Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 12.24

What is the future for extensive areas of reef impacted by fish blasting and coral bleaching and now dominated by soft corals? A case study from Malaysia.

E. Wood, F. Dipper

Marine Conservation Society, Unit 3 Wolf Business Park, Alton Road, Ross-on-Wye HR9 5NB, UK.

Abstract. Reefs in the Tun Sakaran Marine Park, Sabah, have been damaged by fish blasting and also by coral bleaching and crown-of-thorns starfish. Coral communities comprising a mixture of growth forms and including a greater proportion of massive species are recovering better than those with a high proportion of laminar and foliaceous species. An example is at Kapikan Reef, a clear-water site where there were extensive stands of laminar *Montipora* on the shallow fore reef. Collapse of these colonies created rubble that has typically become colonised by soft corals, particularly *Xenia* spp, *Cespitularia* spp (Family Xeniidae) and *Clavularia* (Family Clavularidae). Fields of soft corals have been created, covering extensive areas and acting as a barrier to recruitment of hard corals. Lack of shelter, structural complexity and food in these areas is having a significant impact on fish populations. 71% of fish at the soft-coral-dominated site fell into the 0-5cm length category, and no fish over 15cm were recorded. At the control site, only 35% fell into the 0-5cm category, and individuals up to 35cm were recorded. Currently there are no signs of recovery to a hard-coral-dominated community on the Kapikan reef, and this has implications for biodiversity, reef growth and productivity.

Key words. phase shift, xeniid soft corals, resilience

Indroduction

Globally, coral reefs are in a state of decline, with those in South-East Asia showing some of the most serious losses and degradation ((Wilkinson, 2004). Problems include over-exploitation of reef resources, destructive fishing methods, pollution, disease, coastal development and coral mortality caused by ocean warming. One outcome of these impacts and disturbances can be loss and/or replacement of reef-building corals with other organisms. Reef-building corals are an essential component of healthy reefs, but there are an increasing number of reports of phase shifts from an ecological system where hard corals are dominant to those where non-reef-building organisms such as algae or soft-bodied cnidarians are dominant (Done 1992, Hughes, 1994, Chen and Dai 2004). A better understanding of the factors affecting resistance (ability to withstand impacts) and resilience (ability to recover) can help managers and other stakeholders decide on appropriate strategies and interventions that may help to stem further coral reef decline and promote recovery. This paper describes the response of reefs in Sabah, Malaysia to disturbances that have led to a phase shift from hard corals to soft corals, and have had a secondary impact on fish populations and biodiversity.

Materials and Methods

The Tun Sakaran Marine Park is situated off the south-east coast of Sabah, East Malaysia (Fig. 1). It was gazetted in 2004 and covers an area of 350 km^2. The reefs have been monitored since 1998 using rapid assessment techniques and quantitative surveys based on Reef Check methodology as described in Hodgson et al. 2006. A Reef Check monitoring site was first established on Kapikan Reef in 1998, and was re-surveyed in 1999, 2000, 2004 and 2007. Fish censuses were carried out on the same reef in May 2008 at sites dominated by soft corals, with a control site on the adjacent Mantabuan reef. For the fish censuses, counts were made along 10 belt transects, each 5m wide x 20m in length. Each 20m transect was split into 5-m sections and all specimens were recorded. Fish were identified to species where possible, or to family, and were assigned visually to size classes.

Results

The Kapikan reef is approximately 3.5km in length and has a gently-sloping profile. The shallow fore reef (1 – 5m depth) is up to 100m wide and has a very poorly developed spur and groove formation manifested as low undulations. The reef rim is not

M

well defined, but curves gently, with a slightly increased degree of slope below about 10m depth.

Figure 1. Location of study site: Tun Sakaran Marine Park. Kapikan reef (K) Mantabuan reef (M)

Hard and soft coral cover

Preliminary surveys along this reef in 1998 revealed areas of intact coral, with laminar and leafy *Montipora* and staghorn *Acropora* common, but with many other genera and growth forms present. Xeniid soft corals were widespread and common, sometimes forming patches many metres in diameter. In addition to the healthy stands of live coral, there were places where corals had been broken, probably as a result of fish blasting that is widespread in the area. In 1998, significant bleaching of hard corals due to an increase in sea surface temperature was noted on this reef, with as many as 30% of the colonies affected.

