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Effect of Jetty Pillar Orientation on Scleractinian Corals

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ABSTRACT This study investigated the effect of orientation of the Pulau Tioman Marine Park jetty pillars on the underwater light intensity, zooxanthellae density and chlorophyll content of *Acropora selago* (branching coral) and *Cyphastrea japonica* (encrusting coral). There was significant difference in Photosynthetically Active Radiation (PAR) level between orientations of jetty pillars. However, the coral cover showed no significant difference between orientations suggesting that corals are able to grow if minimum PAR level is available. In *Cyphastrea japonica*, the difference in zooxanthellae density was significant between pillar orientations but *Acropora selago* showed otherwise. This difference in *C. japonica* was due to their zooxanthellar adaptation to different PAR levels. The chlorophyll *a* and c_2 content of both coral species between pillar orientations showed no significant difference. Zooxanthellae density and chlorophyll content of *A. selago* were almost similar compared between the jetty and the natural reef at Kampung Air Batang suggesting that the jetty's corals are viable species. Thus, we suggest that the construction of jetties in corals reef areas should consider pillar design and orientation in order to provide hard substrate and help to rehabilitate corals in the damaged construction area.

ABSTRAK Kajian ini menyiasat kesan orientasi tiang jeti Taman Laut Pulau Tioman terhadap keamatan cahaya dalam air, densiti zooxanthellae dan kandungan klorofil *Acropora selago* dan *Cyphastrea japonica*. Kajian mendapati perbezaan Radiasi Aktif Fotosintesis (PAR) adalah signifikan antara orientasi tiang jeti. Namun begitu, litupan terumbu menunjukkan sebaliknya dan ini mencadangkan bahawa terumbu boleh tumbuh sekiranya terdapat tahap PAR yang minimum. Dalam *Cyphastrea japonica*, perbezaan densiti zooxanthellae antara orientasi tiang jeti adalah signifikan tetapi *Acropora selago* pula adalah sebaliknya. Perbezaan *C. japonica* ini adalah kerana adaptasi zooxanthellae terhadap tahap PAR. Kandungan klorofil *a* and c_2 kedua-dua spesies terumbu tidak menunjukkan perbezaan yang signifikan antara orientasi tiang. Densiti zooxanthellae dan kandungan klorofil *Acropora selago* adalah hampir sama jika dibandingkan dengan jeti dan terumbu semula jadi di Kampung Air Batang mencadangkan bahawa terumbu di tiang tumbuh secara normal. Justeru, pembinaan jeti dalam kawasan terumbu karang haruslah mengambil kira rekabentuk dan orientasi tiang supaya boleh membantu memulihkan terumbu yang telah terjejas.

(**Keywords:** Marine park jetty, Photosynthetically Active Radiation (PAR), Chlorophyll)

INTRODUCTION

The productivity of hermatypic (scleractinian) corals is due to the presence of photosynthetically active zooxanthellae that live symbiotically in the soft tissues of these corals. The composition of photosynthetic pigments such as chlorophyll *a*, *c* and carotenoid in zooxanthellae has been reported to be similar to that of free-living planktonic dinoflagellates [1]. Much of the photosynthetic processes in corals are dependent on these pigments which are sensitive to light changes. Coral zooxanthellae resemble sessile plants that photoadapt to light changes in their habitat which can be affected by cloud cover, turbidity, phytoplankton density, shading and sedimentation. Suspended inorganic and organic particles in seawater can reduce light penetration as they are able to scatter and absorb light [2].

Photosynthesis in zooxanthellae requires an optimum light wavelength or Photosynthetically Active Radiation (PAR) of 400-700 nm. However, zooxanthellae can photoadapt through changes in their photosynthetic systems including the ability of light-harvesting by photosynthetic units [3]. The coral host can also adapt to low light condition by increasing the concentration of chlorophyll *a* and peridinin in zooxanthellae [1, 3, 4], or by increasing the zooxanthellae density in the coral endoderm to enhance absorption of light [4]. On the other hand, if the PAR is in excess which may cause photoinhibition of zooxanthellae, the coral host plays significant role in responding to reduce its effects [5].

