (Fig. 1), with black tubing penetrating the frontal light cancelling fabric partition of each cell.

The water in each aquarium is then allowed to overflow into PVC collection trays which overlap with a PVC guttering system which runs across the lower outer edge of each shelf (Fig. 1). Each tray is pierced with a 1.5cm hole to ensure water only flows into the guttering to limit system leaks. Vertical guttering channels the overflow down to collection trays on the floor, positioned at the four corners of each unit (two along each of the 920cm sides of the system), each housing a bilge pump (Rule submersible 100gph, 24V). Each bilge pump channels the collected overflow back into the nearest header tank. The water circulation system can be used in two modes: continuous flow or tidal flow (see section 4).

High quality seawater used in the facility is collected from Station L4 (https://www.westernchannelobservatory.org.uk/) and held in PML's main seawater tank. The seawater passes through 10 and 1μm filters before being supplied to the MARLAN *via* a hose located within the main mesocosm laboratory. To maintain water conditions, each header tank is fitted with an industrial filtration system (Tetra 1200L/hr flow for 500L aquaria) to remove large particulate waste and help regulate nutrient levels. The latter needs to be routinely monitored using standard aquarium trade kits and partial water changes made when required.

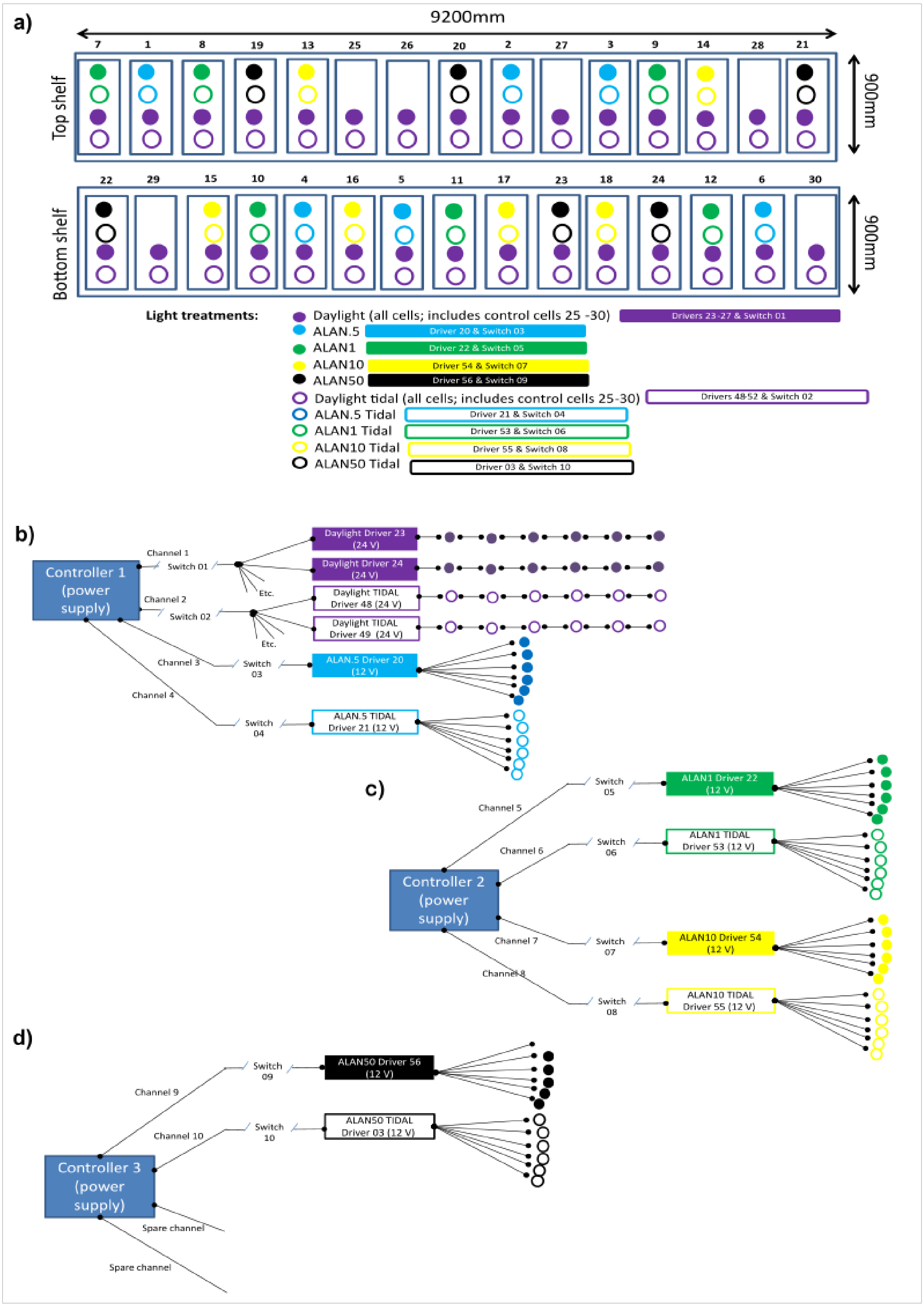

**Fig. 2**: Schematic representation of the (a) lighting system, including (b-d) basic circuit diagrams for each controller.

## 3. The Lighting System

Lighting in the MARLAN holding system is supplied and controlled independently from lighting in the main mesocosm laboratory, and is schematically represented in Fig. 2, with system specifications given in Table 1. This system comprises of state-of-the-art light controlling technology, currently distributed over ten fully customisable, individual light channels, which provide light treatments to holding cells. Each light channel configuration was designed to replicate the natural daylight cycle and four separate ALAN treatments (through the employment of lights delivering appropriate levels of illuminance; and the mimicking of regionally and seasonally appropriate solar arc (varying solar intensity over the day and day length) for daylight channels, as per manufacturer software). These light channels are fully customisable to respond to future uses of the facility (e.g., the testing of different LED colours, employing