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In-situ artificial shading improves effective quantum yield and coral color of the tropical corals *Acropora muricata* and *Porites lutea*

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ABSTRACT

Declines in coral reefs areas are commonly attributed to thermal stress-induced coral bleaching. Previous observations have noted that coral reefs bleached less during heat stress in low-light conditions, such as higher turbidity or cloud cover. Artificial shading has been proposed as an adaptive strategy to mitigate the deleterious effects of coral bleaching and improve coral resistance to stressors. However, the widespread application of this method requires more in-depth studies to investigate the effects of shading on coral health. This study implemented 80% artificial shading *in-situ* on two common species of Indo-Pacific corals at Pulau Rawa, Johor, Malaysia. *Acropora muricata* and *Porites lutea* fragments were collected to study the effect of lowered light on effective quantum yield (ΔF/Fm'; 21 days), coral health scores (color saturation; 30 days), and linear growth (*A. muricata* only; 30 days). Shading significantly increased effective quantum yield in both species by 3.6% and 4.5% in *A. muricata* and *P. lutea* on Day 21, respectively. Although the increment is lower, *A. muricata* achieved higher effective quantum yields than *P. lutea* in both shaded and control treatments. Implementation of shading had also enhanced the coral health scores in *P. lutea* by 29.3% on Day 30 compared to their non-shaded counterparts. The growth of *A. muricata* was not significantly affected by shading during the study period, though shaded corals displayed slightly less growth than non-shaded corals. Artificial shading was shown to have beneficial effects on coral photosynthesis and health during non-bleaching periods. This study lends further credence to artificial shading being used as a mitigation tool for future coral bleaching events, as photosynthetic efficiency and color are indicators of coral bleaching resistance. However, prolonged lowered light conditions may reduce photosynthetic output quantity and result in possibly slower growth rates. This tradeoff between factors of resistance and the different responses to shading in the two species studied implies the need for pilot studies before shading implementation. Further research should consider the short-term and long-term effects of shading removal and possible effects on coral adapted to different light environments before shading can be broadly used.

1. Introduction

Coral reefs, despite occupying 0.2% of the ocean, are one of Earth's most biologically diverse and productive ecosystems (Buddemeier et al., 2004; Plaisance et al., 2011). Global increases in sea temperatures have induced more frequent and severe coral bleaching events. Coral bleaching occurs when the coral host expels photosynthetic symbionts of the family Symbiodiniaceae, resulting in visual loss of coral color (Siebeck et al., 2006), with prolonged bleaching leading to coral death (Baird and Marshall, 2002). With the increasing frequency and intensity of mass coral bleaching events (Szereday et al., 2024) the loss of these coral reefs can be catastrophic to human communities that depend on these ecosystems (Chaijaroen, 2022). In Malaysia, coral reefs protect coastlines against wave action, support the fishing industry, and provide direct and indirect economic benefits worth up to USD 800 million annually (Zuhairi et al., 2018).

Previous studies have reported that coral reefs experiencing cloudy weather during periods of thermal stress did not bleach as severely as nearby areas with clear skies (Gonzalez-Espinosa and Donner, 2021; Mumby et al., 2001; Penin et al., 2007). Similar observations have also been recorded for reefs in moderately turbid waters compared to reefs in clearer, high-visibility waters (Golbuu et al., 2011; Sully and van

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