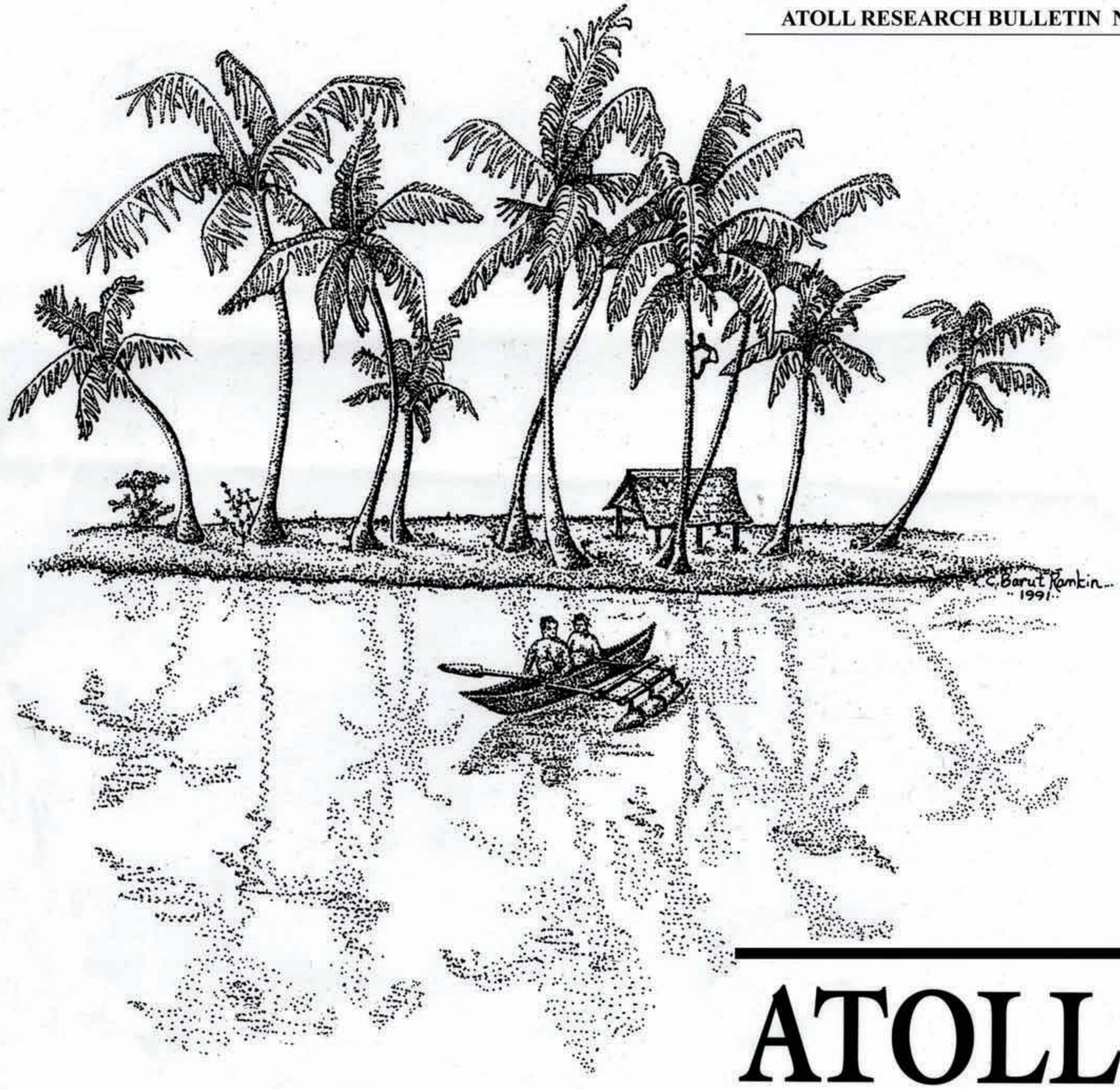

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TSUNAMI IMPACTS IN ACEH PROVINCE AND NORTH SUMATRA, INDONESIA

BY

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ABSTRACT

The huge earthquake and resulting tsunami which occurred on December 26, 2004 off the west coast of Sumatra resulted in regionally variable patterns of impact in and around the Indian Ocean basin. The coast of Sumatra was close to the earthquake epicenter and was the first to be struck, within one hour of the event. A collaborative expedition between the Khaled bin Sultan Living Oceans Foundation, Reef Check International and IUCN (World Conservation Union) to the northwest coast of Sumatra and Aceh Province, Indonesia, was conducted in October 2005.

Reef surveys were conducted using two methods: Manta Tow and the Reef Check Plus protocol. A total of 9 sites (8 offshore island sites and 1 mainland Aceh site) were surveyed over a distance of 650 km. Typically tsunami damage was observed as overturned coral colonies and tree debris on the reef. Over half of the reefs surveyed indicated that there had been no tsunami damage and only 15% of the sites surveyed indicated a high level of damage. However, even in areas where severe tsunami damage was recorded and corals were killed as a result of the event, there were still large areas of intact reef present, which will be able to repopulate the damaged reef in the future. Similar post-tsunami surveys in Thailand suggest that full recovery of these reefs should occur within the next 5-10 years.

There was evidence that the earthquake caused both uplift and subsidence of some islands. These processes have resulted in three impacts on reefs: 1) extensive mortality of uplifted reef-flat corals, 2) the bringing of reef-front corals into the reef-flat zone and 3) the relocation of reef-flat communities to the reef-front. Both uplift and subsidence therefore have implications for near-future reef ecosystem dynamics in the region.

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INTRODUCTION