Artificial reefs have been suggested as one of the possible ways to rehabilitate marine habitats damaged by human impacts [6]. The Marine Park jetty at Pulau Tioman can also be considered an artificial reef because substantial coral growth has been observed on the jetty pillars since its construction in 1997. Interestingly, corals of diverse species and sizes were found growing on different orientated pillars. The coral growth could be attributed to the jetty pillaring design whereby pillars only receive sunlight at certain angles of their orientation, and the pillar may also be partially shaded by the jetty's platform further obstructing light that fall on it. The available light that reaches on the pillars is further complicated by the sun's movement throughout the day. The changing light mosaics on the pillars as created by the sun movement, jetty platform shading and the pillar orientation itself, presumably affect the coral growing on it, hence providing an interesting research enquiry. Therefore, the objective of the present study was to investigate whether the orientation of jetty pillars affected the corals growing on them in relation to light quality. As proxies to coral growth potential, zooxanthellae density and chlorophyll content in the coral were measured. Two species of scleractinian coral were studied, *Acropora selago* (branching coral growth form) and *Cyphastrea japonica* (encrusting growth form) because they were the only two species from each growth form that were present on every pillar orientation studied.

METHODS

Study Site

The Marine Park Centre jetty (2°51'01.80" N, 104°09'42.82" E) at Pulau Tioman provided the site for the present study which was carried out from 2nd to 5th February 2008, during the north-east monsoon. During the study, there was a massive ongoing beach nourishing activity on the beach front of the Marine Park Centre (MPC). The MPC jetty also serves as the main entry point to Kampung Tekek for passenger ferries during the monsoon season from November to March. Therefore, human activities were assumed to have increased at the jetty for the last 3 months prior to the study.

Determination of Pillar Orientation

The orientation of the pillars were determined using a compass while SCUBA diving. Only the Pillars 1, 2 and 3 were studied (Figure 1) because Pillars 0 were more exposed to sunlight as compared to the other pillars which had smaller sunlit area. The outer surfaces of the pillars facing northwest at a bearing of 330° were referred to as 'Orientation 1' (OR1) whereas 'Orientation 2' (OR2) refers to the surface of the opposite pillars facing southeast at a bearing of 150°. 'Orientation 3' (OR3) refers to the inner surface of the OR1 pillars facing southeast.

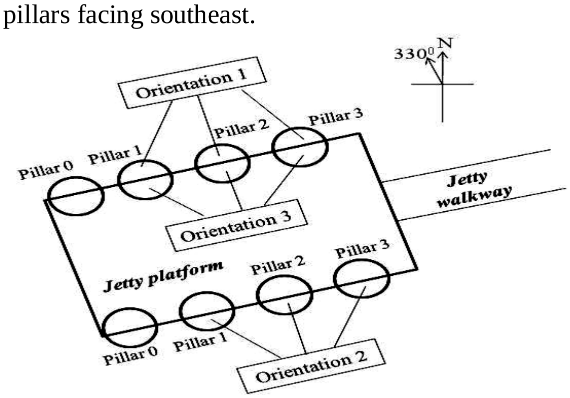

Figure 1. Schematic diagram showing the position of all three orientations, Orientation 1 (OR1), Orientation 2 (OR2) and Orientation 3 (OR3) and their bearings. Pillars 0 were more exposed to sunlight and not comparable as replicates.

