Using relative return-on-effort (RRE) scoring to evaluate a novel coral nursery in Malaysia

Running Head: RRE scoring a novel coral nursery

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ABSTRACT

Coral reefs in Malaysia have been degraded by environmental and anthropogenic stressors, and enthusiasm for coral propagation aimed at site restoration is rapidly growing as a local management tool. However, coral propagation activities in the region are in their infancy and little data currently exists to guide and inform effective practices. We therefore established the first multi-taxa coral tree nursery (6 species, 300 fragments) in Malaysia and tracked survival and growth to determine the relative return-on-effort (RRE) over a ~14 month monitoring period. We observed differences in growth and survival among six coral species and were successful at benchmarking results against coral restoration operations globally and in the East Asian Seas region. Major findings include 1) overall ranges in species level survivorship of 34-94% and specific growth rate of 0.14-0.29 % day^{-1}, leading to variable RRE scores among species, 2) variable growth rates among coral species based on seasonal changes in environmental conditions, 3) similar RRE scores to other nursery locations worldwide, which suggests effective practice and 4) calculation of RRE scores for species not previously reported in nursery culture (*Acropora florida, A. hoeksemai,* and *Echinopora horrida)*. Ultimately, our study supports previous findings that RRE is an effective technique for comparing coral nursery performance and offers valuable insight to guide future restoration activities in Malaysia.

IMPLICATIONS FOR PRACTICE

1. Few studies have examined the potential for coral propagation as a restoration-based management aid in Malaysia despite accelerating reef degradation.
2. Although novel to the region, coral tree nurseries may have a useful role to play in propagating corals for reef restoration in SE Asia, but immediate efforts should focus on detachment as a main source of lower survivorship (and return-on-effort) for some species.
3. Relative return-on-effort (RRE) scoring can be used to benchmark novel nursery and outplanting activities in SE Asia with those elsewhere, allowing comparisons of interventions and dissemination of best practice.

INTRODUCTION

Malaysia is estimated to contain approximately 4,000 km^2 of coral reef (Convention for Biological Diversity 2019), providing multiple environmental and economic benefits to the country (Mcleod et al. 2010; Sakarno et al. 2015). Unfortunately, many Malaysian reefs have been negatively impacted by sedimentation, overfishing, predation, climate change, and physical damage caused by boats, divers, and snorkelers (McLeod et al. 2010; Praveena 2012). Furthermore, the Global Coral Reef Monitoring Network's most recent report for Malaysia (identified in the East Asian Seas Region) reported high variance in coral cover indicative of exposure to disturbance (GCRMN, 2021).

Given the degraded state of many reef sites along the eastern coast of Peninsular Malaysia (Safuan et al. 2021), local communities are highly motivated to proactively rehabilitate coral reefs, but this requires developing informed approaches that maximize local effectiveness.

Reducing the negative impacts of coastal construction, unsustainable tourism, and other detrimental activities in these regions is essential to limit further declines in coral reef health. In addition, the eastern coast of Peninsular Malaysia will benefit from direct action to increase coral cover and habitat complexity where natural recovery processes alone are no longer capable of rehabilitating the ecological functioning of reefs (e.g., Hein et al. 2021). The use of low-cost coral propagation and planting approaches have increased in popularity in the last decade (Bostrom-Einarsson et al. 2020), particularly those reliant on asexual propagation techniques in which wild colonies are fragmented and grown within *in situ* nurseries prior to outplanting (Young et al. 2012; Lirman & Schopmeyer 2016).

In Malaysia, coral propagation has primarily focused on using benthic-attachment methods (e.g., PVC frames) to grow *Acropora* spp. (Chan & Sukarno 2016; Xin et al. 2016). However, to our knowledge, there have not been any studies to compare the performance of multiple coral species in order to improve the productivity of coral nurseries. In addition, the coral tree nursery design (Nedimyer et al. 2011) widely used in the Caribbean (Lohr and Patterson 2017; VanWynen et al. 2021) has not previously been reported in Malaysia. The coral tree design, which suspends corals from the nursery structure, may have several benefits compared to the benthic attachment methods traditionally used in the region. First, suspended nurseries are suggested to improve growth in corals because the structure allows for better use of 3-dimensional space (Nedimyer et al. 2011). Furthermore, tree nursery may prove beneficial compared to a benthic nursery given Malaysia's northeast monsoon season, known to bring heavy rain and winds to the region (Suhaila et al. 2010), as the corals are able to move in response to flow (O'Donnell et al. 2017). Lastly, it is possible that corals growing on tree nurseries, attached by a single monofilament line, are less exposed to benthic corallivores

(Rotjan et al. 2008) and competition with algae (Henry et al. 2021); a common stressor for corals on the reef (Lirman 2001; McCook et al. 2001).

