Guidance on using Photosynthetically Active Radiation (PAR) as a method to measure light availability for aquatic photosynthetic organisms facing acute impacts

1 Purpose and scope

This purpose of this document is to provide general guidance in the use of photosynthetically active radiation (PAR) sensors for monitoring aquatic photosynthetic organisms such as seagrasses.

Light requirements (specified as PAR) are included as a Water Quality Objective (WQO) for some coastal waters under the *Environmental Protection (Water) Policy 2009*.

2 Associated documents

Sampling design and preparation:

- *Record keeping, including taking field photographs and videos*
- *Sampling scope and design*
- *Permits and approvals*

Biological assessment: Guidance on seagrass monitoring

3 Introduction

Photosynthetically active radiation (PAR) refers to the spectral range (400 to 700 nanometres) of solar radiation that is used in photosynthesis. This is relevant for primary producers such as seagrass and phytoplankton as well as for most reef-building corals which contain photosynthetic algae (zooxanthellae) that live in their tissues and provide coral with their primary food source. Insufficient PAR can lead to reduced growth or loss of seagrass, corals and other photosynthetic organisms. Measurement of PAR can therefore be used as a surrogate indicator to assess potential impacts on photosynthetic plants. Telemetered PAR data allows for real time monitoring and management of activities that can potentially impact these organisms, such as dredging. PAR is preferred to turbidity for measuring potential impacts from total suspended solids to seagrass as it provides a biologically relevant indicator.

Acute related pressures or impacts are defined as typically less than 3 months and related to either discrete coastal development activities or weather-related events that impact water quality (such as cyclones) (Collier et al. 2016). However, the specific time-scale over which an acute event occurs can be longer. For instance, a 12-month dredging campaign may be classified as an acute pressure since it is a well-defined activity that adds pressure to the light environment that is distinct from background water quality conditions. Chronic pressures would relate to longer-term changes to the light environment such as those that occur due to changes in river catchment activities and sediment loads from coastal communities. These are sustained in the long term without a clearly defined end date for the pressure.

4 Planning a monitoring program

For field deployment, loggers should be attached to permanent station markers. For intertidal and subtidal areas, this is above the sediment-water interface such that the sensor is at the same height as the species being monitored (e.g. top of the seagrass canopy), so they are collecting light equivalent to what is reaching benthic flora. When designing a monitoring program, key considerations are:

- The most commonly used sensors, and the ones recommended for monitoring, are flat "2π" sensors. Differences in sensor design and shape will influence how they intercept radiation – different instruments may produce different measurements (Long et al 2012 and references therein); therefore, it is recommended that the same brand of sensor be used for all sites in a monitoring program.
- PAR should be recorded at or just above the flora that are being managed because PAR changes with depth due to light attenuation,
- A reference logger that measures incident surface PAR should be deployed near the site (in the air) as benthic PAR is in part a function of the incident PAR reaching the water surface (which can be impacted by cloud cover etc.), so it is needed to separate out water column and atmospheric effects.
- PAR should be logged continuously and recorded, at a minimum, of 15 minute intervals.
- Two loggers should be deployed at all sites, in case of loss or logger fouling.
- It is essential that a self-cleaning or wiper system is used with the loggers to ensure the sensor remains clean (un-fouled) – typically the lens is wiped every 15 minutes.
- If real time management of an activity is required, these instruments should be combined with a telemetry system.
- Each light logger has a unique serial number that should be recorded within a central secure database. The logger number should be recorded on the monitoring site datasheet with the time of deployment and retrieval.
- At permanently submerged sites, the loggers should be checked by SCUBA divers every six to twelve weeks and replaced if fouled. The length of time between logger replacements is site-specific due to variation in fouling rates.
- Photographs of the light sensor and/or notes on the condition of the sensor should be recorded when the logger is retrieved. If major fouling is noted (e.g. wiper failure), the data are truncated to include only those data collected before fouling began. If minor fouling is noted (up to ~25% of the senor covered), back corrections can be made to the data, allowing for a linear rate of fouling (linear because with minor fouling it is assumed that the wiper was retarding algal growth rates, but not fully inhibiting them).
- Loggers must be calibrated or checked against a certified reference Photosynthetically Active Radiation (PAR) sensor using a stable light source enclosed in a casing that holds both the sensor and light source at a constant distance. Calibration must be repeated between each deployment period.
- Manufacturer's instructions must be followed at all times.
- A correction factor should be applied to logged data to account for the difference between the calibration (if performed in air) versus the deployment conditions (in water). This is due to the difference in light absorption properties between air and water by the sensor (Kirk 1994). When assessing data from intertidal loggers, the application of the correction factor must take into account exposure history (i.e. shifts between inundation and exposure to air), and only be applied to data when the logger was inundated, assuming the calibration was done in air.

