Chapter 10

Coral Reef Ecosystem Enhancement in Singapore's Highly Urbanized Port

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Coastal development activities to support economic development and population growth have caused widespread degradation of Singapore's coral reefs. This provided opportunities for the development of science-based strategies to mitigate complete reef loss and ensure the maintenance of genetic diversity from affected areas. Here, we summarize key lessons from a five-year research program that aimed to maximize the conservation and restoration of stony coral diversity from Sultan Shoal, a southern offshore island predicted to be impacted by the expansion of Singapore's port operations. Prior assessments of environmental conditions helped determine the suitability of potential recipient sites as nurseries for stocking coral material from Sultan Shoal and subsequent transplant locations. The customization of nursery design and regular maintenance regimes were

Reclaiming Eden: Responsible Living, Engineering, and Architectures
Edited by David S.-K. Ting and Jacqueline A. Stagner

ISBN TBA (Hardcover), TBA (eBook)
www.jennystanford.com

essential for enhancing the survival and growth of transplanted corals. The suitability of 30 coral species as candidates for transplantation was tested, thereby generating growth rates for the planning of future restoration efforts. Concurrently, protocols for transplantation were also refined to achieve greater ecologically-effective outcomes. These efforts led to the provision of valuable ecosystem services to recipient sites, such as increased habitat for various reef biota and the contribution of genetic material from sexually mature coral transplants, underscoring the importance of regular monitoring to assess long-term outcomes of restoration.

10.1 Introduction

Coral reefs provide key functions such as food and nursery grounds that sustain at least 25% of the world's marine species and contribute ecosystem services including coastal protection and livelihoods for hundreds of millions of people [1]. However, significant reef degradation and hard coral loss driven largely by frequent and severe global-scale bleaching events have occurred particularly over the last three decades [1]. These trends are exacerbated by impacts from a multitude of localized anthropogenic activities such as coastal urbanization, pollution, and unsustainable resource use practices [2–4], which have resulted in far-reaching consequences. In particular, human pressures such as coastal development and overfishing have resulted in potentially irreversible losses in coral cover in Bahrain and China [5, 6]. A concomitant reduction of ecosystem functions has also been observed with reef degradation – some impacts include a reduction in the functional diversity of reef fishes with increased tourist developments in Mexico [7], and a decrease in coral carbonate production rates at sites nearer the highly urbanized Singapore mainland [8].

Ensuring that coral cover and diversity do not deteriorate further is therefore highly essential for maintaining the resilience and functioning of reef ecosystems. While coastal development projects often have to proceed for the purposes of economic growth but usually result in the destruction of large swathes of coral reef, mitigation strategies such as the planned relocation of organisms to other unimpacted sites can be carried out to reduce permanent losses in genetic diversity and reef function. This approach has been increasingly adopted at various scales, with different reef organisms such as hard corals, sponges, and echinoderms (e.g. [9–13]). These relocation efforts also provide valuable opportunities to establish new concepts and principles for coastal environment management and investigate scientific aspects to fill knowledge gaps.

The need to develop sustainably is especially important in tropical Southeast Asia, where almost all coastal cities are associated with coastal developments located in close proximity to coral reefs and marine protected areas. Singapore, for example, has seen significant changes to its marine and coastal environment over the past five decades. Its territorial waters are among the world's busiest, with more than 80% designated for port and shipping activities, while the remaining areas are used by various sectors such as military, petrochemical, aquaculture, and recreation [14]. To cater to economic development and population expansion, land area has increased by 26% to 734.3 km^2 since the country's independence in 1965 [15, 16]. Over 60% of Singapore's coral reefs have been lost due to land reclamation and coastal armoring [14]. Large-scale coastal development activities have also increased sedimentation and turbidity levels that smother reef organisms and limit light penetration required for coral growth, consequently restricting their colonization and establishment to the shallows [17, 18].

Since the 1990s, at least five major coral relocation exercises have been carried out in Singapore as mitigation measures to counteract reef loss from areas designated for land reclamation [19]. In the early 2010s, plans were announced to consolidate port operations at the western coast to support Singapore's future needs, creating the mega container terminal, Tuas Megaport [20, 21]. An environmental impact assessment in 2012 determined that the planned dredging and reclamation activities would negatively impact the reef fringing Sultan Shoal, a small offshore island approximately 5 km southwest of the Singapore mainland [22, 23]. To mitigate the permanent loss of reef life from Sultan Shoal, environmental consultants relocated 2300 coral colonies to reefs at the southern offshore islands of St John's and Subar Darat [22, 23] (Fig. 10.1). Concurrently, the Maritime and Port Authority of Singapore and the Tropical Marine Science Institute also commenced research to maximize the conservation and restoration of scleractinian diversity. Making full use of 1380 loose coral fragments (or 'corals of opportunity') from 30 species, the overall aim of this research program was to build on existing reef restoration and rehabilitation strategies, improve the scientific understanding of processes necessary for the development of restored reefs, and design sustainable coastal management solutions. Here, we document the key lessons learned from this effort to enhance Singapore's coral reefs while maintaining its standing as a Green Port.