On December 26, 2004 an earthquake measuring 9.3 in magnitude (Bilham, 2005) occurred at latitude 3^{o}N, off the west coast of Sumatra where the northward moving Indo-Australian plate is subducted below the continental Eurasian plate. This earthquake was the most severe event since the Alaskan earthquake of 1964 and was the second largest since modern seismographic recording began over a hundred years ago. The energy it released was as much as all the global earthquakes combined between 1976 and 1990. This huge earthquake triggered tsunami waves, which caused devastation throughout the Indian Ocean basin. The coast of Sumatra was the first to be struck, within one hour of the event. The tsunami waves reached Sri Lanka and India in 2-3 hours, Seychelles and Mauritius in 7 hours, East Africa in 9 hours and South Africa in 11-14 hours. This tsunami event was the most catastrophic such event in recent history resulting in the deaths of over 300,000 people (Spencer, 2007).

The effects of hurricanes and cyclones on coral reefs have been well documented for more than 20 years (e.g. Woodley et al., 1981; Bythell et al., 2000) but there are no such reports on the effects of tsunami waves on coral reefs. At the International Coral Reef Initiative's (ICRI) 10th Anniversary meeting in the Seychelles in April 2005, a review of post-tsunami reef damage assessments was made. The review revealed that numerous reef surveys had been conducted throughout the Indian Ocean (e.g. Thailand, Seychelles, Maldives, Sri Lanka) to observe coral-reef damage following the December 2004 tsunami, but there was an evident lack of surveys along the west coast of Sumatra, the coastline closest to the epicenter of the earthquake. Northwest Sumatra experienced very severe terrestrial tsunami damage; water inundation reached 3-4 km inland and wave scour and coastal subsidence set back the shoreline by 1.5 km (Borrero, 2005). The aim of this expedition was to survey a 650 km stretch of the west coastline and offshore islands of Sumatra, Indonesia, from Sibolga to Banda Aceh (in Aceh Province) (Fig. 1) in order to document the state of the reefs in this area following the December 2004 tsunami and to fill a gap in the knowledge of the impacts of the tsunami around the Indian Ocean basin.

