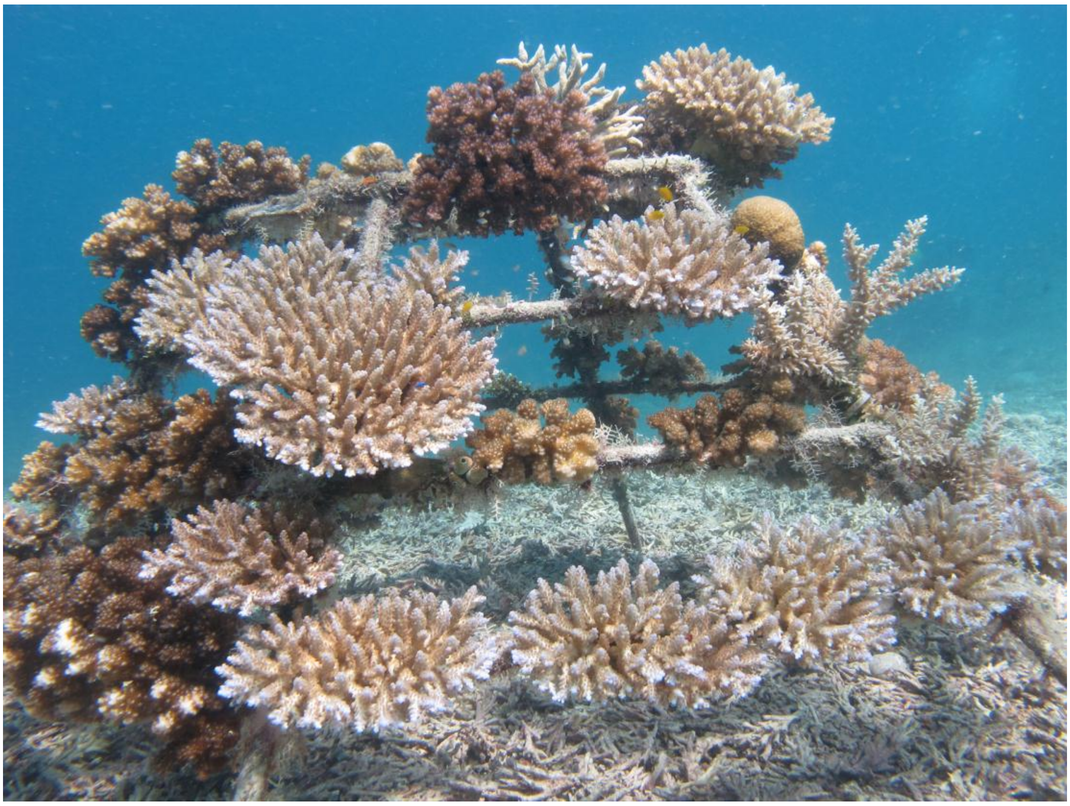
Progress Report 2014:

Coral Frame Programme
Tun Sakaran Marine Park



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2014

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CONTENTS

SUMMARY

There has been extensive damage from fish bombing in the Semporna area (and elsewhere in Sabah) since this destructive practice began at least 50 years ago. Virtually every reef has been affected at some time, causing structural damage and loss of diversity.

The Marine Conservation Society and Sabah Parks, through the Semporna Islands Project, are demonstrating 'conservation in action' in the Tun Sakaran Marine Park by making and setting up 'coral frames' in bombed areas.

This report describes progress since the first coral frames were deployed at fish bombed sites in the Tun Sakaran Marine Park in June 2011. A total of 200 frames have now been made and deployed on the reef front of the fringing reef at Sibuan, Mantabuan and Kapikan and on the Southern Rim Reef off Boheydulang.

The frames were placed along the reef front at depths between 3-6m, where the greatest damage has been inflicted. Each was seeded with 85-90 coral fragments, attached with plastic cable ties. The coral fragments were preferentially sourced from loose colonies, provided they were not damaged. Some pieces are also taken from attached, donor colonies.

The frames have proved to be very stable and show no signs of deterioration. Survival of the fragments in the first few months after seeding depends on a wide variety of biological and environmental factors. For reasons unknown, initial survival at Mantabuan was only just over 50%, but thereafter survival has been between 87 – 99% between monitoring surveys.

Growth rate depends primarily on the species and growth form. Branching corals (particularly *Acropora* and *Pocillopora* species) have shown the fastest growth, with some colonies of *Acropora* attaining more than 30cm diameter after 1.5-2 years. Trials were carried out with a few foliose and small semi-massive corals but these have significantly slower growth and the foliose corals showed poor survival.

The bars of the frame are stable and elevated off the reef surface and vacant spaces provided a suitable surface for attachment of other organisms. Natural colonists consisted mainly of hydroids and seasquirts and these were cleaned off as far as possible in order to reduce competition with the coral fragments. A few hard corals, soft corals and sea fans also appeared on the frames, having settled as tiny post-larval forms.

A range of fish roamed onto the frames to feed and/or shelter. Observations of their behaviour showed that they often hovered inside the frame and sometimes moved quickly from frame to frame in seek of refuge. Other fish appeared to be visiting mainly to feed and were observed browsing on the surface of the bars or the attached organisms.

The first fish colonists were noted about 9 months after deployment and were tiny juvenile pomacentrids (humbug, *Dascyllus* species) and unidentified wrasse. They were living in coral fragments (especially *Pocillopora* and *Acropora*) that had grown to a large enough size to provide a safe refuge.

The numbers, size and variety of resident fish increased over time and after 2 years, between 70-90% of the frames were colonised by anything between one and well over 50 fish. Most of these individuals were small species that will probably remain on the frames, but a few (e.g. groupers) were juveniles that will move away and extend their territories/home range as they grow into adults.

The coral frames have undoubtedly been a success and it is to be hoped that their presence will continue to enhance biodiversity. It is acknowledged that, given the size of the Park (over 100km of reef front), the frames can repair only a fraction of the reefs that have been damaged by fish bombing. However, the programme is of considerable value for various other reasons. In particular, it has established a robust methodology that can be used by Park managers, the private sector and local communities to help regenerate damaged reefs or create additional habitat.

The coral frame programme has also helped to increase awareness by highlighting the impacts of fish bombing on the reefs and showing that positive steps can be taken to encourage re-growth and recovery.

The success of the project is shown by the fact that the methodology has already been replicated by the private sector at Pulau Pom Pom (Semporna) and in other parts of Sabah, including Kudat and the Tunku Abdul Rahman Park. In addition, having evaluated different methods of reef restoration, the Malaysian Federal Department of Fisheries have assigned funds for the deployment of more frames in Tun Sakaran Marine Park over the next two years.

It is hoped that the private sector, local communities, conservation organisations and management authorities will work together to further develop and monitor the coral frame programme.

INTRODUCTION

Extensive damage has been inflicted on coral reefs in the Semporna area (and elsewhere in Sabah) from the use of explosives to 'catch' fish. Fish bombing began at least 50 years ago and surveys indicate that virtually every reef has been affected at some time.

When used on the reef, each bomb causes significant damage and sometimes complete destruction over an area up to 5m in diameter. Delicate and branching corals are reduced to rubble and even massive corals may be broken apart. Those that remain intact are generally bleached and will die. Once the living layer of coral has gone, the remaining calcium carbonate skeleton may remain bare, be colonised by other marine life and/or be subject to biological and physical erosion.

Figure 1. Intact and healthy reef with corals hundreds of years old.

Reef degradation caused by fish bombing affects responsible fishermen who rely on intact, healthy reefs for their livelihoods and everyday needs. Fish bombing also reduces the value of the reef for biodiversity and tourism and has a negative impact on the local economy.

Figure 2. Recently-bombed reef showing destruction of both massive and branching corals. Reefs that have been reduced to rubble may never fully recover.
Photo: ©Adam Broadbent Scubazoo

Concerted efforts are being made to curb fish bombing, but even if it completely stops, it may be decades before bombed reefs recover. In some cases they may never revert to hard coral-dominated reefs but remain as shifting banks of rubble or become dominated by banks of non-reef forming soft corals, as has occurred on the east side of Kapikan (Tabbah Kumai).