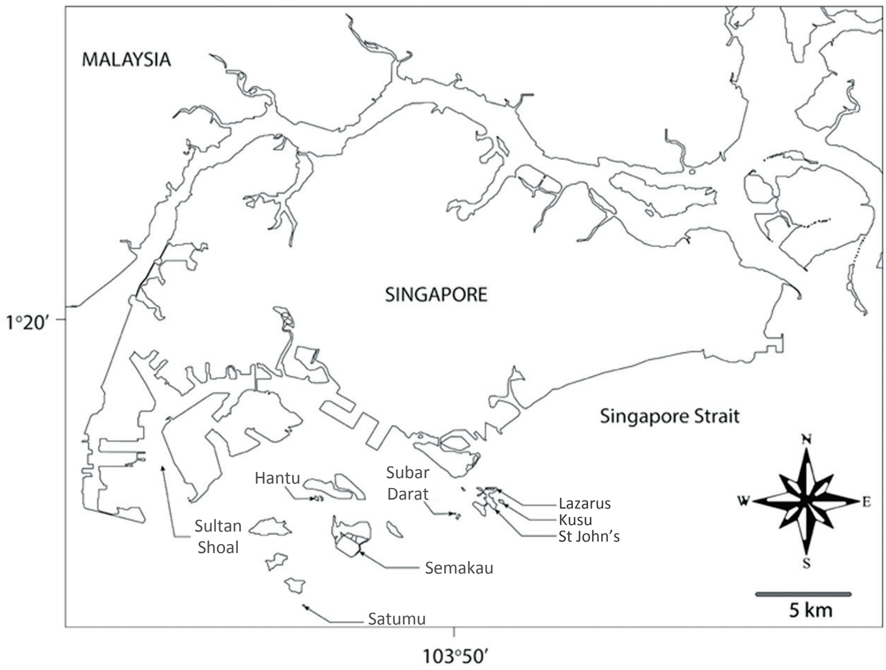

Figure 10.1 Map of Singapore and study sites.

10.2 Looking Before You Leap: Pre-Assessments Are Important for Reef Restoration

Identifying recipient sites with comparable and appropriate environmental conditions to donor sites will help minimize stress on coral propagules and augment their survival and growth rates [24–26]. To evaluate the suitability of recipient sites for Sultan Shoal's coral fragments, assessments were conducted in 2013 and 2014 at several locations. This included reefs fringing six of Singapore's southern offshore islands (Kusu, Hantu, Satumu, Semakau, St. John's, and Subar Darat) as well as two seawalls (Lazarus East and Lazarus West) (Fig. 10.1). Compared to Sultan Shoal, Semakau and Hantu registered higher sedimentation rates while Satumu and Subar Darat experienced much stronger currents [23]. These sites were thus considered less appropriate for receiving the coral fragments due to the greater risks of smothering by sediment or abrasion of soft tissues.

Based on similarities in environmental conditions (water quality, tidal range, site accessibility, and the presence of suitable substrates for transplantation) to Sultan Shoal, three sites were selected for the establishment of nurseries to rear coral fragments [23]. Lazarus East and Lazarus West were chosen as they are relatively sheltered environments with sandy seabeds that facilitated the installation of coral nursery frames. As coral communities have naturally established on many coastal defense structures in Singapore [27–29], there was also potential for the adjacent granite rock seawalls at both sites to be platforms for coral transplantation to create new reef habitats. In addition, the reef fringing northeastern Kusu Island was also identified as a rehabilitation site as it was a degraded environment with many dead coral boulders on which coral fragments could be transplanted.

Beyond site selection, the types and amount of corals to be relocated are also important considerations. Strategically selecting corals, by taking into account genetic diversity, can increase their resilience to environmental disturbances at the recipient site [30]. Our evaluation of four coral species (*Echinopora lamellosa*, *Merulina ampliata, Podabacia crustacea,* and *Duncanopsammia peltata*) showed that approximately 40% of the total colony count represented 80% of the genetic diversity of each species at Sultan Shoal [31]. The analyses also showed that it was more beneficial to collect colonies of gonochoric (single-sex) species from a larger reef area to ensure sufficient genetic diversity. These findings represented a useful means of estimating the appropriate diversity of corals to be relocated from the donor site. Our use of 'corals of opportunity' (COPs) from across Sultan Shoal's **reef** also ensured that the relocated material was genetically varied.