Studies designed to maximize the efficiency of local coral propagation will be critical to help reduce cost and potentially improve future restoration outcomes (Hein et al. 2020; Shaver et al. 2020). Understanding inherent variation amongst coral species (e.g., growth performance and survival rates), or populations within species (e.g., Baums et al. 2019; Cunning et al. 2021), could improve nursery outcomes and later restoration efforts. Furthermore, a better understanding of how certain species perform amidst the fluctuating conditions (i.e., water flow, sedimentation, and temperature) of the northeast monsoon season may identify seasonal variation in coral growth and help guide future nursery management in Malaysia. Ultimately, our study seeks to inform future management and fill knowledge gaps of relative coral species performance in Malaysian nurseries.

An approach to standardize relative return-on-effort (RRE) was recently developed (Suggett et al. 2019) and applied to benchmark performance of Great Barrier Reef coral nurseries (Howlett et al. 2021). RRE in essence “scores” coral nursery (or outplanting efficiency) via commonly measured metrics for survivorship and growth. This system identifies potential yield, based on trade-offs in growth and survivorship, for any propagation or restoration action. In doing so, the RRE method establishes a baseline for improvement of coral stock selection and culture environments. Furthermore, expanding a standardized scoring system for cultured corals helps determine if certain species or growth forms are performing in relation to global averages (Suggett et al. 2019), which genera or species are the most efficient to propagate in a given nursery, and further identify if regional variation in performance differs by species or technique.

Ultimately, we seek to encourage a collective learning process that guides restoration practitioners to maximize efforts by region, species, and methodology.

To expand the RRE concept to Malaysia, we constructed five suspended coral tree nurseries (following Nedimyer et al. 2011) along the western leeward coast of Pulau Lang Tengah (Lang Tengah Island). In March 2020, these nurseries were stocked with six common hermatypic coral species from around the island. Coral growth and survival data were collected over a 414-day period (which included a full NE monsoon season) and utilized for the standardized RRE scoring system (Suggett et al. 2019; Howlett et al. 2021). We specifically sought to (1) determine the highest performing species that exhibit fast growth and high survival in a nursery setting, (2) compare and integrate RRE results from other locations (3) evaluate the impact of the northeast monsoon season on species growth and survival and (4) present data on the first multi-taxa coral nursery in Malaysia to establish and refine coral propagation techniques for wider application in the region.

MATERIALS AND METHODS

Study location

Pulau Lang Tengah is within the Perhentian and Redang marine protected area of Terengganu state, on the east coast of Peninsular Malaysia (Figure 1A). This study location was selected due to the historic and current presence of coral reefs around the island (Aikanathan & Wong 1994; Harborne 2000), minimal coastal development, and motivation by the local community to implement active coral restoration.

Coral fragment collection

Six species targeted for study were, *Acropora florida, A. hoeksemai, A. muricata* (formerly *A. formosa*), *Hydnophora rigida, Porites cylindrica* and *Echinopora horrida* (Figure S1). These species were selected due to their varying morphologies, their important role in building reef structure, and previous surveys identifying these species as among the dominant taxa in the area (see Harborne et al. 2000 and Safuan et al. 2021 for information on natural abundance and distribution of these species). Source corals selected were visually healthy (e.g. no signs of disease or tissue loss), and collected from Pasir Besar Reef (5.795475°, 102.89185°) and Batu Kuching Reef (5.790243°, 102.903366°) (Figure 1). With the exception of *A. muricata*, all material was already naturally detached from the substrate (fragments of opportunity) and collected between 8.2 and 12.2 m depth. Fragments of *A. muricata* were removed via bone cutters from larger colonies attached to an existing coral nursery at a depth of 5.5 m. At each survey, three measurements were taken of each fragment: maximum length (L), width (W) perpendicular to maximum length, and vertical height (H) while suspended from the nursery (Fig. S1C & S1F). All three measurements were taken in cm using calipers, or tape measure when dimensions exceeded 15 cm, and used to calculate geometric mean radius (GMR; cm) for all fragments based on Loya (1976). Geometric mean radius was used to linearize colony measurements, which decreases the influence of initial size on growth rate. Initial GMR (Mean ± SEM) for each species was: *A. muricata* (1.72 ± 0.1), *A. hoeksemai* (1.56 ± 0.1), *A. florida* (2.16 ± 0.1), *P. cylindrica* (2.28 ± 0.1), *E. horrida* (2.81 ± 0.1), *H. rigida* (3.3 ± 0.1) (Figure 2B). All fragments remained underwater and were transported directly to the nursery after collection.

Nursery Construction

RRE scoring was conceived to be applied in practical settings, so corals were distributed within the nursery following standard culture methodologies rather than as an experimental design to evaluate interspecific variability. In March 2020, five coral tree nurseries were built at Pasir Besar Reef (5.794699°, 102.892106°) based on designs described by Nedimyer et al. (2011). All five tree nurseries were installed at a depth of 12.5m, 5m apart in a straight line, and anchored in sand substrate using two Duckbill Earth Anchors® and one 15 kg concrete block for each nursery. Corals were suspended using monofilament line and aluminum crimps (Figure 1B). Each tree nursery was stocked with 50 coral fragments of a single species plus 10 fragments of *A. muricata* (total n = 300 fragments). Fragments were hung in a staggered fashion to minimize damage or fusion caused by contact with other fragments.