different light fixtures). The system further includes the lunar simulator previously described in Tidau, Whittle et al. (2022), which provides appropriate illuminance that modulates the full lunar cycle, as specified for a given location and period of the year. A total of five individual light sources are therefore available to each cell, simulating the solar input and the ALAN source, both modulated over the tidal cycle (Section 4); and the lunar cycle (moon zenith and phase). In each MARLAN cell (Fig. 2a), all natural (sun and moon) and artificial light sources can thus be simulated. The sun and the ALAN channels are available to each cell in two different illuminance levels (four channels in total), and the two channels for each source alternately operates, depending on the tidal phase (section 4). The lunar signal is not available with tidal modulation at this stage, due to technical limitation.

### *Controllers and light fixtures*

Three USB and Bluetooth enabled light controllers/power supplies (BioLumen Master control unit) control four light channels each (Fig. 2b-d). Channel 1 and Channel 2 control BioLumen 500 Natural Daylight and 380mm Freshwater (Ultra Daylight) 9W fixtures, respectively, all of which are stepped up in series, *via* identified drivers (Fig. 2). The former is used to simulate the solar arc at full illuminance for the specified time of year and location (as per supplier design), the latter being used to simulate the same solar arc at 30% of illuminance. The full illuminance solar simulator is used during periods of emersion, and the 30% solar signal used in periods of immersion (see section 4). Channels 3, 5, 7 and 9 simulate four different ALAN treatments during emersion periods, and Channels 4, 6, 8 and 10 simulate their respective treatments during immersion, at 30% of the original illuminance (see section 4). Channels 3-10 control 380mm Freshwater (Ultra Daylight) 9W fixtures, via identified drivers (Fig. 2).

### *Drivers*

In Channels 1-2, BioLumen Power Pod Pro 24V drivers are used to control five individual series of six fixtures setup in parallel. In all other channels, BioLumen Power Pod Pro 12V drivers are used, one per channel, each controlling six fixtures setup in parallel.

The light conditions applied to each cell, *via* each channel, can then be specified *via* the setting up of individual drivers, using the Biolumen interface. The interface provides the ability to specify the relative intensity of light a specific fixture may deliver relative to its maximum.