REEFS OF NORTH SUMATRA

Sumatra, with a coastline of approximately 4,500 km (excluding offshore islands) is one of the least known Indonesian islands with regard to coral reef distribution (Tomascik et al., 1997). Extensive fringing reefs, approximately 200 m in width, occur in the north, around Aceh, along the west coast, and around the northern islands, especially Pulau Weh (Tomascik et al., 1997). An 85 km long barrier reef is reported 20 km off the coast of Aceh, but this is a submerged or drowned system 13-20 m below the surface, and the degree of active coral growth here is unknown (Spalding et al., 2001). Sea surface temperature along Sumatra's coastline ranges from 26^{o}-30^{o}C and salinity ranges from 33-34 ppt (Tomascik et al., 1997). Indonesia, specifically eastern Indonesia, is known to be the world's centre of coral biodiversity, exhibiting 581 species within 82 genera (Veron, 2000). Coral diversity in Sumatra has not been documented.

Figure 1. Map of Aceh Province, Sumatra, Indonesia illustrating expedition itinerary 17-31 October 2005. Numbers represent site numbers as defined in Table 1. Red dot indicates approximate December 26, 2004 earthquake epicenter.

Table 1. Regions and survey sites as shown on Figure 1.

Region	Site Name	Site Number on Fig. 1
Banyak	Pulau Bangkaru	1
	Pulau Baleh	2
	Pulau Bagu	3
North Aceh coast	North Aceh coast	4
Northern Islands	Pulau Nasi Besar	5
	Pulau Buro	6
	Pulau Weh	7
	Pulau Rondo	8
	Pulau Bunta	9

METHODS

Two primary survey methods were used during the expedition: the Manta Tow method and the Reef Check Plus protocol (Hodgson et al., 2005). The Manta Tow method is a rapid visual assessment, enabling a very large area to be surveyed in short period of time. It involved a snorkeller holding onto a 'Manta Board' being towed behind a boat (English et al., 1997). The snorkeller recorded a visual assessment of the reef observed (i.e., percentage cover of live coral, rock, rubble, etc.). The Reef Check Plus methods focussed on a much smaller area of reef but the surveys were more detailed, surveying the benthic, fish and invertebrate communities along a 100 m transect line. Typically, shallow (3-5 m) and deep (8-10 m) Reef Check Plus surveys were conducted at each site. These two methods have various advantages and disadvantages but by employing them in combination the advantages were maximized and the disadvantages were minimized. These two survey methods enabled general characteristics of the reefs of north Sumatra to be recorded. In addition to these standard methods, particular note was made of tsunami damage on the reefs. Tsunami damage was identified as:

1) Mechanical damage: Broken pieces of coral
2) Overturned / rolled coral
3) Sedimentation: Run-off from land being washed onto reef

The level of tsunami damage observed was also recorded as 'low', 'medium' or 'high' by estimating the number of overturned and/or broken coral pieces observed during each Manta Tow. 0–10 pieces indicated 'low' tsunami damage, 10-30 pieces indicated 'medium' tsunami damage and 30+ pieces indicated 'high' tsunami damage. A 'piece of coral' was defined as being less than 15 cm in diameter along its longest axis.

In total, nine offshore island sites (Karang, Bangkaru, Baleh, Bagu, Nasi Besar, Buro, Rondo, Weh and Bunta) and one mainland site (north coast of Aceh Province, east of Banda Aceh city) were surveyed (Fig. 1).

RESULTS

Reef Characteristics

Benthic survey results have been combined into three groups: Banyak region, north coast of Aceh and northern islands (Table 1; Fig. 2). Banyak region reefs were shown to be dominated by hard coral cover (39% cover) and rock (29% cover) with moderate amounts of rubble and sand. Recently killed coral represented only 0.1% cover in the Banyak region. Reefs of the northern island were dominated by rock (37% cover) and rubble (29% cover), followed by hard coral cover (25% cover). Recently killed coral represented only 0.3% cover in the northern islands. Reefs of the north Aceh coastline showed marked differences compared to the other two areas. Here the reef was dominated by rock (35% cover), and although hard coral cover was identical (25% cover) to that recorded in the northern islands, soft corals were also evident in the coral community (11% cover). The north Aceh coastline displayed a higher proportion of recently killed coral (3% cover) but a much lower proportion of rubble (11% cover) compared to the other two sites.