Monitoring

Two HOBO Pendant® data loggers (Onset Computer Corporation, USA) were fixed on two of the tree nurseries to record temperature every 90 minutes *in situ* (Figure 2A). Monitoring was conducted on days 0, 30, 60, 90, 215, and 414 for growth and survivorship. To capture possible seasonal variations in growth and survival, monitoring dates include the end of the warm season (day 215), and after the annual northeast monsoon season (day 414). Individual fragments were identified by their fixed position on the tree and repetitively measured. Colony dimensions were used to calculate GMR (cm) and specific growth rate (SGR, % day^{-1}). Specific growth rate is calculated as,

$$SGR = ([\ln(G_1)-\ln(G_2)] \times 100) / t$$

where t is total time of growth (days) and G_1 and G_2 are final and initial size (cm), respectively. Colonies found to be broken to the extent that they were smaller than their initial size at any monitoring interval were excluded from growth calculations. When a coral was found to have partial tissue loss, the entire skeletal extent of the colony was still recorded. Colonies found to have no living tissue or lost were considered “dead” for the purpose of calculating survivorship. Trees were cleaned of algae and other fouling organisms at each monitoring event.

RRE Calculation

RRE scores for each coral species were calculated using relative growth and survivorship. Relative growth was calculated for each individual colony using methods described in Suggett et al. (2019) as,

$$\%\text{Growth} = \left(\left[\Delta G_{(t2-t1)} / (t_2 - t_1)\right] / G_{t1}\right) \text{ x } 100$$

where G is size (cm) and t_1 and t_2 are the study start and end months, respectively. Mean relative growth was calculated for each species and (ln) transformed, resulting in a number between -2 and +8. Survival data were arcsine (%survivorship/100) transformed to produce a value between 0 and 1.571 (i.e. 0% and 100% survivorship) for each species. To generate an RRE score, potential value ranges for survival (0 to 1.571) and growth (-2 to +8) were used as minimum and maximum values on the x and y axes of a coordinate grid. RRE values range from 0 to 20 and are assigned at regular intervals on the x-y plane with values increasing proportional to distance from the origin. For details on how to calculate RRE using a coordinate grid, refer to Suggett et al. (2019) electronic supplementary material Figure S1.

Statistics

All statistical tests were performed using R software (v.1.1.456 RStudio, Inc.) and conducted at a significance level of $\alpha = 0.05$. Means are presented as mean ± standard error (SE). Data were assessed for normality using visual assessments of residual plots along with the Shapiro-Wilk test and for homogeneity of variance using Levene's test. Data were log transformed and reassessed when ANOVA assumptions were not met. Overall survival was determined at the level of individual fragments and compared among species using Chi-Square contingency analysis. Further, to evaluate survival throughout the 414-day monitoring period, Kaplan-Meier analysis was completed using the R package 'survival' (Therneau 2015). For the Kaplan-Meier, a pairwise comparison using a Log-Rank test was employed to examine pairwise differences. A Kruskal-Wallis rank sum test with Holm correction method was used to compare SGR among species in the nursery, with each colony considered as a replicate. For this comparison, SGR was used in preference to relative growth because it modulates initial fragment size variation. For the Kruskal-Wallis rank sum test, a Dunn test was used to compare pairwise differences using the 'FSA' library in the R package 'CRAN'. A paired t-Test was used to compare SGR before and during the northeast monsoon season for each species (i.e. day 0-215 and day 215-414, respectively). Non-normally distributed data were analyzed with a Kruskal-Wallis rank sum test.

RESULTS

Coral growth and survival

Specific growth rate among coral species differed at the conclusion of the study (Table 1; $H^2 = 29.63$, $p < 0.01$; Figure S2). *Acropora muricata* and *A. hoeksemai* exhibited the fastest (0.29 ± 0.03 % day^{-1}) and slowest (0.14 ± 0.12 % day^{-1}) growth rates, respectively. Coral survivorship also differed among species (Kaplan-Meier $X^2 = 78.4$ df = 5, $p < 0.01$). Kaplan-Meier survival and *post hoc* analysis based on species is presented in Figure S3. Greatest survivorship was observed for *E. horrida* (94%) and least for *A. muricata* (34%; Table 1). Detachment from the nursery was responsible for mortality in all species. *Acropora hoeksemai* and *A. muricata* exhibited the highest detachment rates at 30% and 22%, respectively (see supplementary material Table S1). In addition, partial mortality was observed as a result of predation by *Tenellia* spp. (predominately on *P. cylindrica*), *Waminoa* spp. (predominately on *H. rigida)*, disease (only observed in 2.3% of fragments), and overgrowth by algae.