Determination of Photosynthetically Active Radiation (PAR) Levels

The determination of Photosynthetic Active Radiation (PAR) levels in this study was done by installing three Odyssey® Data Recorder PAR light loggers at the study sites. Light loggers were installed by SCUBA diving before the start of every study and retrieved after the termination of each study. The first study was carried out to compare the PAR level among orientations and this was done by installing the light loggers on each orientation, all at the same depth of 3m with measurements taken at every 30 min-intervals from 1230 hours to 1830 hours. The second study was carried out to compare the PAR level between jetty and natural reef. This study was done by installing one logger at the natural reef at Kampung Air Batang, whereas one logger each was installed at OR1 and OR2 at 3m depth with measurements taken every 30-min intervals from 0900 hours to 1200 hours.

Coral Cover

The coral cover on each jetty pillar was studied using a modified combination of the Linear Point Intercept Method [7] and the Underwater Video Transect Method [8] to suit the vertical structure and cylindrical shape of the pillars. Three polypropylene ropes with coloured markings at every 10 cm, serving as transects, were suspended from the top of the pillar at a distance of 20 cm apart from each other (Figure 2). Video recordings of these vertical transects (T1, T2 and T3) was taken perpendicularly at a constant speed from surface to 6 m depth using a Canon® A360 camera. Similar video recordings were repeated for all pillars of the 3 orientations. The percent coral cover was estimated from the percentage of the number of markings occupied by corals to the total number of markings on the transect line [9].

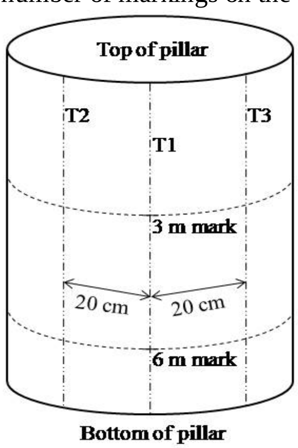

Figure 2. Schematic diagram showing the positions of the transect lines (T1, T2 and T3) and the distances of 20cm between each transect line.

Coral Sampling

Three samples each of *Acropora selago* and *Cyphastrea japonica* were collected from different colonies growing on the pillars at the OR1 and OR2 making a total of 12 samples collected. There were no scleractinian corals found on the pillars at OR3. Samples of approximately 1 cm-length A. *selago* and 1cm-width *C. japonica* were collected using a hammer and chisel. The collected samples were kept in a refrigerator at 4ºC before being analyzed in the laboratory.

Coral Surface Area

Surface area of the coral sample was determined using the aluminium foil wrapping method [11]. The method requires the predetermination of a standard or linear equation (y=mx+c) by regression of the measured surface area (y) of several pieces of aluminium foil on their corresponding weights (x). Surface area for the living layer of each coral sample was then determined by cutting and placing aluminium foil over the entire coral skeleton surface before moulding the foil to fit all depressions and projections. V-shaped notches were cut when necessary to ensure good fit and care was taken to avoid overlaps of aluminium foil and uncovered spaces. Excess of aluminium foil were cut off. The aluminium foil was then removed from the coral sample and weighed. Its surface area was then determined from its weight based on the predetermined standard equation.

Zooxanthellae Isolation

Coral tissues were removed from the skeleton by using Waterpik® water jet with artificial seawater of 35 ‰ [10]. The coral tissues in artificial seawater were blended to disintegrate the zooxanthellae until a homogenous mixture was obtained. The volume of this homogenous mixture was then measured in a measuring cylinder before the mixture was subject to chlorophyll and zooxanthellae analyses.

Zooxanthellae Density

The homogenate from the zooxanthellae isolation method was pipetted into a 1.5 ml microcentrifuge eppendorf tube and a few drops of 10% formalin were then added. The content in the eppendorf tube was then evenly mixed by a vortex mixer. A drop of homogenate was then pipetted onto a Spencer® Bright-Line Improved Neubauer haemocytometer with 0.1 mm^2 x 0.1 mm depth grid, before the zooxanthellae were counted under a compound microscope at 100x magnification.

Eight replicates counts were made to for each sample. Only the healthy, non-degenerated zooxanthellae were counted because the degenerated ones would have lost their chlorophyll pigments [12] and would affect the determination of chlorophyll content in the zooxanthellae. Zooxanthellae density was determined by dividing the number of zooxanthellae with the coral surface area.