10.3 Well-Designed Nurseries Improve Coral Recovery and Production

Coral nurseries, typically stocked with material fragmented from healthy parent colonies, help promote coral growth in a sheltered environment until the propagules attain a suitable size for transplantation [32–35]. They can also serve as repositories that preserve reef diversity against impending impacts from environmental changes such as coastal development, and at the same time generate new material for future restoration endeavors [36, 37]. Here, we focused on (1) optimizing nursery design and maintenance, and (2) increasing coral yield.

10.3.1 Nursery Design and Maintenance

In total, 98 nursery tables were deployed at Lazarus East, Lazarus West, and Kusu. To reduce sediment accumulation and facilitate the stable attachment of coral fragments, the nursery frames were elevated at least 0.5 m above the substrate and designed with mesh-net platforms (Fig. 10.2). We tested different designs and found that nursery tables with horizontal mesh platforms were more stable in areas with moderate wave action, compared to those with sloped or vertically oriented platforms. For fragments of species such as *Pocillopora acuta*, vertically oriented platforms were more detrimental to their survivorship [38]. In addition, macroalgae and biofouling organisms often colonized these nursery frames and inhibited coral growth. Monthly maintenance of the nurseries was necessary to reduce sediment accumulation and biofouling, and was effective at encouraging coral growth.

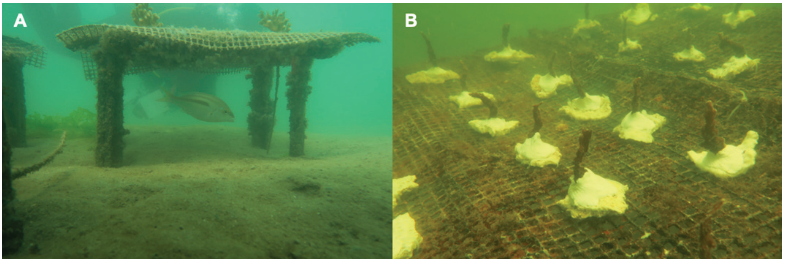

Figure 10.2 (A) Elevated nursery frames and (B) mesh net platforms helped reduce sediment accumulation and facilitated attachment of coral fragments.

10.3.2 Increasing Coral Yield

Instead of sourcing directly from healthy parent colonies (which could limit genetic diversity and introduce collateral damage), COPs which would have otherwise perished due to abrasion from currents and sediment were salvaged from Sultan Shoal's reef and progressively transferred to the coral nursery tables. Thirty species of COPs were collected over the course of the project, enabling a comprehensive evaluation of their responses in the nurseries. Overall survivorship after a year of rearing was high, at 92%. One year later, in May 2015, 15 species had high survivorship (>80%), while five species (*Merulina ampliata, Favites halicora, Favites pentagona, Porites rus,* and *Pectinia paeonia*) had survival rates of less than 50%. These observations helped to identify the species that fared the best in *in situ* nurseries under such conditions and shaped subsequent coral-rearing protocols in the project.

The coral nurseries also accelerated the recovery of fragmentation injuries and enhanced coral yield in Singapore's sedimented waters. Fragments reared in the nurseries grew significantly faster compared to those that were directly transplanted, although the benefit of a nursery phase on survival rates was species-specific [39]. However, while the nursery-reared corals of some species can be further fragmented to limit the need for harvesting from the wild, the growth rates of the new fragments may be reduced [14]. Such a method may need to be tested for its viability for different species.

10.4 Species Trait Characterization and Transplantation Protocol Customization Are Essential to Improve Restoration Outcomes

Coral transplantation is a common strategy to rapidly increase the amount of live coral cover at degraded reefs [25]. This approach may also be adapted to improve the biodiversity and ecological value of coastal defense structures [27]. Following a period of rearing, coral fragments were transplanted from the nurseries onto granite rock seawalls and degraded reefs at Lazarus and Kusu. This involved scrubbing the substrate thoroughly and using marine epoxy to attach the corals securely [27]. In addition to effectively promoting the colonization of reef biota at the study sites, our findings underscored the need to: (1) test and characterize species suitability for restoration, and (2) develop transplantation protocols for effective restoration outcomes.

10.4.1 Testing and Characterizing Species Suitability

In order to maximize the recovery of marine biodiversity and ecosystem functioning, it is necessary to test a variety of coral species for their suitability in restoration projects. Growth rates indicate suitability and allow for projections of transplant establishment at restoration sites to be made. However, information for only about 10% of the world's coral species is available in the literature [40], underscoring the need for more extensive and empirical determination of this key trait. While some species have registered high survival and growth rates from previous projects [39, 41, 42], understanding how a wider range of coral species fare within local contexts will increase long-term success rates. It is also essential to understand site- and taxonspecific responses to disturbance events (e.g., thermal stress), so that 'winners' and 'losers' can be identified to formulate more effective strategies [43].