When comparing SGR before (day 0-215) and during (day 215-414) the northeast monsoon season, significant differences in growth rates were found in all species with the exception *of A. muricata* and *A. hoeksemai*. *Acropora florida* grew significantly faster during the monsoon season (0.19 ± 0.02 % day^{-1}) than compared to before the monsoon season (0.09 ± 0.01 % day^{-1}). In contrast, all non-acroporids grew significantly faster before (0.19 ± 0.01 to 0.24 ± 0.03 % day^{-1}) than during (0.08 ± 0.01 to 0.11 ± 0.02 % day^{-1}) the northeast monsoon season. Table S2 contains specific growth rates for all species during and outside the northeast monsoon season.

RRE

Based on growth and survivorship values from throughout the nursery propagation period, RRE scores across all species ranged from 11 to 15 (Table 1). *Acropora florida* and *E. horrida* had the highest RRE score of 15. Apart from *A. muricata*, all species in the present study generated RRE scores greater than the global average for all coral species identified by Suggett et al. (2019) (11.52 ± 0.19). RRE scores from Suggett et al. (2019) are presented as mean ± standard error (SE) and represent both nursery and restoration activities to date. Distribution of growth versus survival of all corals in the present study in relation to species analyzed in Suggett et al. (2019) is presented in Figure 3A and 3B.

DISCUSSION

Interest in active coral reef restoration in Malaysia is growing. Here we report for the first time, growth, and survival in coral tree nurseries over an extended period of natural seasonal variance that included a monsoon season. Importantly, this study demonstrates the feasibility of achieving high survival in a coral tree nursery despite exposure to the northeast monsoon season. We also report growth, survivorship, and RRE in Malaysia, which future nursery activities in the region can compare with. To our knowledge, previous nursery studies in Malaysia have all employed benthic attached methodologies and only *Acropora* spp. (Chan and Sukamo 2016; Xin et al. 2016), whereas our study is the first example of a suspended coral nursery with various branching taxa. We identified (1) variable RRE scores amongst six coral species propagated in a coral tree nursery, (2) Nursery performance and RRE scores exceeding or similar to those of Malaysian and global averages, (3) variable growth rates among coral species based on seasonal changes in environmental conditions, and (4) Calculation of RRE scores for previously unexamined species in global restoration activity (*A. florida*, *A. hoeksemai*, and *E. horrida*).

Although the majority of our RRE scores were higher than the global average for all coral species identified by Suggett et al. (2019), high variability was observed. *Acropora muricata* growth rates greatly exceeded those of the other five species and were generally similar to previous studies (e.g., of the genus *Acropora*) (Lirman et al. 2014; Suggett et al. 2019; Henry et al. 2021). However, low survival in *A. muricata* resulted in the lowest RRE score of 11 observed in the study. Howlett et al. (2021) studied six *Acropora* spp. on the Great Barrier Reef and found RRE scores ranging from 10.24 ± 0.21 to 16.00 ± 0.01. In comparison, we observed RRE scores ranging from 11 to 15 among three *Acropora* spp. Although *A. muricata and A. hoeksemai* generated the two lowest RRE scores, we are cautious to suggest that these species should be avoided as detachment was a large factor in mortality of these species. In addition, the greater depth change experienced by *A. muricata* (i.e., 5.5 m to ~9.75 m), in comparison to all other species (~10.2 m to ~9.75 m) could have resulted in mortality due to the inability to acclimate to the lower light environment. However, a study by Lohr et al. (2019) observed acclimation of *A. muricata* when taken from a high light environment to a low light environment within 21 days. High early survival (i.e., day 0-30) suggest that light acclimation was not likely a major driver of mortality in *A. muricata*. Of the *Acropora* spp. examined, *A. florida* scored among the highest. Lastly, because *A. muricata* was the only species dispersed across multiple trees, we are unable to preclude the impact this had on performance when compared to the other corals in the study.

While *Acropora* spp. have historically been the most popular for nursery propagation and restoration activities (Schopmeyer et al. 2017; Boström-Einarsson et al. 2020), our results suggest that *E. horrida*, *H. rigida* and *P. cylindrica* are also suitable candidate species for nursery propagation along the eastern coast of Peninsular Malaysia. Unfortunately, we have no data on how these species will perform once outplanted at our site and this is a recommended research area for future studies. Previous studies have shown nursery performance may not predict restoration outcomes once these corals are planted (O'Donnell et al. 2018). Although improving nursery performance is essential to the long-term success of restoration activities, high performing nursery corals will be of little value if they do not survive when returned to the reef. Thus, future work outplanting these same species is clearly needed to improve RRE estimates in terms of coral biomass successfully restored to the reef. Restoration literature suggests that growth and survival in a coral nursery are influenced by a multitude of factors including species (Suggett et al. 2019; Howlett et al. 2020), genotype within species (Lohr and Patterson 2017), initial colony size (Lirman et al. 2014; Henry et al. 2021), location, and environmental conditions (Schopmeyer et al. 2012; Lirman et al. 2014). For this reason, although we compare findings with past coral nursery studies, it is important to emphasize that our results are specific to the context of local environmental conditions, techniques, and species used, and thus warrant further investigation across diverse reef sites as propagation interest in the region continues to grow.