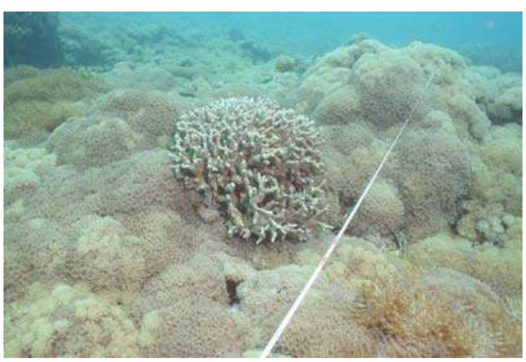


Figure 2. Kapikan reef 2007, heavily colonised by *Clavularia* and *Xenia* at a depth of 5m

Rapid assessments made along this reef annually since 1998 have revealed a gradual increase in the proportion of soft corals, and an expansion of the patches to form extensive fields (Fig. 2). The soft corals involved are *Xenia* spp, *Cespitularia* spp (Family Xeniidae) and *Clavularia* (Family Clavularidae). *Braireum* and *Efflatounaria* are also present, forming smaller patches. The soft corals have successfully colonised rubble, much of which on this reef consists of plates up to 15cm in diameter. Larger pieces of old coral and the tops and sides of scattered limestone blocks created by the death of massive corals on this reef have also mainly become colonized by the same assemblage.

Results from the Reef Check monitoring site established on this reef in 1998 show an upward trend in cover by soft corals on both the 4m and 9m depth transect. Soft corals were already well established on the shallow transect in 1998 (43% ±SE 2.68) and by 2007 cover had increased to 75.63% ±SE 2.43 (Fig. 3). On the 9m depth transect soft coral cover rose from 0.6% ±SE 0.25 in 1998 to 38.75% ±SE 2.25 in 2007.

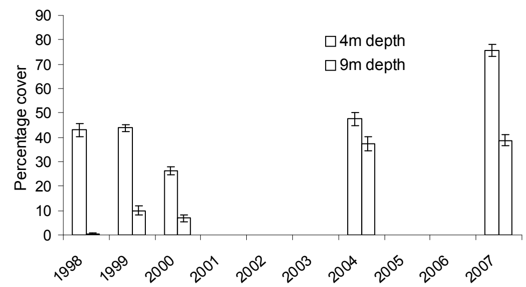
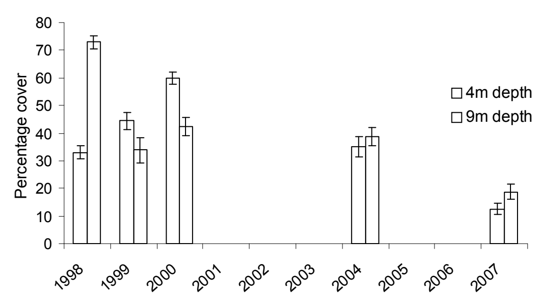


Figure 3. Percentage cover by soft corals at the Kapikan monitoring site

Live hard coral has fallen over the same period (Fig. 4). Hard coral cover on this reef could be declining for a number of reasons. Destructive fishing, crown-of-thorns starfish and bleaching have all been recorded and may be acting separately or synergistically. During the first Reef Check survey in 1998 bleaching was in evidence, with an estimated 30% of colonies bleached at 9m and 10% at 4m



depth.

Figure 4. Percentage cover by hard corals at the Kapikan monitoring site

Damaged reefs in other parts of the Park show different responses. Rapid assessments over the same period, together with detailed information from 10 other monitoring sites, show that in many places where shallow-water coral assemblages dominated by *Acropora* and other branching corals have suffered damage, they have been reduced to smaller fragments of rubble. Unlike the larger rubble pieces on the Kapikan reef, these areas have not been colonized either by hard or soft corals.

In habitats where massive hard corals have died, there have been phase shifts to alcyoniids such as *Sinularia*, *Litophyton* and *Sarcophyton*, but this is not as comprehensive as the xeniid-*Clavularia* invasion seen on the outer reefs. Xeniids and *Clavularia* also occur on the inner reefs, but form discrete clumps rather than extensive fields.

Fish censuses

Fish counts were carried out on a typical section of the Kapikan reef dominated by xeniids and *Clavularia* and on a section of the adjacent Mantabuan reef where invasion by xeniids and *Clavularia* had not occurred. Both sites are subjected to similar levels of fishing.

Mean soft coral cover at the fish census site on Kapikan was 66.6% (± 7.94) in comparison with only 2.04% (± 0.65) at Mantabuan.. Conversely, mean hard coral cover was 3.6% (±0.99) at Kapikan and 46.62% (± 5.02) at Mantabuan. Both census sites had similar amounts of rubble (around 20%), but the Mantabuan reef had a greater proportion of rock (16.75% ±2.54) than Kapikan (2.85% ±0.85).