Between 2015 and 2019, 1354 nursery-reared corals were progressively transplanted in batches to the seawalls and degraded reefs at Lazarus and Kusu (Fig. 10.3). These transplants contributed 7.9 m^2 of live coral area over four years. Targeted long-term monitoring of 163 transplants at Lazarus East revealed a high overall survivorship of 74.2%, but performances among species were wide-ranging. Transplants of three species (*Mycedium elephantotus*, *Pachyseris speciosa,* and *Turbinaria mesenterina)* did not survive, indicating their relative unsuitability as candidates for biodiversity restoration on seawalls. The surviving transplants of all other species grew larger, with the exception of *Echinophyllia aspera,* which registered a reduction in live tissue area (see Table 10.1; Figs. 10.4–10.6). Through our monitoring efforts, linear extension rates from transplants of 27 coral species were also determined, enabling projections of transplant establishment for future restoration efforts.

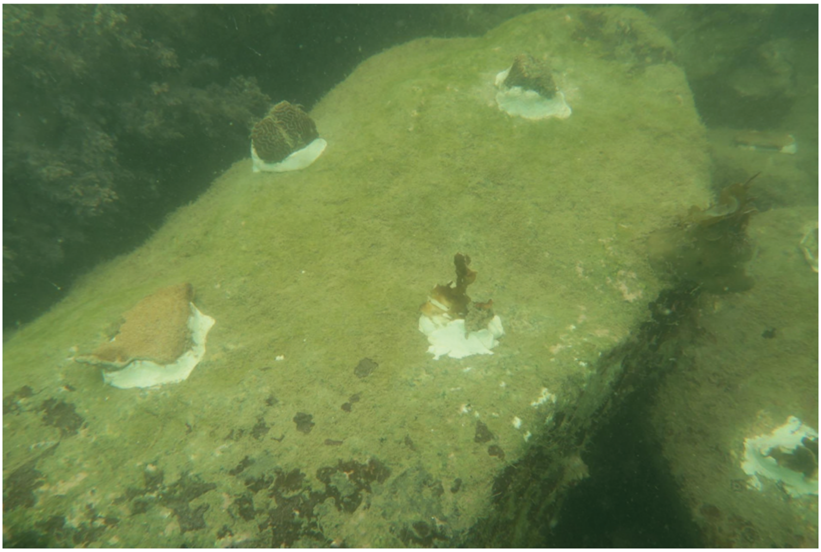

Figure 10.3 Coral fragments newly transplanted on a seawall at Lazarus Island, Singapore, in 2016.

Table 10.1 Survivorship and linear extension rates (mean ± S.D.) of corals transplanted on the Lazarus East seawall at Lazarus Island, Singapore

Species	Growth form[a]	Transplantation period (month)	Survivorship (%)	Linear extension rate (cm/year)
Acanthastrea echinata	Massive	37	100	1.3[b]
Acanthastrea rotundoflora	Encrusting	46	66.7	2.1 ± 0.2
Cyphastrea microphthalma	Massive	46	100	0.8[b]
Diploastrea heliopora	Massive	25	100	1.3 ± 0.2
Dipsastraea favus	Massive	25	90	1.3 ± 0.5
Duncanopsammia peltata	Laminar	46	50	1.2[b]
Echinophyllia aspera	Laminar	25	78.6	–0.02 ± 2.7[c]
Echinopora gemmacea	Laminar	37	100	3.0 ± 0.3
Echinopora horrida	Encrusting, long upright branches	41	14.3	2.2 ± 0.2
Favites complanata	Massive	37	100	0.8[b]
Favites halicora	Massive	46	100	1.6 ± 0.6
Favites pentagona	Sub-massive	46	50	1.2 ± 0.6
Goniastrea pectinata	Sub-massive	25	100	1.2 ± 0.3
Goniastrea retiformis	Massive	46	100	0.8[b]
Goniopora lobata	Columnar	46	100	1.8 ± 0.7
Hydnophora exesa	Sub-massive	37	50	4.3[b]
Leptoria phrygia	Massive	32	100	1.1 ± 0.5
Lithophyllon undulatum	Encrusting	37	100	0.4 ± 0.1
Lobophyllia hemprichii	Massive	37	50	1.0[b]
Lobophyllia recta	Massive	46	100	1.2 ± 0.1
Mycedium elephantotus	Laminar	13[d]	0	–