The present study found overall high nursery performance and RRE scores for most species. Our results support previous studies that found rapid growth rates when using floating tree methods to propagate corals (O'Donnell et al. 2018; Henry et al. 2021). Although floating tree nurseries can be advantageous in many ways, potential trade-offs exist. Kuffner et al. (2017) observed that the skeletal density of a Caribbean *Acropora* spp. was reduced when grown in a floating nursery compared to those placed in a block nursery, which could result in increased vulnerability to breakage. Skeletal density is not easily measured and thus not currently considered in RRE scoring unless breakage leads to mortality (and hence lower survivorship). While RRE rather than a direct comparison of growth rates among species was the primary focus of this study, differences in mean SGR among the six coral species were observed. Our study, among others (Suggett et al. 2019; Howlett et al 2021), observed highly variable relative growth rates for *Acropora* spp. when grown in nurseries, and hence that not all *Acropora* spp. exhibit high growth and survival. In areas where many *Acropora* spp. are present (e.g., the Indo-pacific), closer attention should be given before selecting a species subset as a primary candidate for restoration.

Survival was also variable among species in the present study. In comparison to the global analysis performed by Suggett et al. (2019), all species other than *A. muricata* and *A. hoeksemai* generated survival rates higher than the global average for all species; presumably reflecting local environmental conditions present at our nursery site. While it is important to note that Suggett et al. (2019) includes both nursery and outplanted corals in the global analyses, Xin et al. (2016) also report high mortality rates for *A. muricata* (>50%) in Malaysian nursery settings. In general, corals in nurseries survive at higher rates than those returned to the reef (Henry et al. 2021). For several of the species, detachment from the nursery resulted in lower survival. For example, for *A. hoeksemai,* detachment was observed as the cause of mortality in 15 of the 31 corals reported as dead. Although care was taken to properly secure all coral fragments to the nursery, nevertheless the northeast monsoon season appeared to cause detachment. Additional reasons for detachment include fish (e.g., pufferfish and triggerfish) feeding on the corals and the failure of the crimps that attached the fragment to the structure (S. Szereday personal observation). For these reasons, RRE can improve nursery management by identifying specific areas (e.g., detachment) that led to lower scores and are potentially correctable. Lastly, partial mortality was found in several fragments and is not a factor accounted for in RRE scoring. Thus, given the long-term objectives of a coral nursery (e.g., broodstock propagation, outplanting of whole colonies or fragments), future RRE scoring may need to account for fragment partial mortality.

In addition, our study specifically measured growth and survival of nursery corals across two distinctive seasons: the warm summer season (March to October), and the colder northeast monsoon season (November to February). In areas with this seasonal pattern heat stress induced coral bleaching typically occurs between April and September (Guest et al. 2012; Szereday & Amri 2021). During the first 215 days of our study (March to October), locally recorded sea surface temperatures were the second highest on average since 1985, resulting in moderate to widespread coral bleaching (Szereday and Amri 2021). Despite high temperatures and subsequent heat stress, the three non-acroporid species (*E. horrida*, *H. rigida* and *P. cylindrica)* grew significantly faster during the warmer season. In contrast, *A. florida* grew faster during the cooler monsoon season. Many factors beyond temperature impact seasonal growth rates. For example, seasonal growth patterns may be co-driven by the species-specific capacity to heal lesions and allocate resources towards growth after fragmentation (Denis et al. 2013). Secondly, higher growth rates of *A. florida* during the monsoon season may be explained by less heat stress and greater food availability. During the monsoon period, strong winds increase wave action and vertical mixing, leading to greater primary productivity (Ooi et al. 2013). Greater primary productivity and higher water movement may increase food availability and heterotrophic feeding, which benefits skeletal growth in scleractinian corals (Houlbrèque and Ferrier-Pagès 2009). These findings suggest that coral restoration programs should consider seasonality and align targets and goals accordingly, as coral nurseries and outplanting activities could be timed to maximize benefits arising from species-specific variations in seasonal growth patterns. Lastly, higher growth of coral species during warm seasons may be indicative of higher thermal performance (Maynard et al. 2008), and where corals that exhibit less seasonal growth may already be operating under thermal optima during cooler seasons (e.g., Howlett et al. 2021). Coral restoration programs should select coral species with greater thermal tolerance to ensure resilience against future climate change-driven mass bleaching events (Duarte et al. 2020; Caruso et al. 2021). Therefore, further research is warranted to examine heat stress tolerance of these species.