The specification of individual light characteristics delivered to each cell then requires the parallel use of specific instrumentation to relate that intensity to the desired light characteristic studied. For instance, at the design stage, we employed a waterproof SpectroSense 2+ (Skye) to define the illuminance delivered to each cell by each light channel. To this end, underwater measurements were made at the bottom and centre of each cell during setup, and a variation of less than 0.01lux of light intensity measured across the width and length of individual cells. The nominal light conditions of the original design are specified in Table 1.

The MARLAN's lighting system is supported by an independent Power Supply Unit (OPTI 3000VA), which ensures the system is powered and able to operate for 12 hours in case of temporary power failure.

**Table 1**: Lighting system specifications. ”HT”: high tide, referring to immersion, which is simulated as 1 hour before to 1 hour after high tide.

| Controller | Channel | Nominal Treatment | lux | tidal phase | day time | Seasonal shift? | Driver nr | Cells | Software group | Switch nr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Daylight | 500.00 | all but HT | day | yes | Driver 23 to 27 | All (cells 25-30 are the control cells) | A | 1 |
| 1 | 2 | Daylight tidal | 166.70 | HT | day | yes | Driver 48 to 52 | All (cells 25-30 are the control cells) | B | 2 |
| 1 | 3 | ALAN.1 | 0.10 | all but HT | night | no | Driver 20 | 1 to 6 | A | 3 |
| 1 | 4 | ALAN.1 Tidal | 0.03 | HT | night | no | Driver 21 | 1 to 6 | B | 4 |
| 2 | 5 | ALAN1 | 1.00 | all but HT | night | no | Driver 22 | 7 to 12 | A | 5 |
| 2 | 6 | ALAN1 Tidal | 0.33 | HT | night | no | Driver 53 | 7 to 12 | B | 6 |
| 2 | 7 | ALAN10 | 10.00 | all but HT | night | no | Driver 54 | 13 to 18 | A | 7 |
| 2 | 8 | ALAN10 Tidal | 3.33 | HT | night | no | Driver 55 | 13 to 18 | B | 8 |
| 3 | 9 | ALAN50 | 50.00 | all but HT | night | no | Driver 56 | 19 to 24 | A | 9 |
| 3 | 10 | ALAN50 Tidal | 16.67 | HT | night | no | Driver 03 | 19 to 24 | B | 10 |
| 3 | 11 | spare | | | | | | | | |
| 3 | 12 | spare | | | | | | | | |

## 4.The Tidal Lightscape Simulator

This MARLAN component was co-designed by Queirós (PML) and contractor Digital Enterprise Coordinator Queiroz (Siemens, Portugal), in consultation with Westcott (TMC). The physical system was built by Siemens (Portugal) official partner RD Automação Industrial, using off-the-shelf Siemens industrial equipment (Fig. 3). The equipment is housed in a waterproof case inside the MARLAN. This system's controls can be accessed directly via web-hosted and password protected Node-RED software or via its user interface, both of which were custom developed for this application by Siemens (Portugal, Fig. 3).

The Tidal Lightscape Simulator's software (Table 1) controls a set of relays *via* an industrial PC, with the relays connected to water pumps located inside header tanks in the holding system (section 2), and to the drivers that regulate various lighting fixtures (section 3). The simulator thus controls both water circulation and lighting in the holding system.