Species	Growth form[a]	Trans-plantation period (month)	Survivorship (%)	Linear extension rate (cm/year)
Pachyseris speciosa	Laminar	3[d]	0	–
Pavona cactus	Bifacial	32	72.7	2.0 ± 0.8
		31	80	1.7 ± 0.9
Pavona decussata	Bifacial	46	66.7	3.0 ± 0.1
Pavona explanulata	Laminar	32	87.5	0.6 ± 0.3
Pavona frondifera	Bifacial	37	100	2.4[b]
		31	33.3	2.9 ± 1.7
Porites rus	Digitate	25	70	1.5 ± 1.0
Psammocora contigua	Columnar	32	100	2.4 ± 0.5
		25	100	2.7 ± 0.4
Turbinaria mesenterina	Laminar	8[d]	0	–
Turbinaria stellulata	Massive	37	100	1.8 ± 0.1

[a]Growth forms from Ng et al. (2021) [8].
[b]Only one fragment transplanted or remaining.
[c]Transplants of *Echinophyllia aspera* decreased in size.
[d]Species that did not survive the duration of the study period (maximum period of survival indicated).

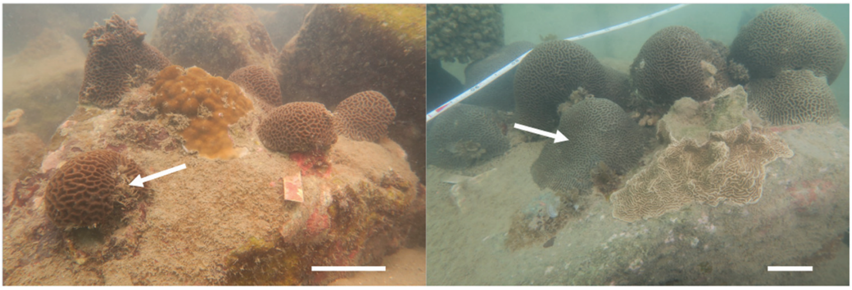

Figure 10.4 *Platgyra sinensis* (white arrow) transplants in 2018 (left), and other corals from the same batch of transplants in 2022 (right) (scale bars = 10 cm).

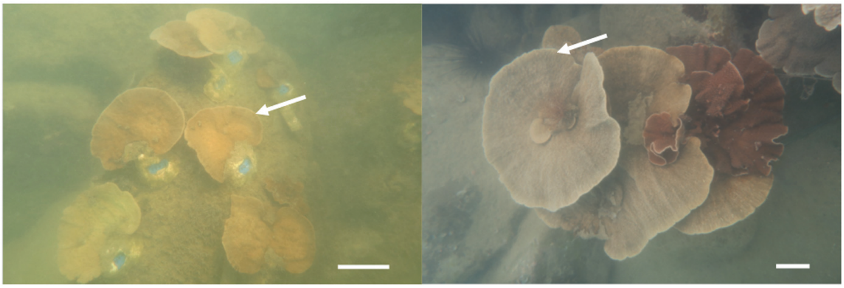

Figure 10.5 *Podabacia crustacea* (white arrow) transplants in 2016 (left), and other corals from the same batch of transplants in 2022 (right) (scale bars = 10 cm).

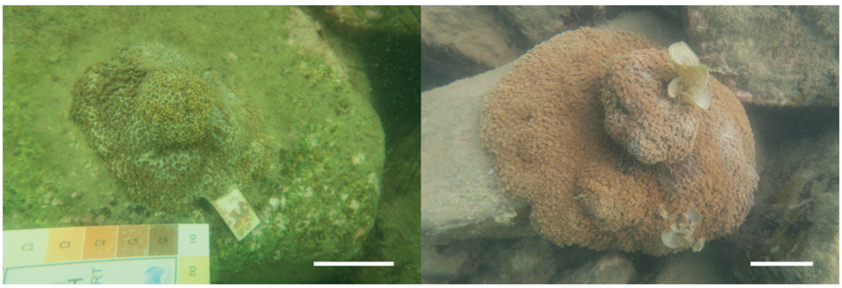

Figure 10.6 *Goniopora lobata* transplant in 2018 (left) and 2022 (right) (scale bars = 5 cm).

10.4.2 Developing Transplantation Protocols to Achieve Ecologically Effective Outcomes

While transplantation was an effective way of accelerating the colonization of scleractinians at the subtidal zone of seawalls [41], customizing existing protocols to suit local conditions further improved these outcomes. For example, transplantation carried out within periods that were less environmentally stressful, such as the inter-monsoon seasons contributed to increased coral growth. Additionally, trials at the Lazarus West seawall indicated that transplantation at shallower depths generated better yield (approximately 1.5 times faster growth rates for transplants at 3 m vs 6 m below chart datum) for certain species (e.g., *Pectinia paeonia* and *Turbinaria mesenterina*), likely due to different resource requirements. We also learned that transplantation in areas with dense macroalgal growth was ineffective, as the macroalgae can outcompete corals and adversely affect the survivorship and growth of coral transplants through allelochemical mechanisms or physical abrasion. In addition, Sam et al. (2021) [42] reported that although larger coral transplants (9–11 cm) have a higher chance of survival due to their reduced risk of complete mortality by predation and sedimentation burial, transplanting smaller coral fragments (2–4 cm) ultimately generated better yield in live coral cover and was the most efficient use of the original coral source material, thereby facilitating planning in the nursery-rearing phase.