Repairing reefs on a big scale is very difficult, expensive and time consuming but small-scale restoration projects can help to make a difference. MCS and Sabah Parks have demontrated ‘conservation in action’ at key sites in the Tun Sakaran Marine Park by establishing ‘coral frames’ in bombed areas. Many methods of reef restoration have been tried around the world and we selected this method having seen evidence of how well it worked in the Maldives, where many shallow areas of coral had been lost due to mortalities caused by coral bleaching as a result of ‘warm-water events’ associated with .

The units were designed and tested by Seamarc Ptv Ltd from the Maldives and have a number of unique and innovative features:

- Made from reinforcing bars which are easily available locally.
- East to handle and get into the water.
- Stable when placed on the seabed because of the shape and because water flows through them.
- The frame creates a shape which, as the corals grow and spread out, provides excellent hiding places for fish.
- The coral ‘seeds’ or fragments are attached so that they can grow from both ends.
- Elevated off the bottom and so protected from coral-feeding crown-of-thorns starfish.

FRAME CONSTRUCTION, DEPLOYMENT AND MONITORING

Equipment and materials lists together with an illustrated step-by-step guide to constructing the frames are included in the first progress report (Wood and Ng, 2012). A person proficient in welding is needed and training is required in order to ensure that the frames are made to a good standard, but other procedures do not require any prior skills.

A base mould was made and all the frames constructed using this as a guide. The 'footprint' of each frame was a hexagon with a maximum diameter of 130cm and height from the ground of 59cm (Figure 3).

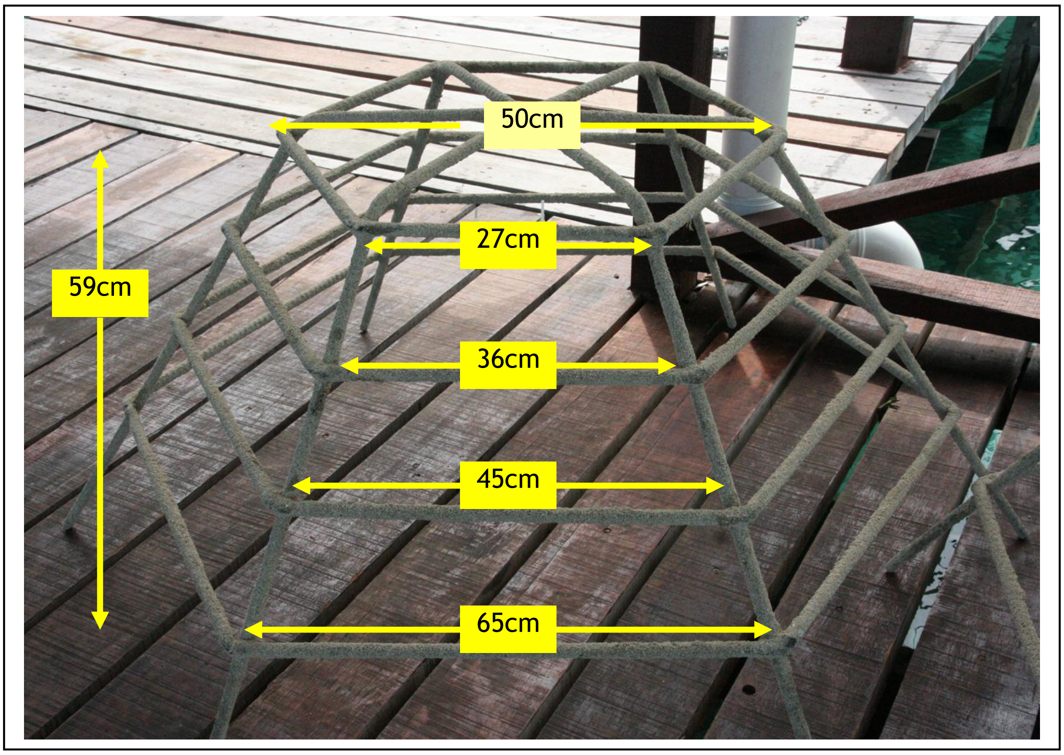


Figure 3. Completed frame, showing dimensions. The overall height from the ground is 59cm and the width of the 'footprint' is 1m 30cm.

The frames were placed on the fore reef at depths between 3 – 8m. In cases where there was a slight slope then the shallower legs were pushed into the rubble in order to keep the frame approximately horizontal. This was not critical but helped give maximum stability.

There was no slippage or movement of the frames apart from a couple of random incidences where we believe the frames were pulled over by boat anchors. In these cases, the frames were moved back into an upright position and corals replaced as necessary.

Procedures for seeding the frames with coral fragments are outlined in the first progress report (Wood and Ng, 2012).

The routine for cleaning and monitoring the frames is also presented in the earlier report (Wood and Ng, 2012). The frequency with which the frame sites were visited for routine works and monitoring depended mainly on availability of boat transport and divers experienced in coral frame work. The aim was to attend to the frames at least every 6 months. During these visits, dead fragments were removed and replaced (provided there was enough space), competitors were removed and the bars were cleaned where necessary with a small brush (toothbrush). Photographs were taken of all or a sub-set of frames, including close-ups of representative corals. Records were made of other colonists and of resident and visiting fish. Fish species and size were noted and counted.

FRAME LOCATION

There are many sections of reef within the Park that have been broken up by fish bombing and we selected a number of contrasting sites where we assessed that deployment of the frames could help to stimulate recovery and improve biodiversity. Five main localities were selected: Mantabuan SW, Mantabuan SE, Kapikan SW, Sibuan NW and Boheydulang South Rim Reef (Table 1 and Figure 2).

Name	Latitude (degree, minute, decimal minute)		Longitude (degree, minute, decimal minute)		Latitude (Decimal degree)	Longitude (Decimal degree)
Mantabuan SW 60 frames	4	37.989	118	47.500	4.63315	118.79167
Mantabuan SE of 60 frames	4	37.904	118	47.575	4.63173	118.79292
Mantabuan SP Substation	4	38.112	118	47.377	4.63520	118.78962
Mantabuan N of substation	4	38.132	118	47.369	4.63553	118.78948
Mantabuan SE	4	38.421	118	48.132	4.64035	118.80220
Tabbah Kumai; Kapikan SW	4	37.695	118	49.604	4.62825	118.82673
Sibuan NW start (W)	4	39.544	118	39.980	4.65907	118.66633
Sibuan NW finish (E)	4	39.512	118	39.993	4.65853	118.66655
Bohedulang S Rim reef	4	35.195	118	46.063	4.58658	118.76772

Table 1. Location of the coral frames within Tun Sakaran Marine Park.

Figure 4. Tun Sakaran Marine Park, showing location of the coral frames.

SURVIVAL AND GROWTH OF CORAL FRAGMENTS

Survival of the fragments depends on a range of biological and environmental factors. Sensitivity to fragmentation and handling is an important influence in the early stages and is likely to vary from one species to another and to the prior health of the donor colony or pieces of coral that are being transplanted.

Survival will also be affected by natural influences on coral health and growth such as water temperature, storms, coral predators, competitors and disease. At one of the sites (Kapikan), a fish bomb had clearly gone off in the neighbourhood of some of frames soon after they were seeded and this had caused the death of many of the fragments. At the next census, survival was good, at 88% (Table 2).

We noted that, in general, the greatest mortality was in the first days, weeks or months after attachment of the fragments. The worst rate of survival noted was at the Mantabuan 60 frame site, where (for reasons unknown) mortalities were quite high in the first year (survival of only 52%). Apart from this, the rate of mortality was much lower, with survival at 87 – 99% (Table 2).

Location	Time elapsed since seeding of frames	Time elapsed since previous census/replacement	N° frames surveyed	Percentage survival since previous census
Mantabuan 60 frame site	2 months	2 months	9	87
	8 mths	2 months	16	79
	1 year	7 months	12	52
	1 yr 2 mths – 1yr 8 mths	5 months	13	92
	2 yrs - 2.5 yrs	6 months	16	99
Mantabuan N of SP substation	5 mths	5 months	19	88
	1 year 4 mths	3 months	14	98
Mantabuan at SP substation	1 year	5 months	10	90
	2 years	3 months	5	98
Sibuan	6 mths - 1 year	5 months	20	91
Kapikan	6 months	2 months	9	88

Table 2. Survival of coral fragments on the frames. This was calculated by counting the number of fragments that had died and needed replacement between each monitoring survey. The right hand column shows % survival, based on monitoring of random frames at different sites.