The tidal simulator's software uses the API Stormglass' (https://stormglass.io/) tidal simulator to extract local tidal phases in real-time, with the location for estimates being user defined. The tidal phases are then used to turn on and off equipment in the holding and lighting system (sections 2 and 3) to simulate different water column conditions; specifically, whether there is a period of immersion or emersion. With regard to water column height, the simulator has been designed to shut off water circulation from 1 hour before and until 1 hour after high tide. During this period, individual aquaria slowly drain out, exposing housed individuals to emersion. This feature allows for the simulation of intertidal conditions, and the period of circulation shutdown can be customised to simulate different regions of the intertidal, or indeed, be switched off to allow for the simulation of subtidal conditions. At the end of set periods, the pumps in the header tanks are re-started, and individual aquaria gently fill up again, exposing housed individuals to immersion (Fig. 3a). The tidal estimates are also used to regulate the lighting system (section 3). Specifically, from 1 hour before and until 1 hour after the low tide time, the light Channels 1, 3, 5, 7 and 9 (regulating the main solar and ALAN signals) are turned off, and the correspondingly dimmer Channels 2, 4, 6, 8 and 10 are turned on. This dims light conditions to 30% of the illuminance simulated by the main light channels (Table 1) to reflect the modulation of light received by seafloor communities in coastal areas as result of tidal action, as estimated by Davies, McKee et al. (2020). After this period, Channels 2, 4, 6, 8 and 10 are shut-off and the main light channels re-instated.

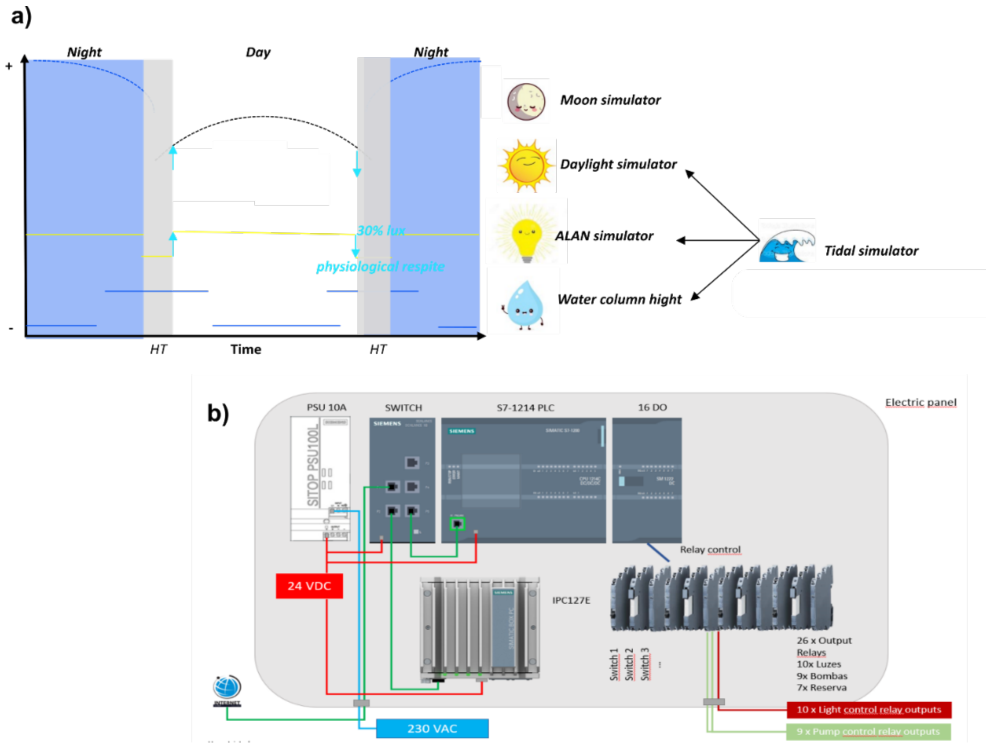

**Fig. 3**: Schematic representation of the effects of the Tidal Lightscape Simulator on (a) water column conditions and (b) its hardware.

## 5. Contributions

The MARLAN Holding System was designed by Queirós, Talbot and Pascoe (PML), and built by Talbot, Pascoe, Nunes, Mesher and Wilson (PML). The Lighting System was designed by Queirós (PML) with support from contractor Westcott (Tropical Marine Centre) and built by Staff (PML). The Tidal Lightscape Simulator was co-designed by Queirós (PML) and contractor Digital Enterprise Coordinator Queiroz (Siemens, Portugal), in consultation with Westcott (TMC), and built by Siemens (Portugal) and their official partner RD Automação.

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