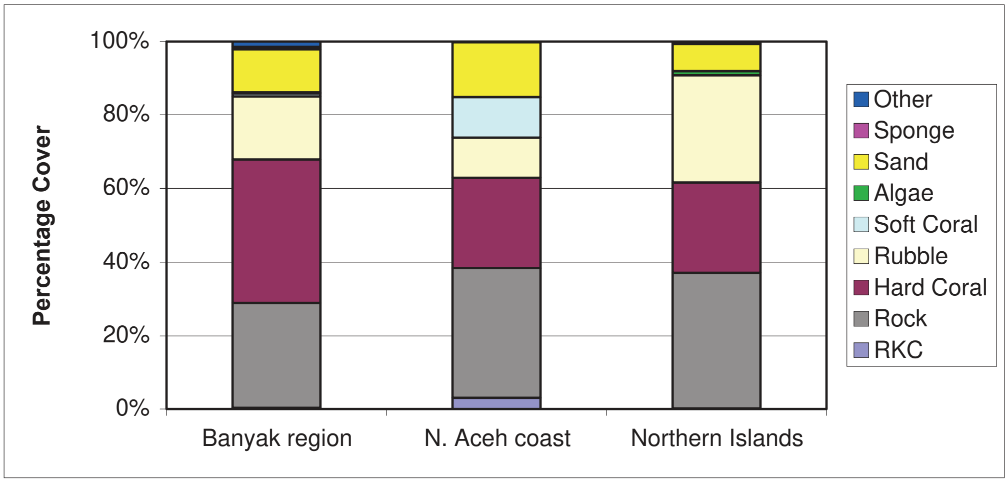

Figure 2. Summary of percentage cover by benthic category for three regions of Aceh. Results from Reef Check surveys (RKC = Recently Killed Coral).

Earthquake Damage: Banyak Region

Two major earthquakes occurred in the waters offshore of Aceh in December 2004 and March 2005. Earthquake damage was observed at Pulau Bangkaru (uplift), Pulau Baleh (subsidence) and Pulau Bagu (subsidence) in the Pulau Banyak group. A large area of largely intact (little erosion was observed and most branching corals were unbroken) reef-flat, approximately 500 m in width, had been completed raised by approximately +2 m, killing the corals through subaerial exposure (Fig. 3). The corals had not yet been eroded and could easily be identified to genus level, indicating that the uplift was recent. Many dead *Porites* microatolls were present, as were colonies of branching *Acropora* and *Pocillopora* and many empty giant clam shells.

In contrast, terrestrial observations at the islands of Baleh and Bagu, two islands which lie less than one kilometer apart from one another in the Banyak group (Fig. 1, sites 4 and 5) indicated that subsidence had occurred as a direct result of an earthquake. Terrestrial tsunami damage was highly evident. Low-lying vegetation close to the shore was brown and dead (Fig. 4a), presumably as a result of salt-water inundation and many buildings had been removed from the coastline (Fig. 4b).