When mortalities occurred, the dead fragments and cable ties were removed and new fragments attached. However, as time progressed there was less need to replace ones that died because the attached corals grew to fill up the vacant spaces.

Photographs on the following pages show the way that the fragments have grown and are providing new coral habitat on fish-bombed reefs.

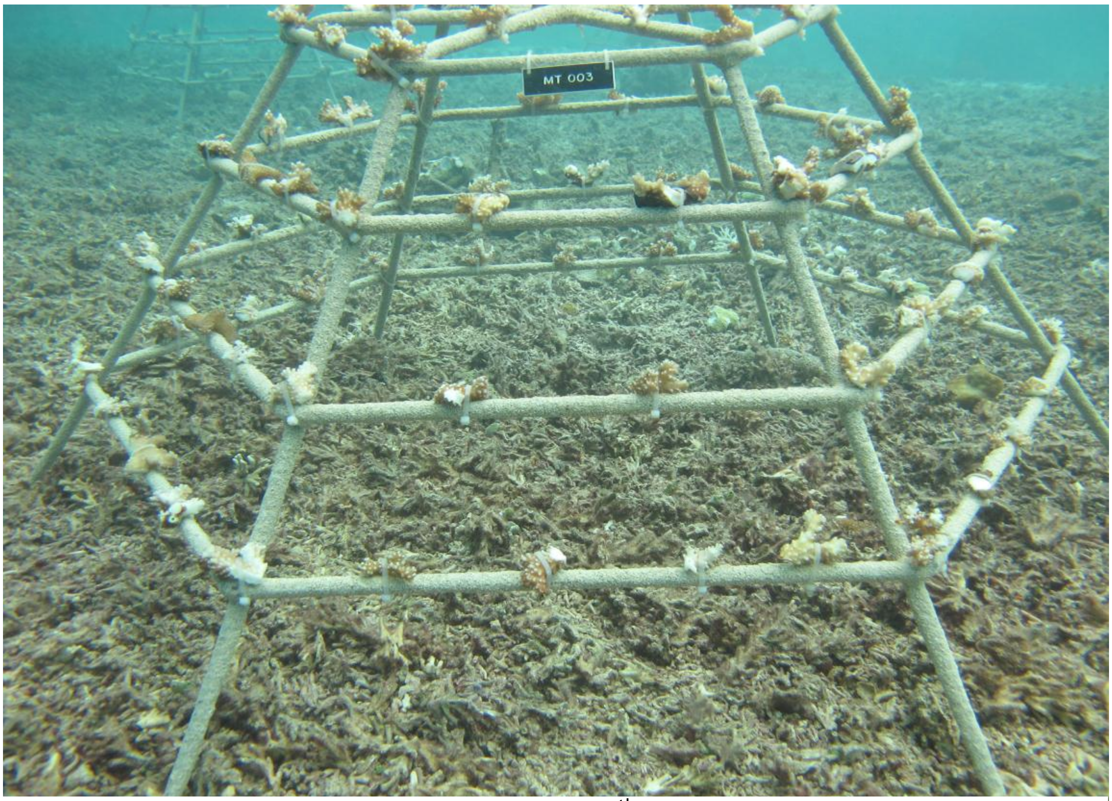


Figure 5. Mantabuan Frame 3: seeded June 12th 2011

Figure 6. Mantabuan No 3 Feb 12th 2013 1 yr 8 months after seeding

Figure 7. Mantabuan Frame 33: February 15th 2012 (3 months after seeding)

Figure 8. Mantabuan Frame 33: January 24th 2014 (2 yrs 2 mths after seeding)

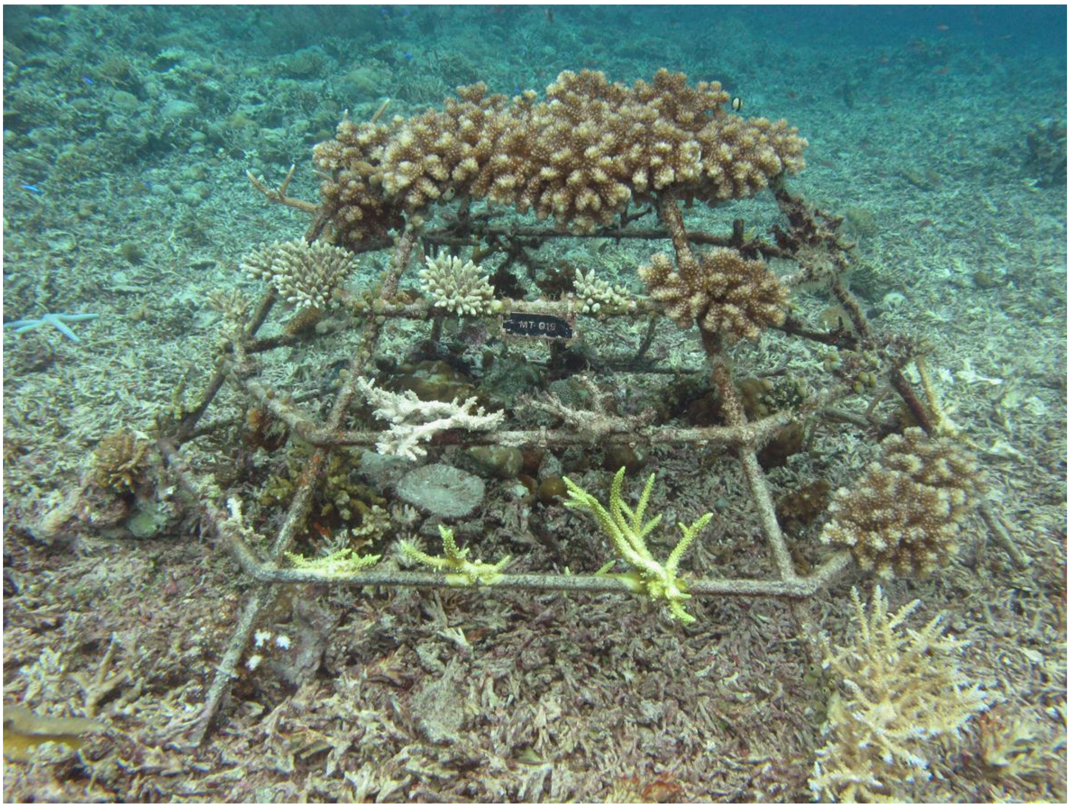


Fig. 9. Mantabuan Frame 19: 15^{tn} September 2012 (1 yr 3mths after seeding)