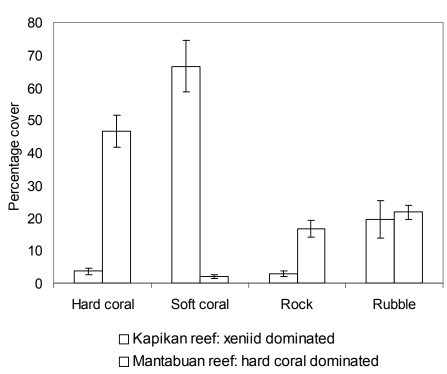


Figure 5. Main benthic components at the fish census sites

A total of 683 individual fish were recorded in the ten 5m x 20m transects on the xeniid-*Clavularia* dominated reef. Observations at the micro-habitat scale revealed that these fish were associated with rubble patches or clustered around the small number of surviving hard corals. Maximum fish length was 15cm, but the majority of fish (71%) were in the 0-5cm size category. The majority of these specimens were small labrid and pomacentrid species and mean density in the 11-15cm size class (the largest represented) was only 3/100m^2 (Fig. 6).

On the Mantabuan reef a total of 1,452 fish were recorded, of which only 35% were in the 0-5cm size category. 21% of individuals were in the 11-15cm size category (in comparison with 4.5% on the Kapikan reef) and the maximum size of fish recorded was 35cm. Representatives from all trophic levels and a wide variety of families were present on the Mantabuan reef, including lutjanids, pomacanthids, scarids, serranids and chaetodontids as well as labrids and pomacentrids. Mean density in the 11-15cm size class was 10 times higher (30/100m^2) than on the xeniid-dominated reef (Fig. 6).

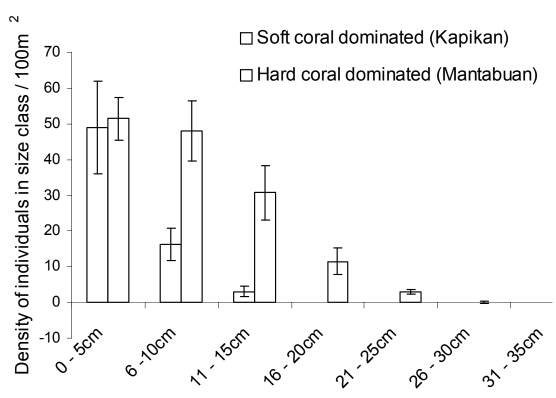


Figure 6. Density of fish recorded on the Kapikan (soft coral dominated) and Mantabuan (hard coral dominated) reefs according to size class.

Discussion

The reefs described in this paper are situated within the Tun Sakaran Marine Park, which was gazetted in 2004 and is currently the largest MPA in Malaysia. The Park lies within the coral triangle and the reefs are of value for their high biodiversity, natural resources and recreational interest. However, like many others in the region, they have been damaged and degraded, particularly by destructive and over-fishing, coral bleaching and predation by crown-of-thorns starfish.

Although the relative contribution to reef decline from each of the different impacts/activities has not been quantified, one of the outcomes at some sites has been a phase shift from hard corals to a predominately xeniid-*Clavularia* assemblage. This particular community change has developed only on the gently-sloping eastern-facing outer reefs where the water is clearest, and where laminar hard corals (primarily *Montipora*) had been common. When these corals collapsed they produced relatively large pieces of rubble that acted as suitable 'settlement plates' for xeniids and their allies. The tops and sides of scattered limestone blocks created by the death of massive corals on these outer reefs have also mainly become colonized by the same assemblage.

Xenia, Cespitularia, *Clavularia* and related forms are well know for their ability to colonise vacant space on reef surfaces, and can spread rapidly by cloning where conditions are suitable (Fabricius and Alderslade, 2001). It appears from this study that the combination of clear water, gentle slope and a disturbed but sufficiently stable substratum on the Kapikan outer reef has given xeniids a competitive advantage over other organisms. Their strategy of larval brooding and effective asexual propagation enables fast clonal growth (Fabricius and Aldersade, 2001) and their success is further enhanced by their ability to produce allelopathic substances that chemically inhibit growth and survival of other organisms (Sammarco et al, 1983, Fabricius and Alderslade, 2001).