In summary, our study supports previous research suggesting that monitoring simple metrics in coral nurseries is beneficial for informing future propagation, in this case specifically in the Terengganu region. Further, employing the RRE methodology facilitates comparison with other coral propagation and restoration projects around the world. Although our findings and recommendations are primarily applicable to the Terengganu region, our results could help to guide nursery propagation techniques and species selection in other regions of Malaysia and the greater Indo-pacific. Ultimately, while our results provide evidence that coral nurseries are valuable tools for propagating corals for local restoration, it remains clear that mitigation of anthropogenic stressors is essential to the long-term recovery of corals reefs and will be required for restoration programs to produce the desired positive impacts.

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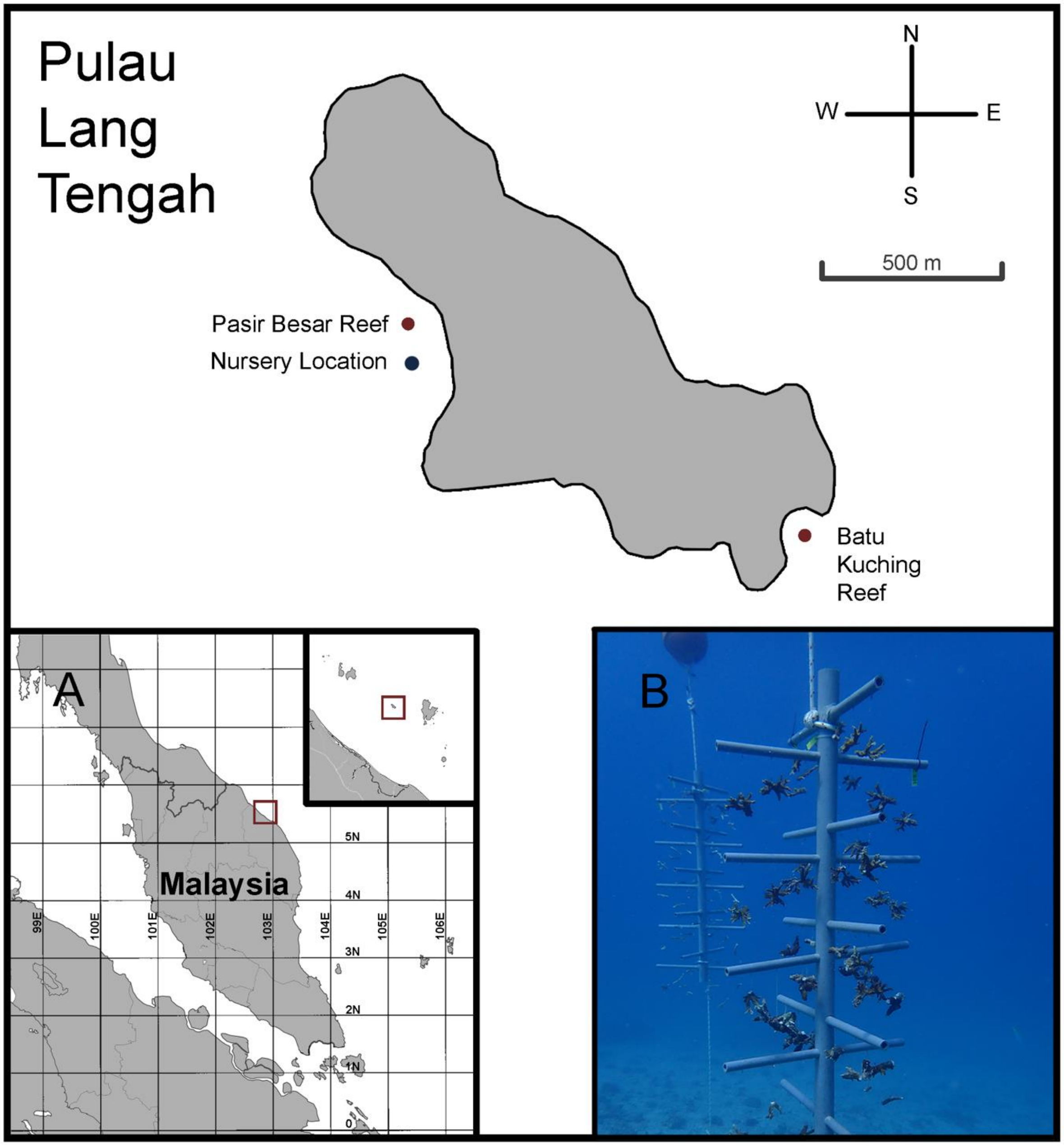

Figure 1 Location of Pasir Besar Reef (5.795475 °N, 102.89185 °E), Batu Kuching Reef (5.790243 °N, 102.903366 °E) and nursery site (5.794699 °N, 102.892106 °E) offshore of Pulau Lang Tengah (Lang Tengah Island). (A) Location of Pulau Lang Tengah, Terengganu, Malaysia and (B) Representative photo of two coral tree nurseries used in the study.