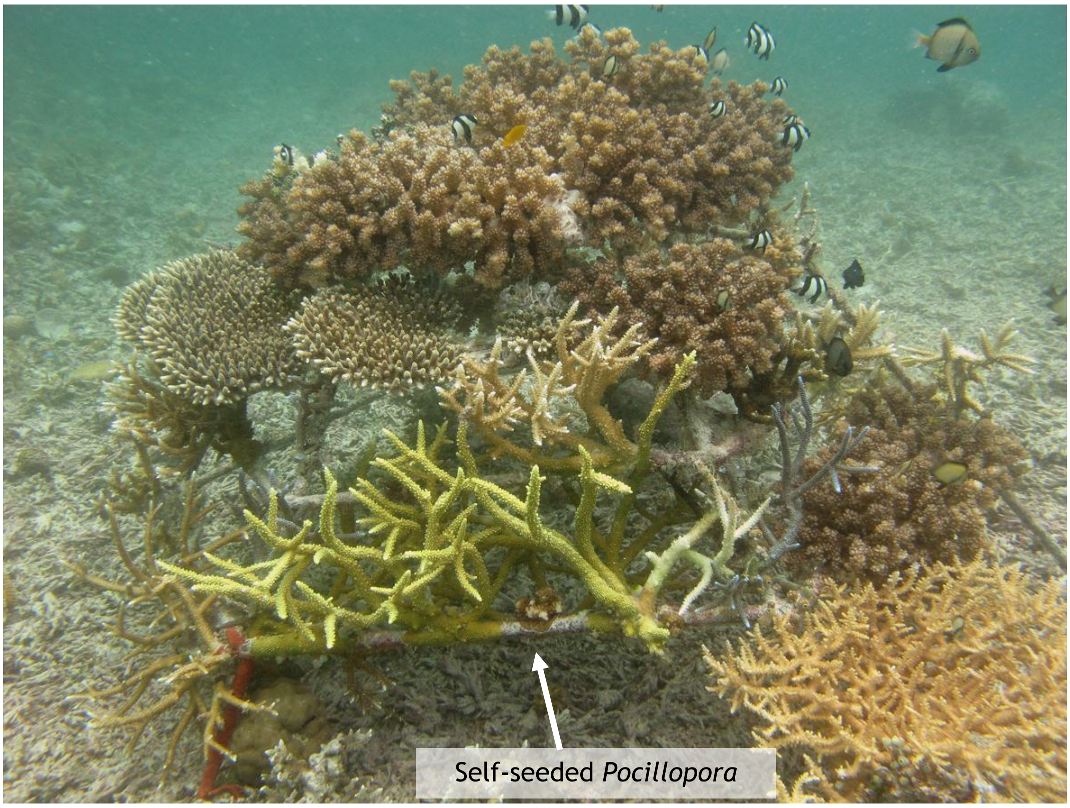


Fig 10. Mantabuan Frame 19: 14th January 2014 (2 yrs 7 mths after seeding)

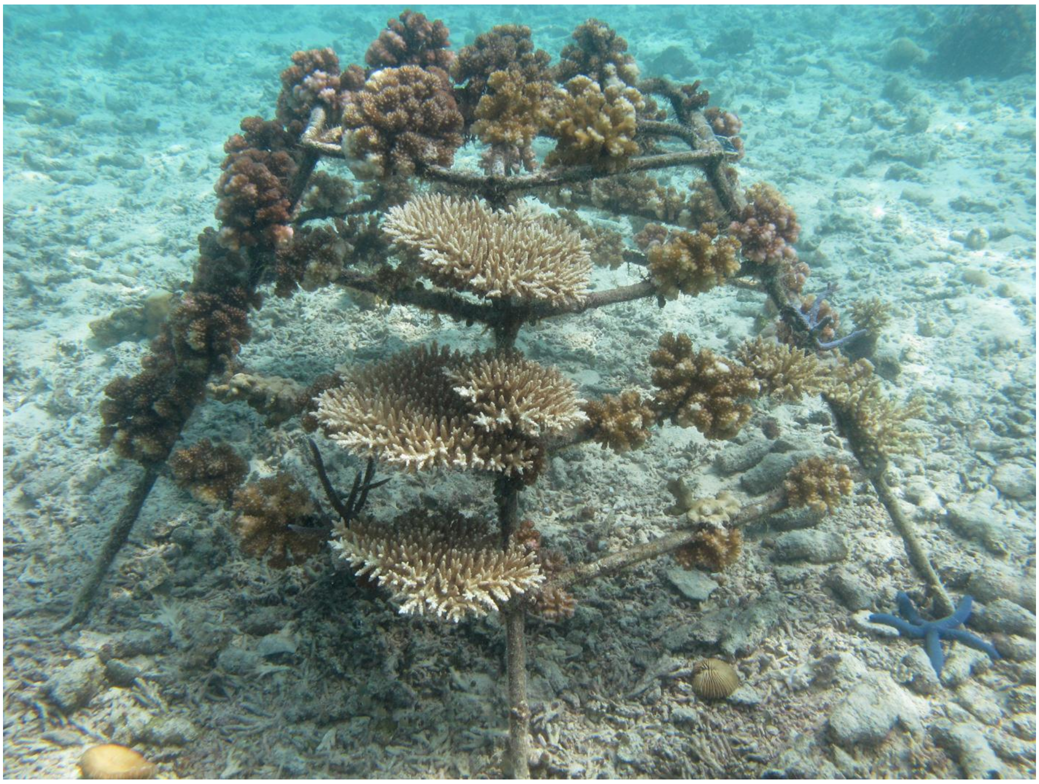


Fig 11. Mantabuan Frame 22: April 26th 2013 (1 year 4 months after seeding)

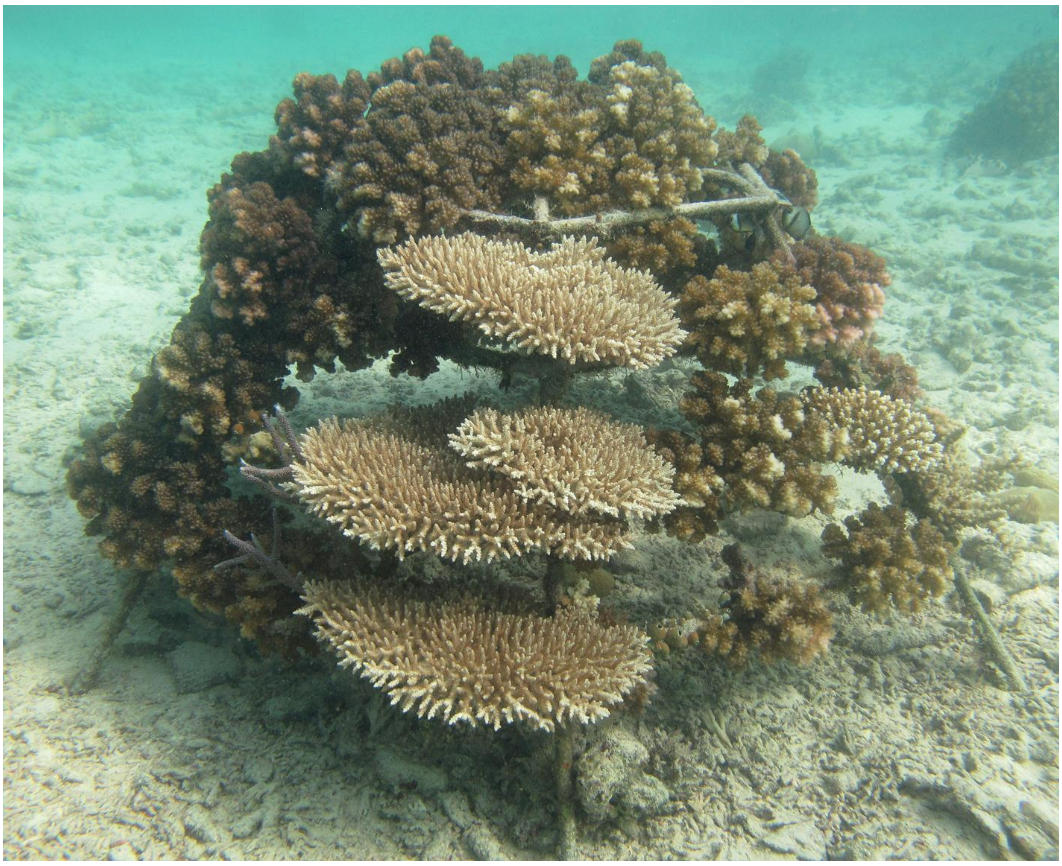


Fig 12. Mantabuan Frame 22: January 14th 2014 (2 yrs 1 mth after seeding)