Chlorophyll Extraction

The homogenate from the zooxanthellae isolation method was pipetted into three 1.5 ml microcentrifuge eppendorf tubes. The volume of the microcentrifuge eppendorf tubes was measured. The three samples (replicates) were centrifuged at 8500 rpm for 20 minutes at 10ºC. The supernatant was removed and then replaced with acetone before evenly mixed with a vortex mixer. The tubes were then kept in the dark at 4ºC for at least 24 hours to extract the chlorophyll pigments. After 24 hours, the tubes were centrifuged again to separate the extracted pigments from the zooxanthellae. The concentration of extracted chlorophyll pigments was determined by using a spectrophotometer. The light bands used were 630nm, 663nm and 750nm [13]. The chlorophyll *a* and c_2 were determined based on the following equations [13]:-

$$\text{Chlorophyll } a\ (Ca,) = 11.43\ (E_{663} - E_{750}) - 0.64\ (E_{630} - E_{750})$$

$$\text{Chlorophyll } c_2\ (Cc_2) = 27.09\ (E_{630} - E_{750}) - 3.63\ (E_{663} - E_{750})$$

Where C*a*, Cc_2 = concentration of chlorophyll in 1µg/ml using 1cm light path quartz cuvette. Thus, the chlorophyll content per unit surface area of coral or per zooxanthella cell was determined as follows:

$$\text{Chlorophyll content } (\mu g/cm^2) = \frac{\text{C } (\mu g/ml) \times \text{Volume of acetone (ml)}}{\text{Coral surface area } (cm^2)}$$

$$\text{Chlorophyll content per zooxanthellae } (\mu g/cell) = \frac{\text{Chlorophyll content } (\mu g/cm^2)}{\text{Zooxanthellae density } (cells/cm^2)}$$

Statistical Analysis

Data on chlorophyll content per zooxanthella and percentage coral cover were respectively logarithmically and arcsine transformed to approximate normality and homogeneity of variance [14], before they were subject to t-test and analysis of variance. PAR data were directly analysed after statistical analysis indicated that they were normally distributed with equal variance.

RESULTS

Photosynthetically Active Radiation (PAR)

The mean PAR level received at OR1 surface of the jetty pillar was 2636 ± 912 µmol m^2/s as compared to OR2 with a mean level of 1666 ± 386 µmol m^2/s, while the lowest was 74 ± 21 µmol m^2/s at OR3 (Figure 3). The ANOVA showed that the PAR levels among the 3 orientations were highly significant different ($p<0.01$). The PAR level at the natural reef was much higher with mean of 2672 ± 1008 µmol m^2/s as compared to the jetty with mean of 772 ± 304 µmol m^2/s (t-test, $p<0.01$) (Figure 4).

Coral Cover on Pillars

The total percent coral cover at OR1 was 25.0%, higher than the percent coral cover of 23.9% at OR2. There were no corals present at OR3. However, the t-test analysis showed that the coral cover between OR1 and OR2 was not significantly different ($p=0.45$).

Zooxanthellae Density

The zooxanthellae density of *Acropora selago* at OR1 (2.30×10^6 cells/cm^2) was slightly higher than at OR2 (1.90×10^6 cells/cm^2) but the difference between the two orientations was not significant (Table 1). On the other hand, the mean zooxanthellae density of *Cyphastrea japonica* at OR1 was significantly higher than at OR2 ($p<0.05$).

Chlorophyll content per zooxanthellae

The mean chlorophyll *a* content per zooxanthella cell of *Acropora selago* at OR1 (2.97×10^{-8} µg/cell) and OR2 (3.20×10^{-8} µg/cell) showed no significant difference. Similarly, the mean chlorophyll c_2 content per zooxanthella cell at OR1 (7.80×10^{-8} µg/cell) was not significantly higher than at OR2 (6.73×10^{-8} ± 0.46 SD µg/cell).