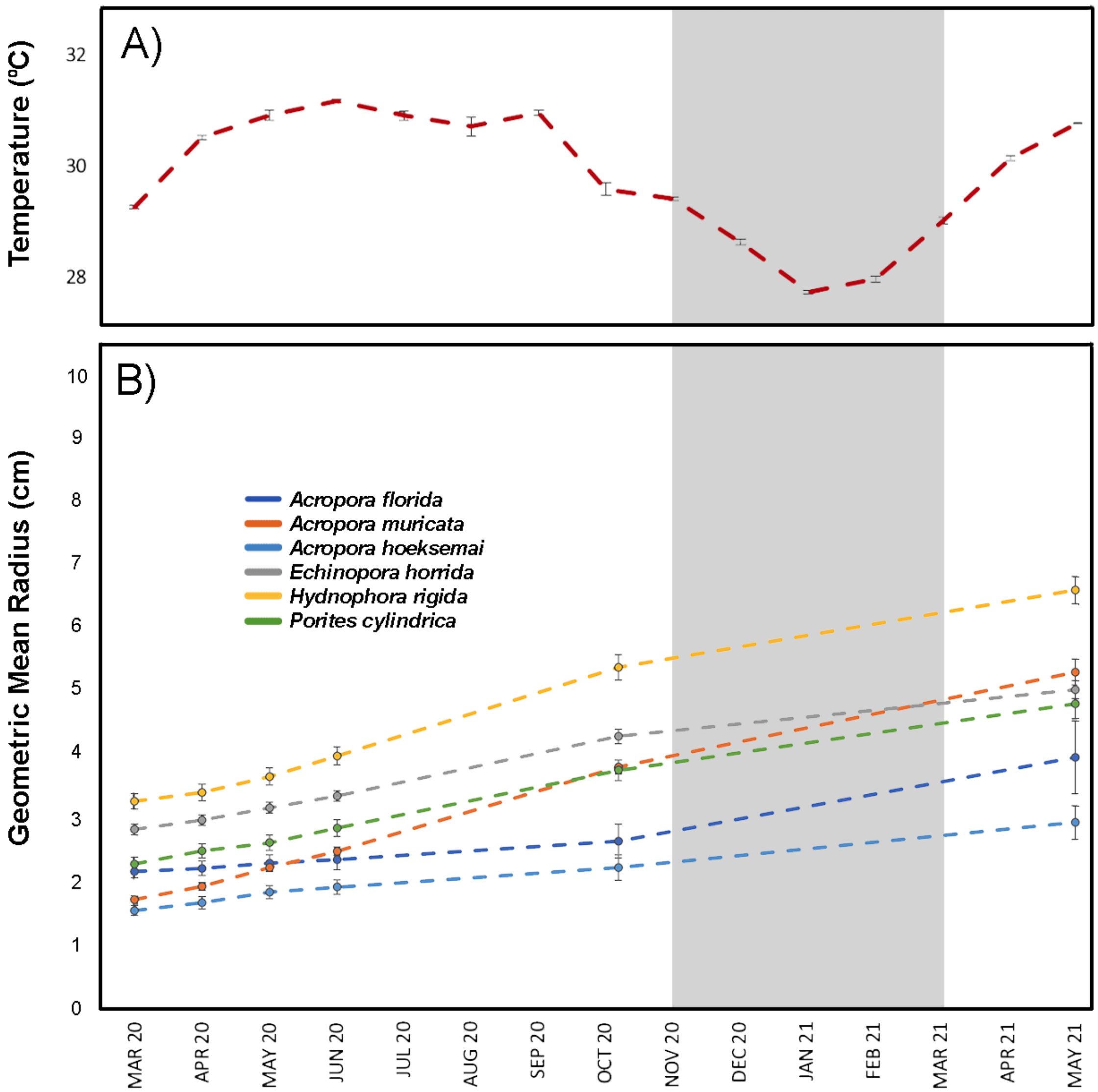

Figure 2 (A) Mean monthly water temperatures for Lang Tengah Island, Malaysia for the duration of a 414-day study. Temperature data was collected by six HOBO Pendant® data logger (Onset Computer Corporation, USA) placed in two different locations (Pasir Besar Reef (5.795475, 102.89185) and Batu Kuching Reef (5.790243, 102.903366)) at depths ranging from 8-10 meters. (B) Geometric mean radius (cm) over time for six coral species grown in tree nurseries located offshore of Pulau Lang Tengah, Malaysia. Data are presented as mean ± SEM. Corals that experienced breakage were excluded from these data. The shaded area represents the northeast monsoon season.