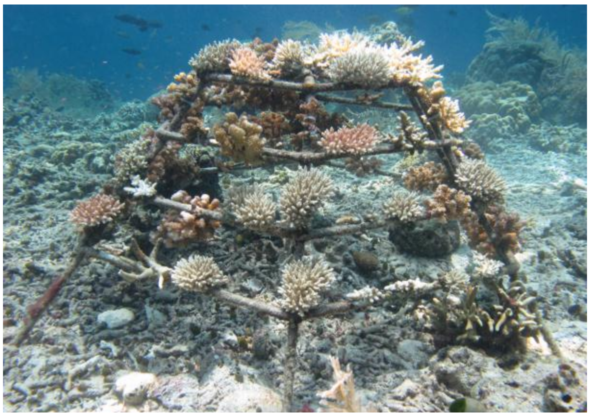


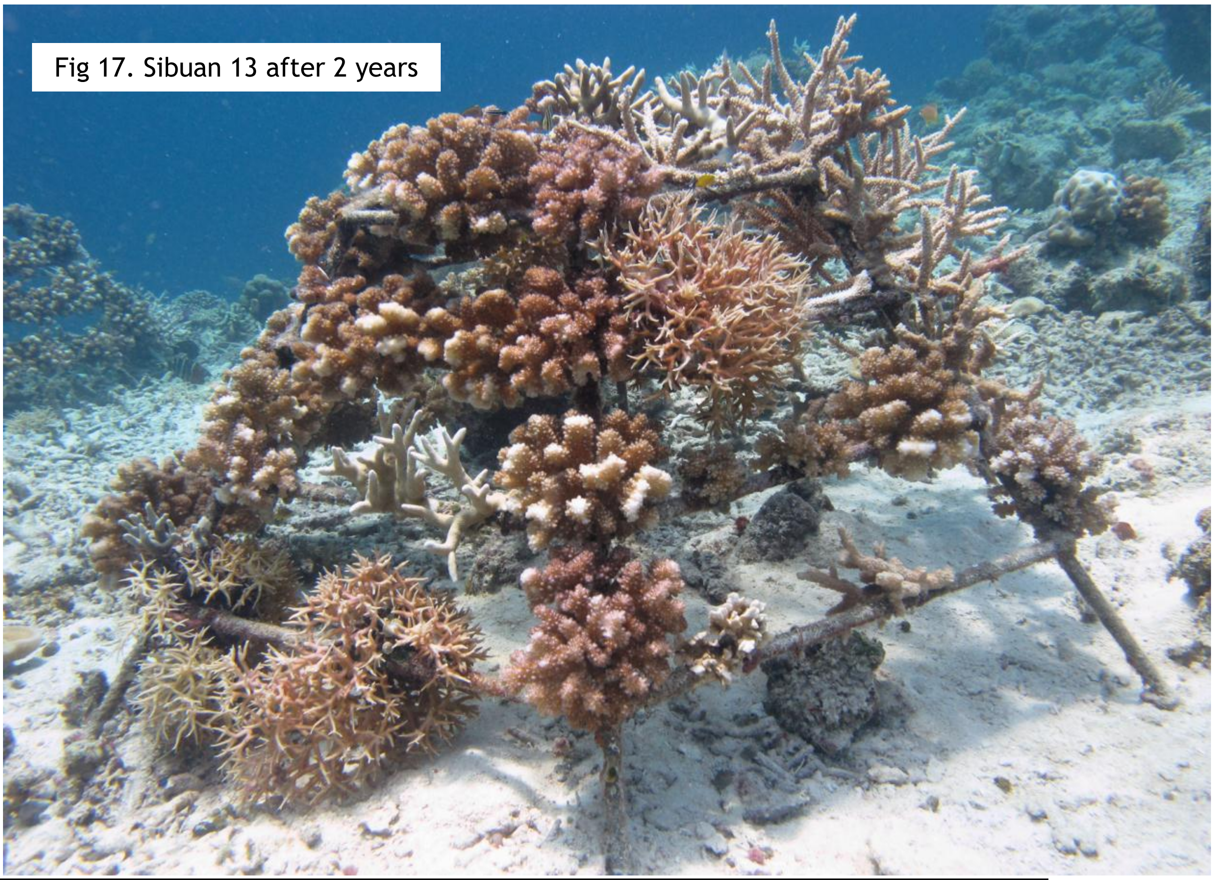
Fig 13. Sibuan 11 after 1 year 4 months

Fig 14. Sibuan 5 after 1 year 4 months

Fig 15. Sibuan 25 after 1 year 4 months

Fig 16. Sibuan 1 after 2 years

Fig 17. Sibuan 13 after 2 years



A brief summary of key findings for the various types of coral used on the frames is given below:

1. Branching Corals

Acropora

Acropora species are known to be amongst the fastest-growing reef corals. In many locations on the shallow reef arborescent (branching) *Acropora* form extensive monospecific or mixed species stands. Other species grow as bushes, plates and tables. We used fragments from a variety of forms and had good overall success, with some strong growth, as shown by the examples below.

It is not unusual for adjacent colonies of some 'staghorn' *Acropora* species to grow together and/or coalesce, so building a large and intricate network of branches.

Figure 18. Mantabuan Frame 17 with *Acropora intermedia* colonies spanning nearly 1m after 2.5 years.

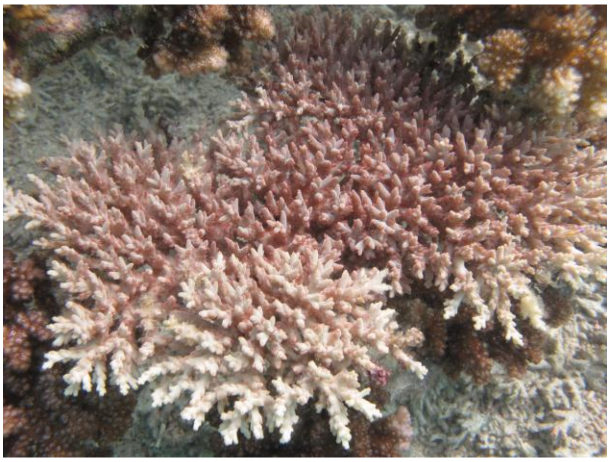


Figure 19. Mantabuan Frame 8. Two colonies of *Acropora loripes* forming a spread of approximately 32cm.

Figure 20. Mantabuan Frame 22. *Acropora cytherea* table 28cm diameter after about 2 years growth.

Acropora florida also showed fast growth. For example, a fragment on the Mantabuan frames had reached a maximum span of 30 cm after just over 2 years of growth (Figure 21).

Fig 21. *Acropora florida* after 2 years growth.

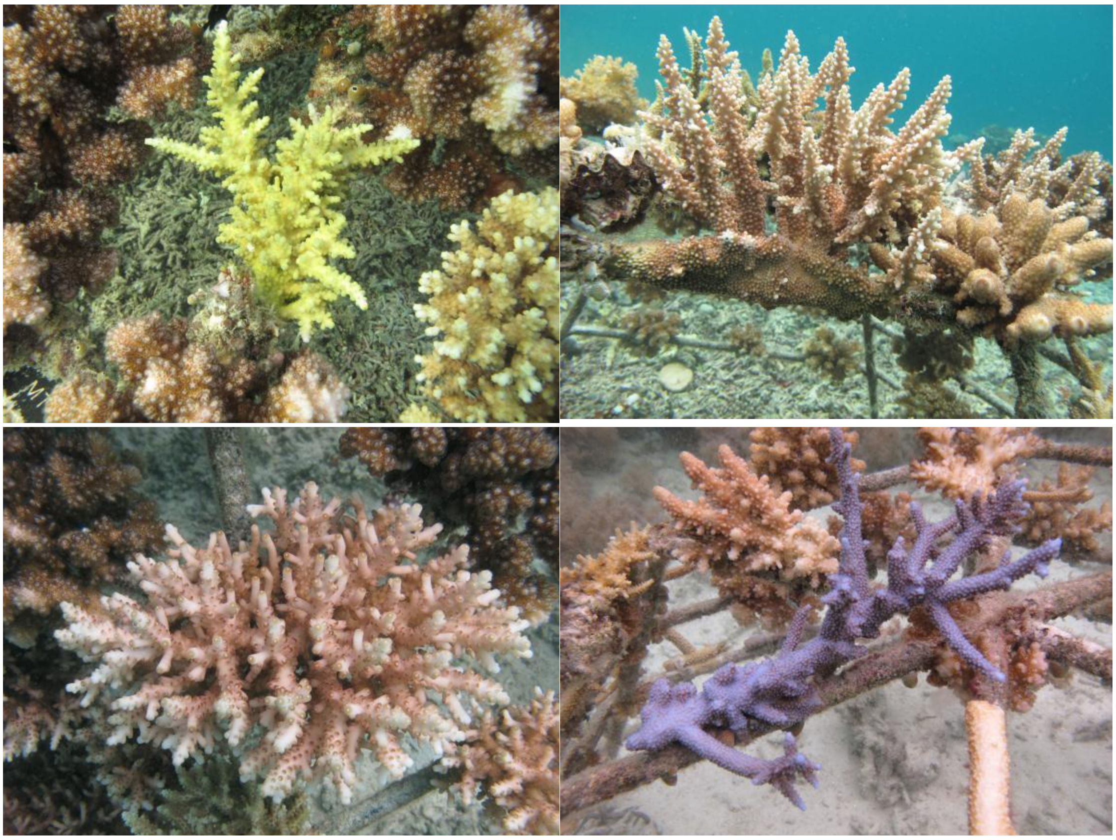


Figure 22. Selection of well-established and colourful *Acropora*

Not all Acroporas grow at the same fast rate. One specimen of *Acropora humilis* monitored throughout the coral frame programme grew from 8cm to 18cm (maximum spread) over a period of 2.5 years, which is slower than many of the plates and more loosely branching varieties.