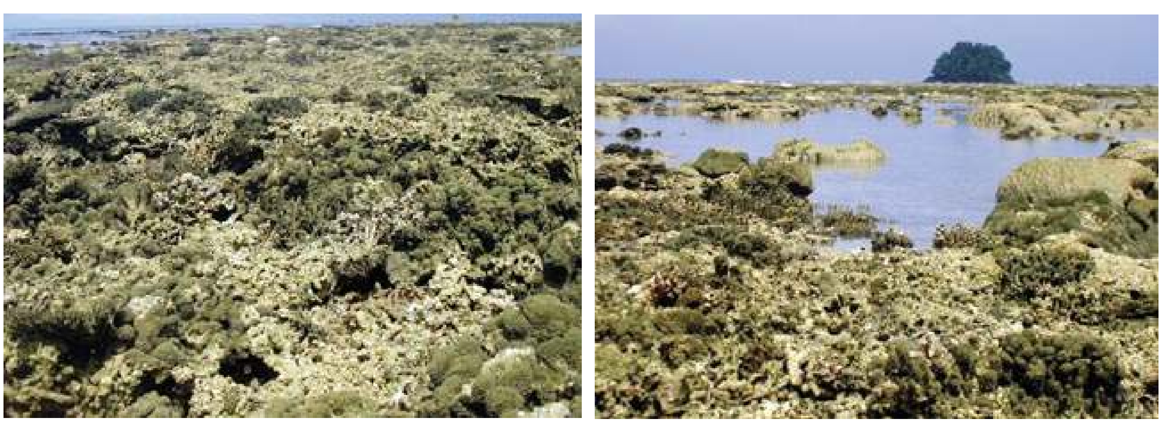

Figure 3. Uplifted reef at Pulau Bangkaru, observed on October 19, 2005.

Figure 4. Terrestrial tsunami damage at Pulau Baleh showing (a) dead vegetation along the coast and (b) foundations of buildings that have been washed away by the tsunami wave.

The houses remaining along the seafront were noted to all have a clear brown mark at approximately 80 cm height up their walls (Fig. 5). It seemed strange for this water mark to remain so clear 10 months after the tsunami hit, but having spoken to the islanders it became apparent that this was an effect of the earthquake as opposed to the tsunami wave. The island had subsided as a result of the December 2004 earthquake and as a result, the buildings along the seafront are now inundated with up to 1 m of water during each high tide. Presumably the coral reefs surrounding these islands must also have submerged by a similar amount, converting intertidal reef-flat communities into subtidal ones.

Tsunami Damage: North Coast of Aceh Province

The north coast of Aceh, approximately 13 km east of the town of Banda Aceh, exhibited differing degrees of tsunami damage. All surveys were shallow (3-5 m depth) as the reef did not extend below 5 m water depth, but instead gave way to a sandy bottom. The five sites were found to harbor different types of reef communities and exhibited varying degrees of tsunami damage. Manta Tows indicated that tsunami damage was generally ‘low’ at this site with only 4 out of 39 tows indicating ‘high’ damage and 4 out of 39 tows indicating ‘medium’ damage. Rock was estimated to dominate the substrate, representing 44% cover although live coral cover represented an average of 31% and rubble represented 25% cover. The first Reef Check Plus survey was conducted at the headland ‘Ug Batukapal’, a site identified by the Manta Tow team as having good live coral cover. Indeed the substrate transect was dominated by live coral cover (32%) with a moderate amount of rock and sand (25% cover for each). Interestingly, soft corals made up 14% of the total substrate at this site, a category that had been little observed elsewhere.

Figure 5. Water mark on house on Pulau Baleh; mark represents the daily height of water inundation at high tide. This house is approximately 70 m inland.

The survey conducted at the headland adjacent to 'Ug Batukapal' indicated a very different type of reef community. Here the reef was composed of large flat solid plates of limestone 'coral pavement' (50% of total transect) interspersed with soft corals; specifically of the genus *Sinularia* and whip corals (Fig. 6a and b). There were few hard corals (hard coral cover was only 6%) compared to the number of soft corals present, which accounted for 27% of the total substrate along the transect line.