Chlorophyll *a* and chlorophyll c_2 content in zooxanthellae cells of *Cyphastrea japonica* were also not significantly different between orientations (Table 2).

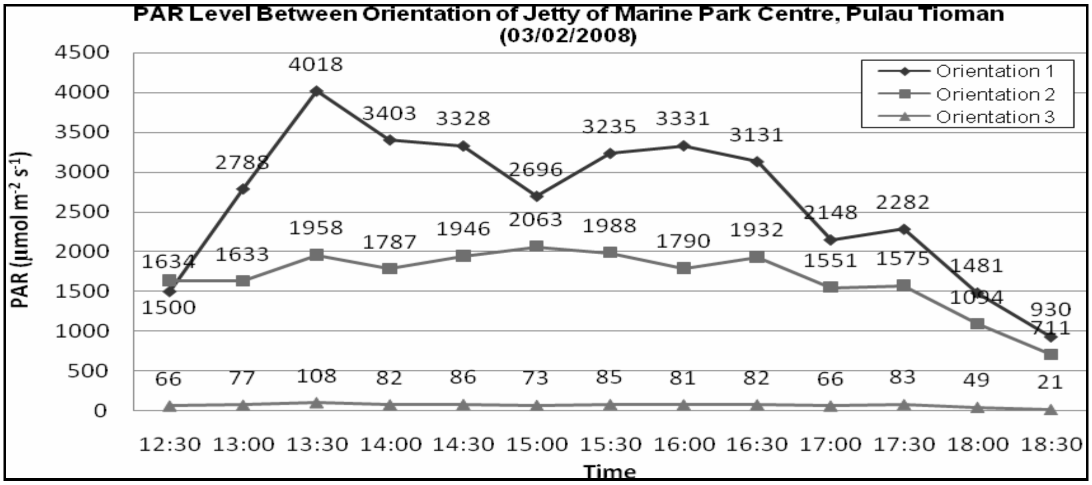

Figure 3. Comparison of PAR level between orientations of Marine Park jetty. PAR level measurements were taken every 30 minutes for 6 hours. The ANOVA showed that the difference among the PAR levels at the 3 orientations was very significant ($p<0.01$).

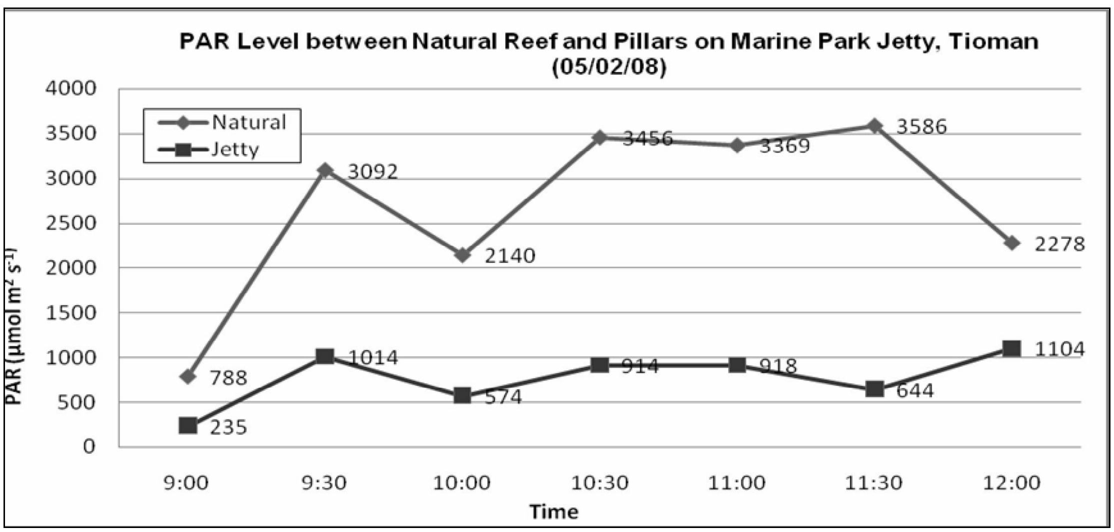

Figure 4. Comparison of PAR level between natural reef in Kampung Air Batang and Marine Park jetty. PAR measurements recorded every 30 minutes for 3 hours. This difference is shown to be significant (t-test, $p<0.01$).