Figure 23 (above)
Acropora humilis
Mantabuan Frame 11
11th June 2011 (8cm)

Figure 24 (opposite)
13th Feb 2013

Figure 25 (below)
14th January 2014 (18cm)

Pocillopora

Pocillopora species are very common on reefs in the Tun Sakaran Marine Park and were used quite extensively on the frames because of their good survival and growth. Most of the fragments used were *Pocillopora verrucosa*, which was readily available in the vicinity of the frames.

Figure 26. Fragment of newly attached *Pocillopora verrucosa*.

Figure 27. *Pocillopora verrucosa* colonies after 2 years.

Around 2 years after seeding, the fragments had grown into colonies about 15-18cm diameter and in many cases formed a dense canopy over the top of the frame (Fig 27). The maximum dimension recorded was 24cm. Unlike some *Acropora* species, adjacent colonies of *Pocillopora* do not fuse with each other, even if they have originated from the same donor colony. It will be interesting to see how they survive/spread as time goes on.

Pocillopora is known as a 'pioneer' and so it was not surprising to find self-seeded individuals on the frames (Fig 28).

a

b

Figure 28
a) *Pocillopora damicornis* approx 12mm, 8 months after deployment of the frame b) Self-seeded colony 9cm diameter.

Seriatopora

Seriatopora is closely related to *Pocillopora* but forms more finely-branched colonies. It is not nearly as common as *Pocillopora* in the shallow areas around the frames and the colonies tend to be rather delicate and more difficult to attach so we only used it sparingly. However, the fragments that we attached survived well and showed rapid growth, with one colony reaching 30cm in diameter after 2 years.

Figure 29.
Seriatopora approximately 8cm diameter after 7 months

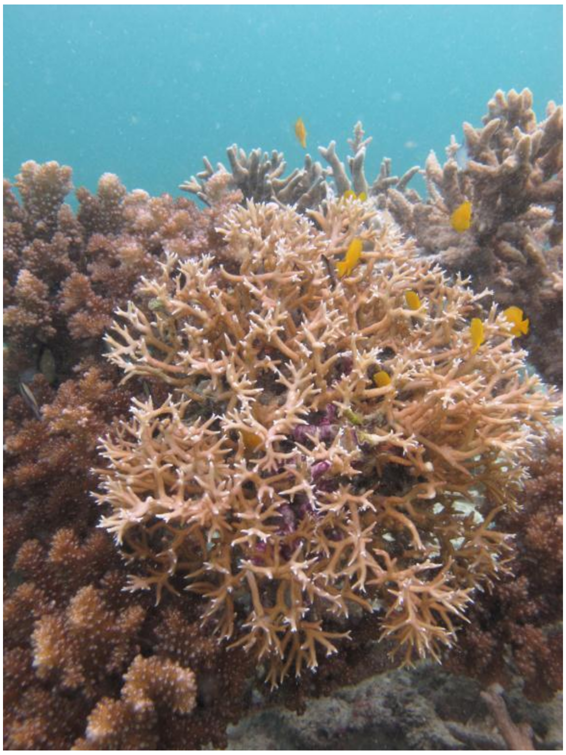


Figure 29.
Seriatopora approximately 30cm diameter after 2 years on Sibuan frame

Porites

Porites is very abundant in the Semporna area and includes branching, pillar-like, sub-massive, massive and encrusting species. We mainly used *Porites cylindrica*, which is one of the commonest branching species. Survival was reasonably good but growth is slower than *Acropora* and *Pocillopora*.

Figure 30. *Porites cylindrica*

Several other branching corals were also tried, including *Hydnophora rigida* (Figure 31), *Pectinia alcicornis*(Figure 32) *Millepora* (fire coral),. These showed good rates of survival and growth.

Figure 31. *Hydnophora rigida*

Figure 32. *Pectinia alcicornis*

Figure 33. *Millepora* sp

2. Leafy Corals

Trials were carried out with a few leafy / foliaceous corals, including *Montipora* (Figure 34) and *Echinopora* (Figure 34). These did not show long-term success.

Figure 34 Newly-attached *Montipora*

Figure 35 *Echinopora lamellosa*

Semi-massive/Massive Corals

Semi-massive and massive corals are known to be amongst the slowest growing of all reef corals, often adding less than one cm annually. However, they are vitally important reef-builders and so we experimented with a few fragments, to investigate whether there was potential for the frames. Loose pieces of massive corals are generally difficult to find but at the Mantabuan 60 frame sites there were a number of unattached nodules on the rubble floor. It is likely that these naturally-occurring 'coraliths' were created after attaching as larvae to pieces of rubble and survived despite being rolled around on the rubble and sand.

Several colonies of *Galaxea* were used (Figure 36) and although some survived for a few months (Figure 36) they did not thrive in the longer-term.

Figure 36
Newly-attached nodule of *Galaxea.*

Figure 37. *Galaxea* after 6 months, showing how the skeleton and tissues have grown over the cable-tie.

The faviid coral *Cypphastrea* was used at the Mantabuan 60 frame site and has become firmly attached. The corallites have grown round the cable tie and the colony had reached a diameter of 7cm after 2 years (Figure 38).

Figure 38. *Cyphastrea* sp on Mantabuan frame after 2 years growth.

FISH COLONISTS

Fish associated with the coral frames fall into one of two categories a) juvenile recruits and b) visitors.

Juvenile recruits

As the corals on the frames grew, they began to provide a suitable micro-habitat for recruitment of juvenile fish from the plankton. Recruits were first noted after about one year when between 10-20% of the frames sheltered small juveniles. After 2 years, between 70-90% of the frames were colonised by anything between one and well over 50 fish.

There were some clear patterns both with regard to the types and sizes of coral that become colonised and the types of fish that settled. Branching species comprised the majority of corals seeded onto the frames and those with a fairly tight branching structure were more likely to be colonised than those with fewer or more widely spreading branches.

Pocillopora has a compact growth form and provides many small spaces for fish to hide (Figure 39). This coral frequently became colonised once it had reached a size of around 12cm or more, especially where colonies grew closely together. *Dascyllus* species were particularly likely to be associated with *Pocillopora* and it is possible that the recruits will remain on the frames into adulthood (Figure 40). When first seen, the juveniles were estimated to be less than 1cm in length but they grew fast and had reached an estimated 6-7cm after only just over a year.

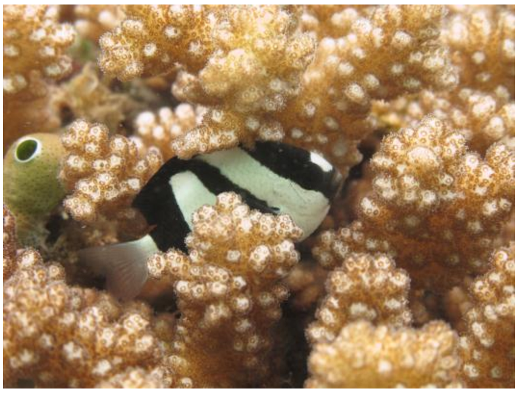


Figure 39
The humbug *Dascyllus aruanus* sheltering on *Pocillopora* at Mantabuan

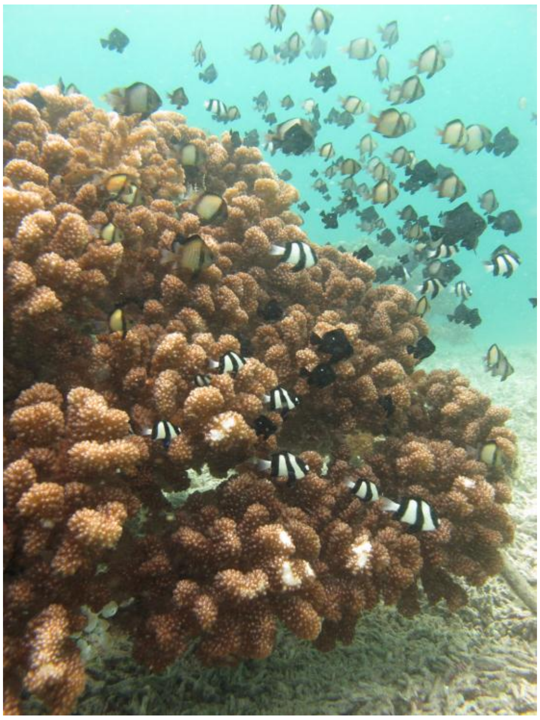


Figure 40. Mantabuan frame 2.5 years after seeding and now supporting dense growths of *Pocillopora* and three species of Dascyllus (*D. trimaculatus, D. aruanus* and *D. reticulatus*).