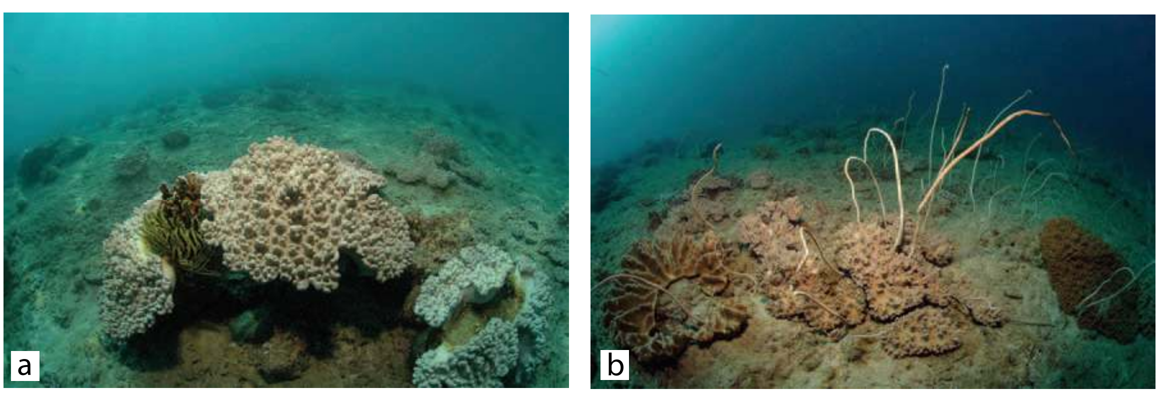

Figure 6. Reef dominated by coral pavement interspersed with soft corals at 3 m water depth: (a) *Sinularia* spp. (b) *Sinularia* spp. and delicate sea whips *Junceella fragilis*, north Aceh coast, October 27, 2005.

Moving eastward, two surveys were conducted in a large bay area. One of these surveys was of particular interest as it identified considerable tsunami damage, specifically overturned dead *Acropora* tables (Fig. 7), overturned live *Porites* spp. (Fig. 8) and tree debris (Fig. 9).

Figure 7. Overturned dead *Acropora* sp. table at 4 m water depth on the north coast of Aceh Province, October 27, 2005.

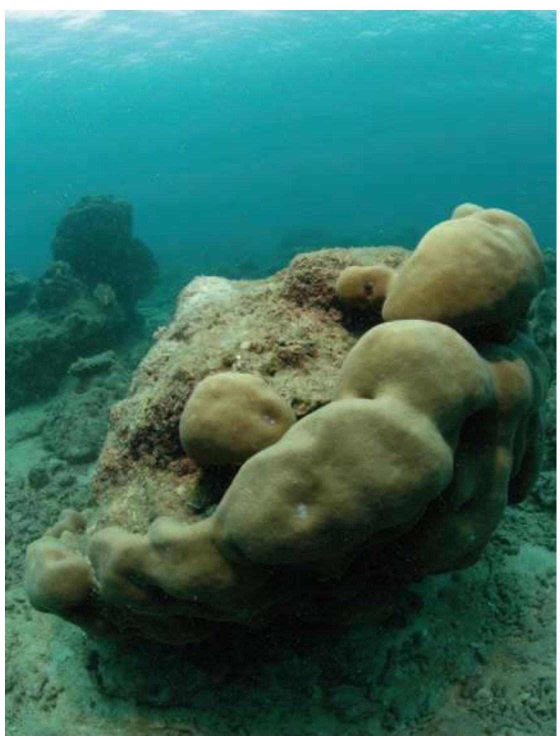

Figure 8. Overturned live *Porites* sp. colony at 4 m water depth on the north coast of Aceh Province, October 27, 2005.

Figure 9. Tree debris on the reef at 5 m water depth; north coast of Aceh Province, October 27, 2005.

The reef was characterised by 31% rock and equal proportions of live coral cover and rubble (21% each). Moving further east, the final survey in this area displayed minimal signs of tsunami damage. Although one tree branch was observed on the reef, no coral had been killed, broken or overturned and the reef displayed large stands of healthy blue coral *Heliopora coerulea* (Fig. 10) and *Porites* spp. Live coral cover accounted for 35% of the substrate.

Figure 10. Large stands of healthy blue coral *Heliopora coerulea* at 3 m water depth off the north coast of Aceh Province, October 27, 2005.

Tsunami Damage: Northern Islands

Pulau Weh (marked by the main town 'Sabang' on Fig. 1) lies off the north coast of Aceh Province and is the largest (153 km^2) and most populated (population ~28,500) of the northern offshore islands. A visit ashore on the north coast of Pulau Weh confirmed that there had been significant impacts from the tsunami wave on land (Fig. 11).