Table 1: Comparison of zooxanthellae density of *Acropora selago* and *Cyphastrea japonica* between OR1 and OR2 with t-test .

	Zooxanthellae density (x10^6 cells cm^{-2})		*p*-Value
	OR1	**OR2**	
Acropora selago	2.3 ± 0.98	1.9 ± 0.93	0.1036
Cyphastrea japonica	5.2 ± 1.3	3.0 ± 0.67	0.00366**

**Significant difference at $p<0.01$

Table 2: Comparison of chlorophyll content per zooxanthellae of *Acropora selago* and *Cyphastrea japonica* between OR1 and OR2 with t-test analysis.

		Chlorophyll content per zooxanthellae (µg cell^{-1})		*p*-Value*
		OR1	**OR2**	
Acropora selago	Chlorophyll *a*	$3.0x10^{-8} \pm 0.80$	$3.2x10^{-8} \pm 0.48$	0.8162
	Chlorophyll c_2	$7.8x10^{-8} \pm 0.80$	$6.7x10^{-8} \pm 0.46$	0.6681
Cyphastrea japonica	Chlorophyll *a*	$2.7x10^{-8} \pm 0.56$	$3.1x10^{-8} \pm 0.63$	0.7093
	Chlorophyll c_2	$3.7x10^{-8} \pm 0.45$	$3.1x10^{-8} \pm 0.46$	0.7039

Comparison of *Acropora selago* from natural reef and jetty

There was only one small colony of *Acropora selago* found in the natural reef and *Cyphastrea japonica* was absent. Therefore, only one sample of *Acropora selago* from the natural reef was taken for trend comparison with the *Acropora selago* from the jetty.

The zooxanthellae density of *A. selago* from the natural reef ($1.043x10^6$ cells/cm^2) was lower than from the jetty ($1.952x10^6$ cells/cm^2) (Table 3). However, the chlorophyll *a* content per zooxanthella cell was higher from the natural reef sample ($6.270x10^{-8}$ µg /cell) than from the over (4.092x10 µg /cell). On the other hand, the opposite was observed for chlorophyll c_2 content with lower concentration at the natural reef ($9.361x10^{-8}$ µg /cell) as compared to the jetty (9.580x10 µg /cell).

DISCUSSION

Photosynthetically Active Radiation (PAR)

The Pulau Tioman Marine Park jetty was built facing the direction 60° from due north. This makes the PAR level theoretically different at OR1 and OR2; results of this study have shown that the different orientations of the jetty pillars receive different PAR levels. The sun's movement also causes the light level to vary at the different pillar orientations. The PAR level at OR1 was higher than at OR2 even though both measurements were taken at the same time in the afternoon. The position of the sun at this time was slightly to the west which gave a higher intensity at OR1. In addition, constant berthing of boats and vessels ferrying tourists and local people at the jetty contributed to the lower PAR measured at OR2. As this study was done during the monsoon period when the Marine Park jetty served as the main entry for all ferries heading towards Kampung Tekek, the amount of activities at OR2 was very high then compared to the non-monsoon season. The PAR levels also varied with cloud cover [15] and this contributed to the variability in PAR readings especially at OR1 throughout the study period (Figure 3). The PAR level at OR3 was consistently lowest due to permanent shading by the jetty platform.