10.5 Toward Long-Term Monitoring of Reef Restoration Efforts

Long-term coral monitoring is key to assessing whether transplants are able to establish at their recipient site, determining if ecosystem services can be provided by the established transplants, and understanding coral species' responses to threats such as corallivory and climate change. As a good indicator of their establishment at the recipient site, we observed that transplants of *Platygyra sinensis* (diameter 15–20 cm) on the Lazarus East seawall spawned naturally during a mass coral spawning event in April 2019 (Fig. 10.7). This indicated that, with proper monitoring and care, asexually propagated transplants can eventually develop into sexually mature colonies that can help seed and contribute genetic diversity to other locations.

Apart from tracking coral performance, it is just as important to document the recruitment of non-coral fauna over the longer term to comprehensively assess the overall contributions of the restoration effort to ecosystem functioning. Although *in situ* coral nurseries are used primarily to culture coral material [44], they can also provide shelter and food for reef-associated organisms. Marine animals from at least 100 taxa were documented at our *in situ* coral nurseries, underscoring their role as platforms for reef faunal recruitment (see Appendix; Fig. 10.8).

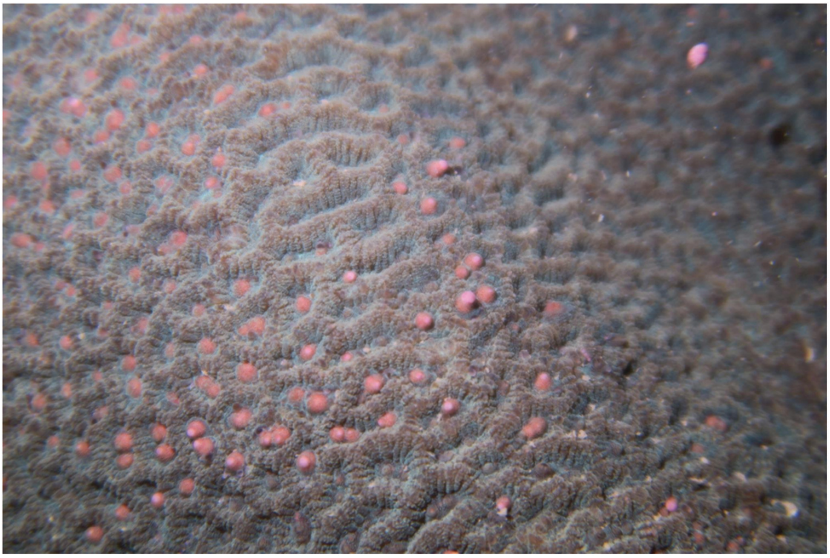

Figure 10.7 Three-year-old *Platygyra sinensis* transplant spawning in 2019.

Figure 10.8 Marine organisms utilizing the coral nurseries: (A) Cuttlefish (*Sepia* sp.), (B) Nudibranch eggs, (C) Spanish flag snapper (*Lutjanus carponotatus*), and (D) Spangled flatworm (*Acanthozoon* sp.).

Juvenile corallivorous butterflyfishes (*Chaetodon octofasciatus*) were observed swimming among and feeding on the *Acropora* spp. and *Pocillopora acuta* colonies that were reared in the nurseries [45]. Dense clusters of cuttlefish eggs were also deposited deep within coral branches, and juvenile cuttlefishes were seen seeking refuge around the *Acropora aculeus* and *P. acuta* colonies [46]. In addition, Wee et al. (2019) [47] reported that the nursery-reared corals also supported diverse epifaunal communities. From just 22 colonies of three coral species, 418 mobile invertebrates from 63 taxa such as crabs, shells, and shrimps were recorded. Each coral host species supported different epifaunal communities, likely as a consequence of different resource provisioning capacities. While a variety of epifauna also colonized dead coral colonies, these were of a different assemblage than those in live colonies.

Finally, coral monitoring regimes should also be complemented with regular checks of corallivores, which at high densities can cause mass coral mortality and negate restoration efforts. Snails, such as *Drupella spp.,* are known to feed exclusively on corals [48, 49]. They are nocturnal, preferring to hide under corals or boulders during the day and actively feed at night [50, 51]. As they also lay eggs on exposed coral skeletons [52], coral materials in nurseries and at transplant sites should be regularly examined and the presence of these snails should be recorded as part of coral monitoring protocols. The affected coral skeletons or egg capsules should be removed to reduce the chance of corallivore outbreaks.