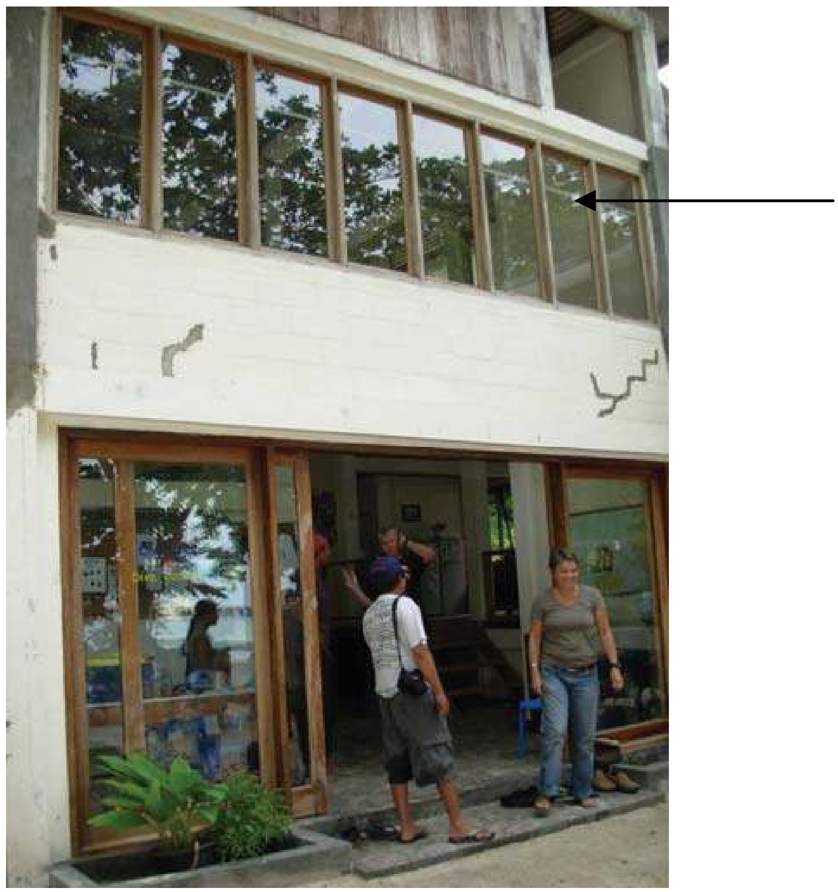

Figure 11. Lumba Lumba dive shop on Pulau Weh; arrow indicates maximum height of wave action (~5 m above sea level) on December 26, 2004.

A single site was surveyed on the southwest coast of Pulau Weh. Manta Tows indicated that there was 44% rock cover and 23% live coral cover with the rest of the substrate being split equally between rubble and sand. Half the tows indicated 'low' tsunami damage and half indicated 'medium' tsunami damage. The Reef Check survey at 6 m depth indicated that although 38% of the substrate was live coral cover, this figure was equalled by rubble cover. Rock represented 22% of the transect line. Although some patches of reef were intact (Fig. 12), there was clear evidence of tsunami damage on the reef along this transect.

Many massive *Porites* spp. colonies had been split into vertical fragments or overturned (Fig. 13a and b) and large colonies of the blue coral *Heliopora coerulea* had been overturned and shattered into small pieces (Fig. 14a and b).

Figure 12. Intact coral reef at 4 m water depth clearly showing healthy *Porites* spp. (far left and far right) and *Heliopora coerulea* (centre front) colonies along transect line at Teluk Balohan, Pulau Weh, October 28, 2005. Transect line shown back left.