The PAR level at the jetty was found to be lower than the PAR level at the natural reef due to permanent shading by the platform and anthropogenic activities that further reduced the penetration of incident light. The PAR difference between sites resembles the situation in Wistari Reef, Australia where unshaded reefs were exposed to higher PAR levels than the shaded ones [16].

Coral Cover on Pillars

There were no corals found at OR3 due to permanent shading by the jetty platform. However, a study in Au'au Channel, Hawaii, shows that scleractinian corals can grow even at 6% of the PAR level received at the water surface [17]. The PAR level at OR3 however was found to be approximately 3% of the average PAR received at water surface. This suggests that the minimum PAR level for coral growth could be between 3% and 6% of the average PAR level received at water surface. Although the PAR level was significantly different between OR1 and OR2, coral covers at both sites were not significantly different which suggests that corals are able to grow as long as there is minimum PAR. Hence, we suggest that when a jetty is constructed, its pillars should be orientated to receive maximum sunlight or at least the minimum PAR level for corals to rehabilitate. The present study also showed that almost 25% coral cover was obtained on the jetty pillars since the jetty was built in 1997, suggesting that coral rehabilitation is viable on such artificial structures.

Zooxanthellae Density

The present study showed that the zooxanthellae density of *Acropora selago* and *Cyphastrea japonica* is in the normal range of $1x10^6$ to $5x10^6$ cells per cm^2 surface for corals in general [1]. The results also correspond to that obtained for *Porites rus* in Pulau Tioman [18]. The present study has shown that photoadaptation in *Acropora selago* does not seem to involve a change in zooxanthella density because zooxanthella density remained quite similar despite the significantly different PAR levels between orientations. Although coral adaptation to different light intensities does involve change in zooxanthellae density, in many cases, photoadaptation involves change in average pigment content within cell rather than zooxanthellae density [19].

The mean zooxanthellae density of *Cyphastrea japonica* at OR1 was however significantly higher compared to that at OR2 which was consistent with the amount of PAR recorded. The pattern indicates a higher density of zooxanthellae at a higher level of PAR. This is however contradictory to the reported inverse relationship between algal density and irradiance [20, 21, 22] which suggests that *Cyphastrea japonica* responds differently to PAR levels. Different coral species exhibit different responses to PAR and ultraviolet (UV) irradiance [23] because corals photoadapt as a whole organism which includes adaptations that involves zooxanthellae, coral morphology and coelenterate tissue [24]. The different response of *Cyphastrea japonica* could be due to its growth form that never produce extensive branching corolla but rather a flat, laminar and encrusting form. The widely spaced corallites arrangement of this species is also a response to low PAR level [25]. These morphological and structural adaptations of *Cyphastrea japonica* increase its light absorption ability under shaded condition which compensates for the reduced zooxanthellae density.

Battey & Porter [23] however found that there was no consistent pattern of a relationship between zooxanthella density and changes in irradiation. The present study supports their conclusion. Thus, there is still no clear cut pattern of how zooxanthellae density changes with irradiance.

Chlorophyll concentration per zooxanthella cell

Both chlorophyll *a* and c_2 concentration of zooxanthellae in *Acropora selago* showed no significant difference between the OR1 and OR2 orientations. Nevertheless, the chlorophyll concentration range of $9x10^{-8}$ to $2x10^{-7}$ μg/cell is very much lower than the estimated range of $5x10^{-6}$ to $12x10^{-6}$ μg/ cell for corals in general [1]. Dustan [26] however reported a chlorophyll concentration in *Montastrea annularis* of between $1x10^{-6}$ to $3x10^{-6}$ μg/cell which is also lower than the estimated range of Sorokin [1], but still higher than in the present study. However, the chlorophyll content as determined from the present study is comparable to that reported for *Goniastrea pectinata* and *Goniastrea retiformis* which ranged from $1x10^{-7}$ to $3x10^{-7}$ μg/cell [26] and for *Porites rus* at $3x10^{-7}$ μg/cell [18]. The concentration of chlorophyll in *Cyphastrea japonica* ranged from $4x10^{-8}$ to $9x10^{-8}$ μg/cell which was even lower than in *Acropora selago.* Chlorophyll *a* and c_2 content of *Cyphastrea japonica* were also not significantly different between the two pillar orientations. Only at OR3 were there no corals due to permanent shading by the jetty platform. The results suggest that varying the photopigment concentration is a limited capability and not the main photoadaptive response of both coral species.