10.6 Conclusion

Our research has highlighted how coral restoration efforts can be innovatively designed to mitigate the loss of coral cover and diversity from intensive coastal development, while also creating new reef communities in areas where reefs did not exist before. The success of site selection, coral rearing, and transplantation protocols as well as monitoring regimes was evident from the high coral survivorship rates and subsequent increases in marine biodiversity at the recipient sites. Sustained efforts in long-term monitoring are necessary to properly assess whether transplants are able to establish at their recipient site and to further determine if ecosystem services can be sustained by the established transplants.

Future Plans

While marine protected areas have an important role in the same way that forest reserves do, additional coral communities established via transplantation within Singapore waters will aid biodiversity conservation by providing "wildlife" corridors that provide ecological connectivity and additional refuges for marine life. If properly constructed, such reefs can also provide socio-economic value as they are a positive reflection of effective water quality management and vibrant ecosystem health in Singapore's Green Port. Concurrently, research should also be conducted into restoring a larger suite of ecosystem functions in degraded reefs or enhancing such functions in man-made habitats via the transplantation of other benthic groups [27]. It is equally important to consider the needs and perspectives of all stakeholders involved, so that reef restoration practitioners can create opportunities to build support and buy-in for the projects, increasing the likelihood of successful implementation and long-term success [53]. Toh et al. (2017) [41] calculated that the inclusion of trained volunteers in fieldwork (i.e., coral culture and transplantation) and data analyses was more cost-effective than if volunteers only assisted with fieldwork, or if only researchers were involved in the effort. Clearly, habitat conservation programs involving the community not only help reduce project expenses but also enhance capacity building and encourage a greater sense of public ownership of the natural heritage [41, 54].

Acknowledgments

This study is part of the project 'Enhancing Singapore's Coral Reef Ecosystem in a Green Port' supported by the Maritime and Port Authority of Singapore, under the project grant R-347-002-215-490.

Appendix

Reef fauna observed utilizing coral nurseries at Lazarus Island, Singapore

Phylum	Class	Order	Family	Genus	Species
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice*	*Eunice* sp.
				Marphysa	*Marphysa* sp.
				Nicidion	*Nicidion* sp.
		Phyllodocida	Chrysopetalidae		
			Iphionidae		
			Nereididae		
			Polynoidae		
			Syllidae		
			Terebellidae		
		Sabellida	Sabellidae		
		Scolecida	Capitellidae	*Capitella*	*Capitella* sp.
		Terebellida	Terebellidae		
Arthropoda	Hexanauplia	Copepoda			
	Malacostraca	Amphipoda	Ampeliscidae		
			Amphilochidae		
			Ampithoidae		
			Ischyroceridae		
			Leucothoidae		

Phylum	Class	Order	Family	Genus	Species
		Decapoda	Alpheidae	*Alpheus*	*Alpheus* sp.
				Athanas	*Athanas* sp.
				Synalpheus	*Synalpheus* sp.
			Diogenidae	*Dardanus*	*Dardanus lagopodes*
			Dromiidae	*Cryptodromia*	*Cryptodromia* sp.
			Galatheidae	*Galathea*	*Galathea coralliophilus*
			Galatheidae	*Galathea*	*Galathea johnsoni*
			Hippolytidae	*Hippolyte*	*Hippolyte ventricosa*
			Ischyroceridae		
			Palaemonidae	*Cuapetes*	*Cuapetes* sp.
				Phyllognathia	*Phyllognathia ceratophthalma*
			Pilumnidae	*Pilumnus*	*Pilumnus* sp.
			Porcellanidae	*Lissoporcellana*	*Lissoporcellana spinuligera*
					Pisidia streptochiroides
			Tetraliidae	*Tetralia*	*Tetralia nigrolineata*
			Trapeziidae	*Trapezia*	*Trapezia cymodoce*
				Chlorodiella	*Chlorodiella nigra*