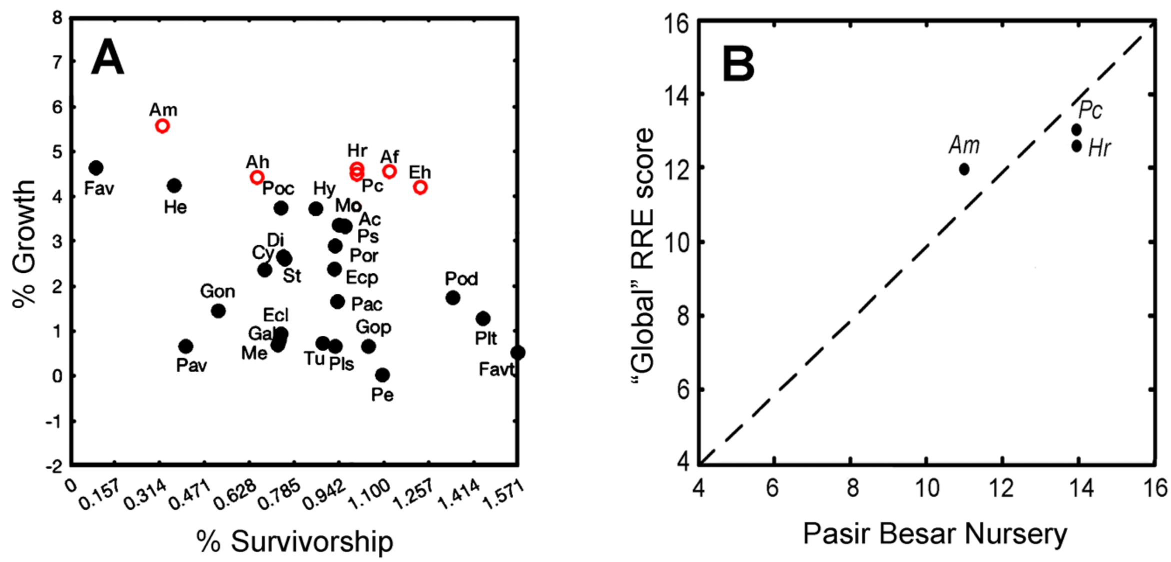

Figure 3 (A) % Growth (y-axis), where % growth data are (ln) transformed resulting in a value between -2 and +8, plotted against % Survivorship (x-axis), where survivorship data (0-100%) are arcsine transformed to produce a value between 0 and 1.571 for each coral species. Unfilled circles represent corals from the present study. Abbreviation for genus and species are: *Acropora muricata* (Am), *A. hoeksemai* (Ah), *Echinoopra horrida* (Eh), *Hydnophora rigida* (Hr), *Porites cylindrica* (Pc), *A. florida* (Af). Solid circles represent genus level and were adopted from Suggett et al. (2019). Abbreviations for genera are: *Acropora* (Ac), *Cyphastrea* (Cy), *Diploastrea* (Di), *Echinophyllia* (Ecl), *Echinopora* (Ecp), *Favia* (Fav), *Favites* (Favt), *Galaxia* (Gal), *Goniastrea* (Gon), *Goniopora* (Gop), *Heliopora* (Hel), *Hydnophora* (Hy), *Merulina* (Me), *Montipora* (Mo), *Pachyseris* (Pac), *Pavona* (Pav), *Pectinia* (Pe), *Platygyra* (Plt), *Plesiastrea* (Pls), *Pocillopora* (Poc), *Podabacia* (Pod), *Porites* (Por), *Psammacora* (Ps), *Stylophora* (St), *Turbinaria* (Tu). (B) Application of RRE scoring to Pasir Besar Nursery data through comparison of nursery RRE scores versus "global" RRE scores. Pasir Besar Nursery RRE scores are determined by distribution of % Growth versus % Survivorship. The diagonal dashed line represents the 1:1, indicating whether the following species performed above or below the "global" RRE scores.

Table 1. Specific growth rate (SGR; % day^{-1}), relative growth (% growth normalized to time in months ([ΔG/Growth initial] x 100)), portion of surviving colonies (initial n=50) and relative return-on-effort (RRE) for six coral species propagated in tree nurseries offshore Pulau Lang Tengah, Malaysia at the conclusion of a 414-day study. A significant difference in mean relative growth (H^2= 29.63, $p < 0.01$), SGR (H^2= 28.29, $p < 0.01$) and survival ($X^2_{(5, 227)} = 78.40$, $p < 0.01$) existed among species. Letters indicate pairwise differences among species.

Species	Growth			Survivorship		RRE Score
	n	SGR	%	*n*	%	
Acropora florida	42	.14 ± .01 *b*	84.1 ± 7.7	50	92.0 *a*	15
Acropora muricata	14	.29 ± .03 *a*	282.0 ± 49.6	50	34.0 *c*	11
Echinopora horrida	47	.14 ± .02 *b*	80.0 ± 5.4	50	94.0 *ab*	15
Hydnophora rigida	43	.17 ± .01 *b*	104.3 ± 6.2	50	86.0 *ab*	14
Acropora hoeksemai	31	.14 ± .12 *b*	96.0 ± 15.8	50	62.0 *bc*	12
Porites cylindrica	37	.18 ± .01 *ab*	119.1 ± 11.5	50	86.0 *a*	14