Previous works [28, 29] have shown that when the light intensity changes, zooxanthellae will respond by first changing their chlorophyll content. If this change in chlorophyll content fails to adapt to the light change, the zooxanthellae will then change their density [28, 29]. In the present study, we found a similar situation. The chlorophyll content was lower than the estimated value but the zooxanthellae density was within the estimated mean value. This showed that the zooxanthellae had changed their chlorophyll concentration albeit a limited one.

Comparison of *Acropora selago* from natural reef and jetty

The zooxanthellae density of *Acropora selago* reported in the present study falls within the range of $1x10^6$ to $2x10^6$cells/cm^2 for coral reefs in open area [16]. The findings in this study support the contention that zooxanthellae density of corals in open area is lower than corals living in low light condition [16]. The difference in zooxanthellae density is related to the light intensity received at both sites. Corals under low light condition adapt by increasing the density of zooxanthellae in them as well as their content of photosynthetic pigments [4]. However, samples collected from the jetty showed a different trend as the content of chlorophyll *a* was found to be lower whereas chlorophyll c_2 was higher than samples from the natural reef. The higher content of chlorophyll c_2 allows higher effiency in utilization of light because chlorophyll c_2 has the ability to absorb more of the blue portion of PAR than chlorophyll *a*. The blue portion of PAR is utilized to compensate for low light condition [24]. Hence, this mechanism is one of the corals' adaptations to low light condition.

There were few differences in terms of zooxanthellae and pigment characteristics between the corals found at the jetty and the natural reef nearby. The comparison of *Acropora selago* at the jetty and in natural reef was made in terms of general trend of coral growth because only one small colony of the same species could be found from the natural reef. However, it is obvious that the corals found under the jetty are able to adapt to different light conditions. Orientation of the jetty affects the quantity and quality of light, which in turn affect coral growth.

Jetties as artificial reefs

The present study indicates that jetty orientation should be an important consideration in the design of any jetty in reef waters so as to encourage the rehabilitation of corals after a jetty is built. Vertical structures of a jetty can provide a novel hard substrate for coral growth with the possibility of recruiting rare corals that are not found in a natural reef [30]. The concrete structures of jetties have been found to more suitable than natural fine sand substrate for coral recruitnent, and have been demonstrated to be highly compatible to the marine environment with high success rate as an artificial reef [31, 32].

Based on the results of the present study, it is recommended that the jetty be aligned at an angle of 45° or 315° due north so as to maximise the pillar area that is exposed to sunlight. Reclining pillars may be more suitable and provide more surface area for coral attachment. However, more studies are needed to determine the suitability of jetties as artificial reefs because other factors such as erosion, sedimentation, hydrodynamics, water quality, larval availability and life history traits of the recruited corals are also considered as important factors [30].

CONCLUSION

At Pulau Tioman Jetty, the pillar orientation affects the amount of PAR received which in turn elicits adaptive morphological and physiological changes in the corals allowing them to grow on the jetty pillars. Both *Acropora selago* and *Cyphastrea japonica*, exhibit neither an increase in their photopigment concentration nor zooxanthellae density in response to subdued light condition under the jetty. *A. selago*, a branching coral species, appears to photoadapt by mainly increasing its chlorophyll c_2 content, while the encrusting and laminar growth forms of C. *japonica* is itself a morphological adaption to increase capture of light energy. Coral reefs could be rehabilitated considerably after damage by the construction of a jetty, if the design of the jetty takes into consideration the pillar orientation.

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