Phylum	Class	Order	Family	Genus	Species
			Trapeziidae	*Cymo*	*Cymo andreossyi*
				Pilodius	*Pilodius cf. granulatus*
			Xanthidae	*Soliella*	*Soliella cf. flava*
		Isopoda	Sphaeromatidae		
		Mysida			
		Tanaidacea	Leptocheliidae		
	Ostracoda	Myodocopida	Cypridinidae		
Chordata	Actinopterygii	Gobiiformes	Gobiidae	*Gobiodon*	*Gobiodon histrio*
				Istigobius	*Istigobius ornatus*
		Perciformes	Apogonidae	*Ostorhinchus*	*Ostorhinchus margaritophorus*
			Blenniidae	*Petroscirtes*	*Petroscirtes variabilis*
			Carangidae	*Selaroides*	*Carangidae leptolepis*
			Chaetodontidae	*Chaetodon*	*Chaetodon octofasciatus*
				Chelmon	*Chelmon rostratus*
			Ephippidae	*Platax*	*Platax teira*
			Haemulidae	*Plectorhinchus*	*Plectorhinchus chaetodonoides*
					Plectorhinchus chrysotaenia
					Plectorhinchus gibbosus

Phylum	Class	Order	Family	Genus	Species
			Labridae	*Choerodon*	*Choerodon anchorago*
					Choerodon schoenleinii
				Halichoeres	*Halichoeres bicolor*
					Halichoeres leucurus
					Halichoeres nigrescens
				Scarus	*Scarus ghobban*
					Scarus rivulatus
			Latidae	*Psammoperca*	*Psammoperca waigiensis*
			Lutjanidae	*Lutjanus*	*Lutjanus carponotatus*
			Monacanthidae	*Acreichthys*	*Acreichthys tomentosus*
			Mullidae	*Upeneus*	*Upeneus tragula*
			Nemipteridae	*Pentapodus*	*Pentapodus paradiseus*
				Scolopsis	*Scolopsis bilineatus*
					Scolopsis monogramma
			Pinguipedidae	*Parapercis*	*Parapercis* sp.
			Pomacanthidae	*Chaetodontoplus*	*Chaetodontoplus mesoleucus*

Phylum	Class	Order	Family	Genus	Species
			Pomacanthidae	*Pomacanthus*	*Pomacanthus annularis*
					Pomacanthus sextriatus
				Dischistodus	*Dischistodus prosopotaenia*
				Neopomacentrus	*Neopomacentrus cyanomos*
					Neopomacentrus filamentosus
				Pomacentrus	*Pomacentrus cuneatus*
					Pomacentrus tripuncuatus
			Pseudochromidae	*Congrogadus*	*Congrogadus subducens*
			Serranidae	*Cephalopholis*	*Cephalopholis boenak*
				Diploprion	*Diploprion bifasciatum*
		Syngnathiformes	Syngnathidae	*Corythoichthys*	*Corythoichthys amplexus*
		Tetraodontiformes	Tetraodontidae	*Arothron*	*Arothron stellatus*
				Monacanthus	*Monacanthus chinensis*
Echinodermata	Holothuroidea	Synallactida	Stichopodidae	Stichopus	*Stichopus horrens*
	Ophiuroidea	Ophiurida	Ophiactidae	*Ophiactis*	*Ophiactis savignyi*
			Ophiotrichidae		

Phylum	Class	Order	Family	Genus	Species
Mollusca	Bivalvia	Arcida	Arcidae	*Barbatia*	*Barbatia amygdalumtostum*
				Mesocibota	*Mesocibota bistrigata*
		Mytilida	Mytilidae	*Musculus*	*Musculus* sp.
		Pteriida	Pteriidae		
	Cephalopoda	Cephalopoda	Octopoda	*Octopus*	*Octopus* sp.
		Sepiida	Sepiidae	*Sepia*	*Sepia* sp.
	Gastropoda	Caenogastropoda	Triphoridae	*Triphora*	*Triphora* sp.
		Littorinimorpha	Rissoidae	*Alvania*	*Alvania ogasawarana*
		Neogastropoda	Columbellidae	*Euplica*	*Euplica scripta*
				Mitrella	*Mitrella* sp.
				Zafra	*Zafra* sp.
			Muricidae	*Drupella*	*Drupella margariticola*
				Drupella	*Drupella rugosa*
		Nudibranchia	Chromodorididae	*Chromodoris*	*Chromodoris lineolata*
			Discodorididae	*Discodoris*	*Discodoris* sp.
			Dorididae	*Doriopsis*	*Doriopsis pecten*

Phylum	Class	Order	Family	Genus	Species
		Trochida	Trochidae	*Jujubinus*	*Jujubinus polychromus*
				Stomatolina	*Stomatolina rubra*
		Littorinimorpha	Cypraeidae	*Erronea*	*Erronea ovum*
	Polyplacophora				
Platyhelminthes	Rhabditophora	Polycladida	Pseudocerotidae	*Acanthozoon*	*Acanthozoon* sp.
				Nymphozoon	*Nymphozoon bayeri*
				Pseudobiceros	*Pseudobiceros hancockanus*
				Pseudoceros	*Pseudoceros concinnus*
					Pseudoceros bifurcus
					Pseudoceros indicus
					Pseudoceros laingensis

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