Other small damselfish (pomacentrids), wrasse and a few juvenile groupers were also recorded on the frames. The groupers and many of the wrasse will move away and extend their territories/home range as they grow into adults.

Figure 41.
A group of young yellow damsels (*Pomacentrus moluccensis*) around *Seriatopora* on the Sibuan frames, together with the humbug *Dascyllus reticulatus* and a juvenile *Chromis* sp.

Two species of juvenile butterflyfish were seen amongst the branches of *Acropora* colonies about 1 year after deploying the frames. They were clearly resident, never venturing away from the shelter of the corals. They were distinct from visiting adult butterflyfish of the same and other species (e.g. *Chaetodon kleini*)) that roamed onto the frames to feed (Figure 43b).

The juveniles recorded were the eight-banded butterflyfish *Chaetodon octofasciatus* (Figure 42) and the eastern triangular butterflyfish *Chaetodon baronessa,* both of which are obligate coral feeders. Individuals up to an estimated 7cm were apparently using the frames as their exclusive territory, but it is likely that they would enlarge their territory/home range as they matured and roam away from the frames.

Figure 42. Juvenile *Chaetodon octofasciatus* living in *Acropora* corals on a coral frame at Sibuan.

Visitors

Visitors to the frame reflected the species mix in the area. The fish involved were mainly adults and it appeared that they were using the frames for shelter or a place to find food. The photographs below show a selection of the visitors. Others included triggerfish (*Sufflamen bursa*) trumpetfish (*Aulostoma chinensis*), goatfish (e.g. *Parapeneus multifasciatus*), filefish (*Aluterus scriptus*), parrotfish, Moorish idol (*Zanclus cornutus*), grouper (*Anyperodon leucogrammicus*), porcupinefish (*Diodon liturosus*) and other species of wrasse (e.g. *Thalassoma lunare, Cheilinus fasciatus*), butterflyfish (e.g. *Coradion chrysozonus, Chaetodon rostratus, C. octofasciatus, C. baronessa*) and bream (e.g. *Scolopsis bilineatus*).

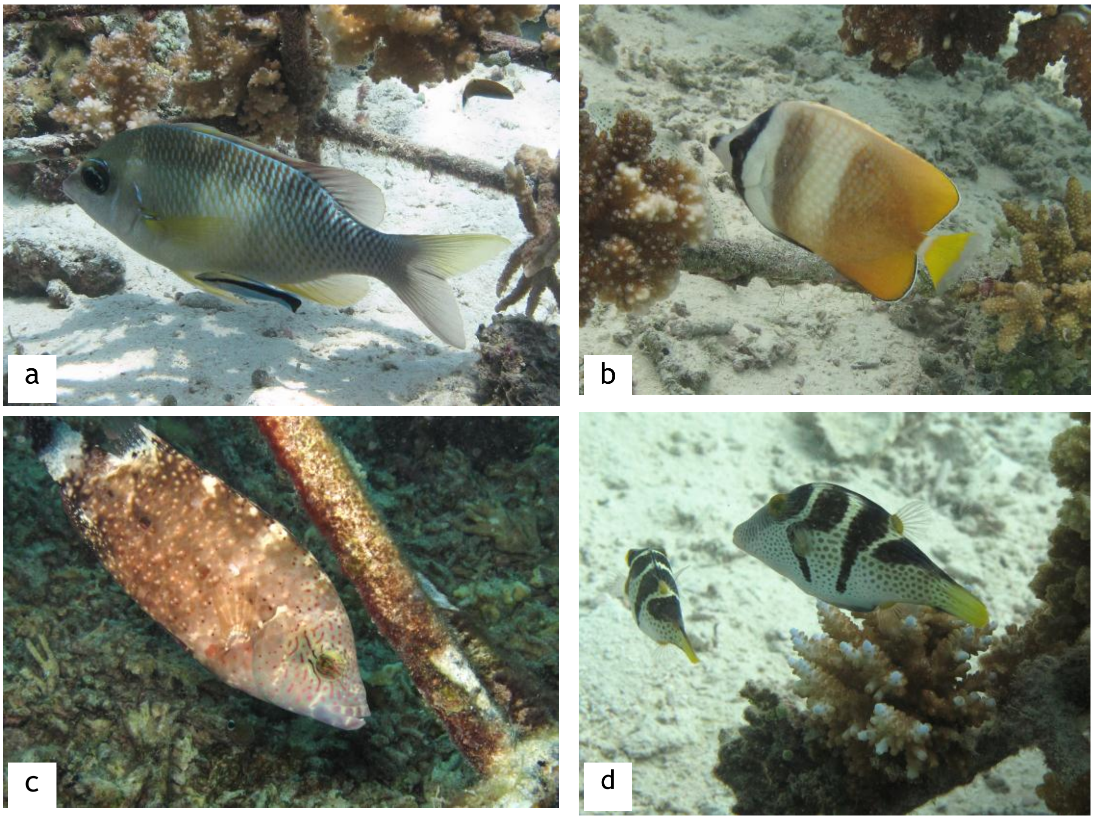


Figure 43.
Visitors to the frame a) Pearly spinecheek *Scolopsis margaritifer* b) Klein's butterflyfish *Chaetodon kleini* c) Floral wrasse *Cheilinus chlorourus* d) Black-saddled toby *Canthigaster valentini.*

Figure 44.
Cuttlefish using one of the frames at Mantabuan as a refuge.

OTHER COLONISTS

Stable, 'bare' surfaces in reef areas are generally fairly rapidly colonised by marine life, provided that conditions are suitable and spores or larval forms are present in the water. The spaces on the frames between the coral fragments provided a stable surface for attachment and it was not surprising to find that they became colonised by a variety of organisms. Some of these plants and animals may be grazed or preyed upon before they grow to any significant size, but others will survive and thrive.

It was noted that the struts of the coral frames soon became covered in a fine film which was probably a mixture of cyanobacteria (often called blue-green algae), diatom films and sediment (Figure 45). These films did not appear to be inhibiting growth of the coral fragments although they may prevent settlement of other organisms so they were brushed off during the initial monitoring phases. There was also some growth of filamentous algae, especially on dead coral fragments (Figure 45) but no macro-algae were seen. Algae can become a nuisance particularly in areas where nutrient levels are high and herbivorous grazers are low in abundance and although this was not an issue on the frames, the tufts were brushed away as a precaution.

Figure 45
Coral frame 6 months after seeding, showing a dead coral fragment covered by filamentous algae and the strut colonised by small upright hydroids and diatom/blue-green algal films.

Certain other groups and species apart from algae are well known as 'pioneer' settlers on empty space on the reef and it was noted that some of these were well represented on the frames. Hydroids were common colonists (Figure 45). They were not examined in detail but it appeared that just a few small species were involved. They formed quite a dense 'fuzz' in places but removing them completely was not easy because attachment was firm and the stems were tough and flexible. Thus they were difficult to either pull off or cut off.