Damaged reefs in other parts of the Park show different responses. In many places, shallow-water coral assemblages dominated by *Acropora* have been reduced to smaller fragments of rubble that have not, as yet, been colonized either by hard or soft corals. These reefs experience similar tidal current and wave exposure to the xeniid-*Clavularia* dominated reefs, but the fragments are probably too unstable to allow colonisation. Where stable limestone blocks remain, alcoynid soft corals belonging to the genera *Sinularia* and *Sarcophyton* are typical colonists. Xeniids occur, but do not form the extensive fields seen on the outer reefs. Similar habitat preferences have been described for the Great Barrier Reef, where alyconiid 'invasions' are associated with disturbed nearshore reefs (Fabricius, 1998) while xeniids invade outer shelf sites (at > 3m depth). In the latter cases, however, the dominant genus was *Efflatournaria*, and the patches were reported to be not larger than tens to hundreds of square metres.

In Komodo National Park (Indonesia) large fields of the soft coral *Xenia* often grow on top of rubble created as a result of fish blasting (Fox et al. 2003). The genera *Sarcophyton*, *Nepthya* and *Clavularia* are also present in these *Xenia* fields.

Phase shifts to cnidarians other than alcyoniids have been reported from a number of locations, and mainly involve coralliomorphs (Kuguru et al. 2004; Tkachenko et al. 2007; Work et al. 2008). A shift to domination by the sea anemone *Condylactis* has been reported from southern Taiwan (Chen and Dai, 2004) following pressure on reefs over two decades from overfishing, coastline development and tourism.

The fields of xeniids now colonizing large sections of the Kapikan outer reef have created an impenetrable blanket that provides few hiding places or feeding grounds for fish. The fish that are present are mainly small species of labrid and pomacentrid that are associated with isolated patches of rubble or small rocks and corals within the xeniid-*Clavularia* fields. This represents a significant reduction in value of the reef for biodiversity, local fisheries and tourism.

The fact that few large fish were recorded even at the hard coral dominated sites could be related to the relatively short transect lines (20m). However, numerous fish surveys conducted throughout the Park using 50m transects confirm that large fish are very scarce. Mean density of reef fish such as groupers and rock cod, snappers, emperors and sweetlips at 12 monitoring sites recorded annually since 1998 has typically been less than one individual per family per100m^2, and at several sites has been zero (Wood, 2008). The reefs in the Park have been heavily fished for decades using hook and line, nets, traps and explosives, so it is not surprising that fish density is low and sizes are small.

The ability of the reef to recover from this phase shift is unknown, but it appears that currently the xeniids are successfully competing with the remaining live hard corals in addition to spreading actively over damaged areas. Thus they are not only forming a physical blanket preventing settlement and recruitment of hard corals, but they are also killing those that remain.

Experimental work has shown that reefs exhibiting a phase shift to algal dominance can recover in situations where herbivorous fish are abundant (Bellwood et al 2006; Hughes et al 2007). However, a parallel scenario is unlikely to exist for xeniids because they have few natural enemies. The only reason why they might die back is from senescence or from mortality as a result of bleaching or physical disturbance (e.g. storms).

Xeniids are known to be susceptible to bleaching (Fabricius and Alderslade 2001) but hard corals are also affected and so a warm water event would most likely cause die-back of both soft and hard coral communities. It is possible that storms could result in the rubble and/or soft corals being dislodged, although wave action is not an important modifying factor at this location. The east coast of Sabah is outside the hurricane zone, and severe storms are relatively infrequent. If the underlying rubble was again 'laid bare' as a result of storms or die-back of the xeniids due to bleaching there is no certainty that hard corals would prevail over soft corals when re-colonisation occurred.

It is difficult to predict what, if any, management interventions might be effective in enhancing the ability of the reefs to revert to hard coral domination. It has been shown that phase shifts to algal domination can be prevented or dramatically slowed down by the grazing of herbivorous fish. Thus a management 'insurance policy' to prevent such phase shifts from occurring is to manage fish populations so that over-fishing of large herbivores such as scarids and labrids does not occur. However, in the absence of effective soft coral 'grazers' it is difficult to know what options exist for managing xeniids and their relatives.

Experimental work on soft coral fields in the Komodo National Park (Fox et al 2003) showed that small hard corals were present beneath the soft coral canopy and 'fared much better' if the soft coral was removed. In addition, hard corals recruited to the cleared rubble, resulting in an increase from an average of 2.94 colonies per m^2 when the soft coral canopy was first cleared to an average of 7.15 colonies per m^2 after 6 months. In another experiment, Fox et al showed that *Acropora yongei* nubbins attached to PVC pipes and elevated 5-10cm above the soft coral canopy survived better than nubbins that were at the same level as the canopy. Survival was 70% after 6 months for the elevated nubbins in comparison with 30% for the nubbins in the canopy. The researchers concluded that soft corals inhibited recruitment, growth and survival of hard coral over the short term but suggested they could facilitate hard coral recovery in the long term. This is because the soft corals stabilise the rubble, and if gaps open up, hard corals may successfully settle in these more stable patches. It would be useful to carry out similar trials at the study site in Sabah to see if clearance of patches within the *Xenia* fields leads to an increase in hard coral cover.