5 Assessment of data

Light is measured as instantaneous irradiance (μmol m^{-2} s^{-1}). Accumulation of instantaneous irradiance should be calculated as daily PAR or irradiance (I_d, mol m^{-2} d^{-1}), which is standard practice and a useful way of expressing the PAR data for management of photosynthetic benthic light.

A simple close approximation to convert a daily series of regularly measured instantaneous irradiance readings (μmol m^{-2} s^{-1}) to daily light integrated PAR or irradiance (I_d, mol m^{-2} d^{-1}) is as follows:

1) Assess recording intervals, and number of days.
2) Delete incomplete days, and calculate how many records to expect in total.
3) Check for missing values. If there are missing values, interpolate instantaneous irradiance readings to fill the gaps.

4) Check that night time readings are close to zero, and noon readings are within the range of expected values (~2000 µmol m^{-2} s^{-1}) for surface readings when sunny; ideally, all instruments will cross-calibrated the loggers, and deployed side by side).
5) Apply the following formula:

$$\text{Daily PAR } I_d \text{ [mol m}^{-2}\text{ d}^{-1}] = (\text{sum of all instantaneous values}) \times 24 \times 60 \times 60 / 1{,}000{,}000 / N \times D$$

$$= (\text{sum of all instantaneous values}) \times 0.0864 / N \times D$$

Where N is the number of samples taken in total, and D is the number of complete days of logger deployment.

A logger was programmed to record one instantaneous value every 15 min for a day. To calculate the Daily PAR:

N = 60 × 24 / 15 = 96.

Sum of the 96 instantaneous readings = 2119.47 µmol m^{-2} s^{-1}.

D = 1.

Thus, Daily Par (I_d) = 1.9075 mol m $^{-2}$ d^{-1} at this location.

Regional catchment-level Water Quality Objectives are being implemented under Queensland's *Environmental Protection (Water) Policy 2009* for Great Barrier Reef catchments. Readers should refer to the specific basin for prescribed Water Quality Objectives for the protection of seagrasses. Generally guidelines in coastal waters are specified as:

1. over a rolling seven day average for deep (>10 m) water
2. over a rolling 14 day average for shallow inshore (<10 m) water.

Note: Absolute light requirements for seagrass may vary between sites and species. Values described in the *Environmental Protection (Water) Policy 2009* provide a conservative guide to the levels of light likely to support seagrass growth from acute water quality impacts. Locally derived, absolute, and species-specific thresholds ideally should be obtained for management of specific activities likely to impact on the light environment. Higher light requirements may be needed for the management of longer term chronic impacts.

6 References and additional reading

Chartrand KM, Ralph PJ, Petrou K and Rasheed MA. (2012) Development of a Light-Based Seagrass Management Approach for the Gladstone Western Basin Dredging Program. DAFF Publication. Fisheries Queensland, Cairns 126 pp.

Collier, CJ, Chartrand K, Honchin C, Fletcher A and Rasheed, M 2016, *Light thresholds for seagrasses of the GBR: a synthesis and guiding document. Including knowledge gaps and future priorities*. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns (41pp.).

Kirk, J.T.O., 1994. Light and photosynthesis in aquatic ecosystems, 3rd ed. Cambridge University Press.

Long MH, Rheuban JE, Berg P and Zieman JC 2012, 'A comparison and correction of light intensity loggers to photosynthetically active radiation sensors'**,** *Limnology and Oceanography Methods* Vol. 10 pp. 416–424.

McKenzie, LJ, Collier, CJ, Langlois, LA, Yoshida, RL, Smith, N and Waycott, M 2016, *Marine Monitoring Program. Annual Report for inshore seagrass monitoring: 2014 to 2015. Report for the Great Barrier Reef Marine Park Authority.* TropWATER, James Cook University, Cairns. 236pp.

Rasheed, MA, McKenna, SA, Carter, AB and Coles, RG 2014, 'Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia. *Marine Pollution Bulletin* Vol. 83, pp. 491–499.

York, PH, .Carter, AB, Chartrand, K, Sankey, T, Wells, L and Rasheed MA 2015, 'Dynamics of a deep-water seagrass population on the Great Barrier Reef: annual occurrence and response to a major dredging program. *Scientific Reports* 5, Article number: 13167. Available from: https://www.nature.com/articles/srep13167