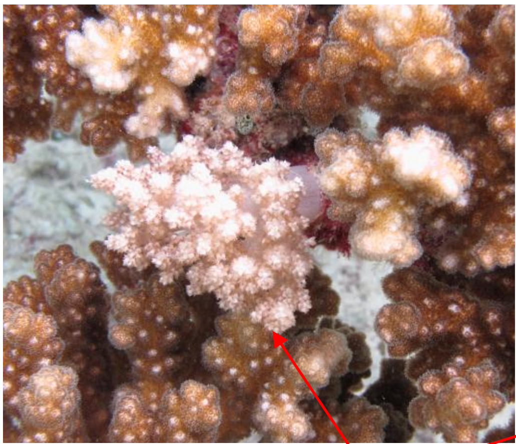
Seasquirts were also early colonists, particularly on the Sibuan frames. They settled on the bars between the corals and although they are not reported to be aggressive (unlike some soft corals) there was a danger that they might overgrow the coral fragments and so as many as possible were removed.

Figure 46.
This specimen of the colonial seasquirt *Didemnum molle* had settled and grown to 19cm in length over a period of only 5 months.

Figure 47. A dense cluster of the colonial seasquirt *Atriolum robustum* attached to one of the Sibuan frames. This is a small species not exceeding about 3cm in height. It appeared within a few months of deploying the frames.

A number of other colonists were also recorded, but at comparatively low density. These included hard corals (e.g. *Pocillopora* (Figure 28), *Acropora* and *Cyphastrea*), sea fans (Figure 48) and soft corals from the family Neptheidae (Figure 50). The latter can grow quite rapidly and may out-compete hard corals but were left in place for the time being.

Figure 48. Small sea fans attached to the underside of the coral frames.



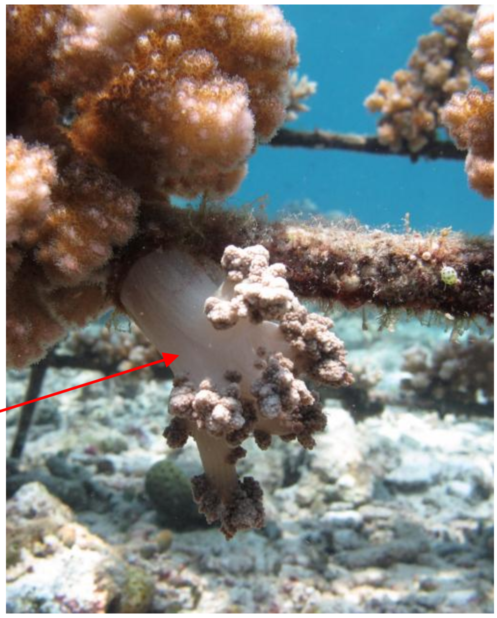


Figure 49. Young colonies of soft corals from the family Nepheidae on the Sibuan frames.

In addition to the attached flora and fauna, a number of mobile animals also took up residence on the frames. Small crabs were commonly seen in *Pocillopora* and a number of hermit crabs and small gastropod snails were also recorded. Starfish and feather stars also sometimes crawled onto the frames.

Lessons Learnt and Recommendations for Continuation of the Coral Frame Programme

Size and design of the frames

Relatively small frames were deliberately chosen for this programme because of the need for structures that could easily be carried on the boat and placed underwater by one or two people without any need for ropes or other equipment. In addition, it was considered that they would fit well with the underwater terrain in the Tun Sakaran Marine Park.

Smaller or larger frames could be made according to need but it is recommended to keep the ‘umbrella’ shape because this has a low centre of gravity and is very stable. It also creates a small ‘bommie’ shape which blends in well with the natural reef.

Coating the frames in resin and clean coral sand is a critically important part of the process because this a) seals the steel reinforcing bars and prevents corrosion and b) provides a ‘coral-friendly’ surface for the fragments. The coating process takes a number of days to complete because the coats have to dry between applications.

Skills and training

Deployment of the frames on the reef needs certified divers able to work well underwater. Again, training is needed to ensure that the divers who are collecting, preparing and attaching the fragments know which corals to select and the correct techniques for preparing and attaching them.

It is also important that the divers are fully briefed about the need to take care when working on the reef. In some cases there is nothing but rubble around the frames and it is safe to kneel down, but careful attention needs to be paid to live corals in the vicinity and divers should be vigilant about keeping fins and equipment away from the reef or other frames.

Figure 51
Good diving practice with fins held well away from the reef while working on the frames.

Site selection

For this programme, the specific purpose was to deploy the frames at sites that had been damaged by fish blasting. These are usually fairly easy to identify because there are significant amounts of low-lying rubble. Corals can die and collapse as a result of other impacts such as crown-of-thorns predation or storm damage but another sign that fish bombs were a cause of the damage is the presence of coral heads that have been split apart or have died on one side as a result of the blast.

Coral frames can also be used to create habitat for fish and other marine life if this is deemed appropriate but it is critically important that they are placed in areas where the conditions are suitable for coral growth. If the water is polluted, light levels too low or sedimentation a problem then the transplanted fragments are unlikely to thrive.

Whilst the frames can be used as an education and awareness tool to demonstrate how reef rehabilitation can work, it is preferable if the effort involved in setting them up is directed towards solving real problems – such as the loss and degradation of reefs due to destructive fishing, boat groundings or mortality and collapse of corals due to bleaching.

Deployment and arrangement of the frames on the reef

Great care needs to be taken to prevent damage to living corals when placing the frames on the reef. At all of the sites selected in the Tun Sakaran Marine Park, there were large patches of sand and rubble and the frames could be dropped from the boat under the direction of a ‘lookout’. If the frames are to be established in smaller gaps in the reef then the safest way of ensuring that the frames land in the correct spot would be to lower them one-by-one on a rope from the boat, with divers controlling their descent.

It is advisable to leave a space of at least 2.5m between the frames in order that the monitoring team can easily access all sides for monitoring and photography.

Species / fragment selection

In order to maximise chances of survival, it is best to use species/fragments that have been collected from the immediate vicinity of the frames. Introducing corals from deeper/shallower water or other locations could add to the stress because they would have to acclimatise to different environmental conditions as well as being handled and/or fragmented.

It is possible to plant-up the frames with fragments of the same species or with mixtures, depending on what would be the most appropriate for the location. Where a single species is used for all or a segment of the frame it is best to place fragments from the same colony adjacent to each other because they are more likely to fuse rather than compete with each other as they grow. However, as shown by *Pocillopora*, this is not always the case.

One of the recognised 'issues' with Acropora is that it is common for the lower branches of staghorn coral to die-back. This may be as a result of shading, predation, sedimentation, disease or other factors but is commonly seen in the wild and was noted on the frames. It may not necessarily lead to the death of the whole colony.

Funding and sponsorship

The programme to date has been supported by the BBC Wildllife Fund and the Lighthouse Foundation. This enabled equipment and materials to be purchased and training courses and fieldwork to be carried out. Sabah Parks are committed to carrying on the programme and the Federal Department of Fisheries have assigned funds for the deployment of more frames in Tun Sakaran Marine Park over the next two years.

In the Maldives, where the design for the frames originated, there is a sponsorship programme run in collaboration with the private sector (http://reefscapers.com/coral-frame-sponsorship/). Around 5 resorts have signed up to the scheme and sponsors (guests) are asked to donate from $150 (RM 484) for a small frame up to US$500 (RM 1,614) for a large one. This type of approach could be tried with resorts in Semporna but whether guests would donate such large sums is unknown. The Maldives is a high-end, luxury holiday destination whereas many of the visitors to Semporna are budget travellers. However, it would still be possible to set up a scheme whereby visitors contributed what they could afford towards a coral frame.

The funds could then be used to pay members of the local community to make the frames, thereby helping the local economy, encouraging conservation action and enhancing reef biodiversity and productivity. Each frame ready for seeding (including the iron bars, resin, brushes, gloves, cable ties and consumables) costs about RM100 (US$ 31; GBP£18). This does not include labour costs, boat fuel and costs of diving equipment).

A feedback mechanism similar to that operating in the Maldives could also be launched to ensure that people who 'adopt a frame' receive information about its progress. As explained on the reefscapers website:

> *When entering the sponsorship program, we will make and transplant your frame, email you its unique reference number and upload photos of it onto this site every six months for you to monitor its progress.*

REFERENCES

Wood E.M and Ng J.V. 2012. Progress report: Coral Frames Programme. Semporna Islands Project/Marine Conservation Society.