In conclusion, human activities and impacts have changed the ecological character of the Kapikan reef from a reef-building to a non-reef-building state, and this altered ecology currently shows no sign of reverting back. Continued studies will determine whether or not the xeniid-*Clavularia* assemblage is a climax community, or whether this set of dominant organisms will be replaced by another or even revert to hard corals. Recovery might occur if the soft corals die back or are torn away by storms, and it is possible that clearance of patches within the *Xenia* fields could be beneficial.

It is anticipated that increased surveillance and enforcement in the area will lead to a reduction in fish blasting and that this will prevent more sections of the reef being reduced to rubble. It is vital that remnant populations of hard coral remain healthy because they will provide a source of coral larvae that could aid recovery of damaged areas.

Acknowledgements

Thanks to Sabah Parks and Marine Conservation Society (MCS) volunteers. This research is part of the Semporna Islands Project, supported by MCS from the Darwin Initiative and the European Community Global Environment Fund.

References

Bellwood DR, Hughes TP, Hoey AS (2006) Sleeping functional group drives coral-reef recovery. Current Biology 16: 2434-2439 [doi 10.1016/j.cub.2006.10.030]

Chen CA, Dai C-F (2004) Local phase shift from Acropora dominant to Condylactis-dominant community in the Tiao-Shi Reef, Kenting National Park, southern Japan. Coral Reefs 23: 508 [doi:10.007/s00338-004-0423-9]

Done TJ (1992) Phase shift in coral reef communities and their ecological significance. Hydrobiologica 247: 121-132

Fabricius KE (1998) Reef invasion by soft corals: which taxa and which habitats? In: Greenwood JG, Hall NJ (eds) Proceedings of the Australian Coral Reef Society 75th Anniversary Conference, Heron Island October 1997. School of Marine Science, The University of Queensland, Brisbane: 77-90

Fabricius K, Alderslade P (2001) Soft corals and sea fans: a comprehensive guide to the tropical shallow water genera of the central-west Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science p 264

Fox HE, Pet SP, Dahuri R, Caldwell RL (2003) Recovery in rubble fields: long term impact of blast fishing. Marine Pollution Bulletin 46 (2003): 1024 -1031 [doi: 10.1016/S0025-326X(03)00246-7]

Hodgson G, Hill J, Kiene W, Maun L, Mihaly J, Liebeler J, Shuman C, Torres R (2006) Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring. Reef Check Foundation, Pacific Palisades, California, USA

Hughes TP (1994) Catastrophes, phase shifts, and large scale-degradation of a Caribbean coral reef. Science 265: 1547-1551

Hughes TP, Rodrigues MJ, Bellwood DR, Ceccarelli D, Hoegh-Guldberg O, McCook L, Moltschaniwskyj N, Pratchett, MS, Steneck RS, Willis B (2007) Phase shifts, herbivory and the resilience of coral reefs to climate change. Current Biology 17: 360-365 [doi: 10.1016/j.cub.2006.12.049]

Kuguru BL, Mgaya YD, Ohman MC, Wagner GM 2004 The reef environment and competitive success in the corallimorpharia. Marine Biology 145: 875-884

Sammarco PW, Coll JC, La Barre S, Willis B (1983) Competitive strategies of soft corals (Coelenterata: Octocorallia): Allelopathic effects on selected scleractinian corals. Coral Reef 1: 659-669

Tkachenko KS, Wu B, Fang L, Fan T (2007) Dynamics of a coral reef community after mass mortality of branching *Acropora* corals and an outbreak of anemones. Marine Biology 151: 185-194

Wilkinson C ed (2004) Status of the coral reefs of the world. Australian Institute of Marine Science. Volume 1 p 301

Wood EM (2008) Summary results of the SIP reef monitoring programme in the Tun Sakaran Marine Park. Marine Conservation Society, Ross-onWye, UK.

Work TM, Aeby GS, Maragos JE (2008) Phase shift from a coral to a corallimorph-dominated reef associated with a shipwreck on Palmyra Atoll. PLoS ONE 3 Issue 8: e2989.