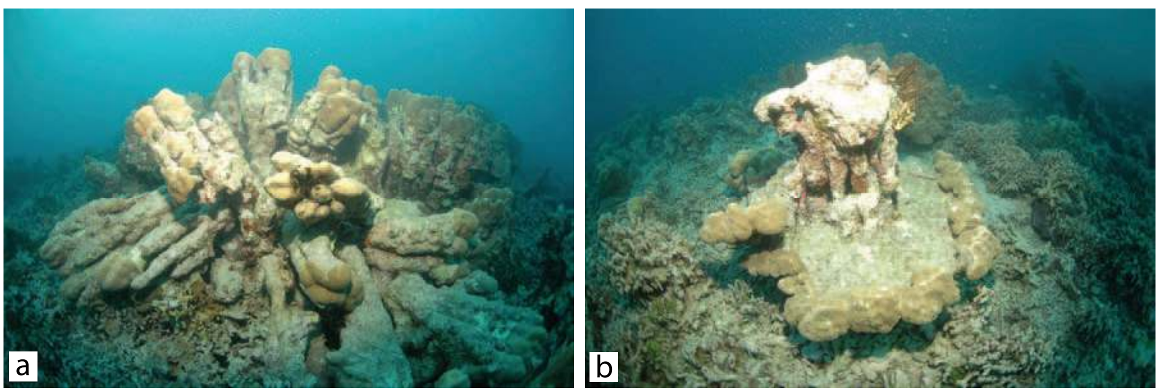

Figure 13. (a) Split *Porites* sp. colony and (b) overturned *Porites* sp. colony at 4 m water depth, Teluk Balohan, Pulau Weh, October 28, 2005.

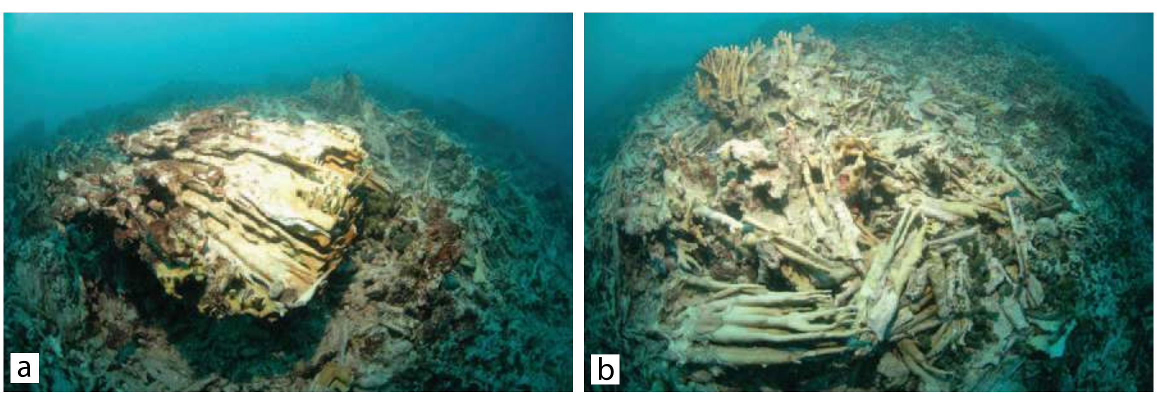

Figure 14. (a) Overturned blue coral *Heliopora coerulea* and (b) shattered blue coral *Heliopora coerulea* at 3 m water depth, Teluk Balohan, Pulau Weh, October 28, 2005.

Pulau Rondo (Fig. 1, site 13) is a small, uninhabited island situated north-west of Pulau Weh and is the most northerly point of Indonesia. Manta Tows and shallow and deep Reef Check Plus surveys were conducted at two sites at Pulau Rondo; one off the west coast and one off the east coast. The Manta Tows indicated that some areas displayed 'low' tsunami impact and some areas displayed 'high' tsunami impact, but the majority showed 'medium' tsunami impact. Live coral cover was estimated to be 50%, with a further 15% of the substrate being reported as 'recently killed coral'.

On the west side of Pulau Rondo, the shallow Reef Check survey was dominated by rock (41%), with a reasonable amount of live coral cover (37%). The deep site on the west side of Pulau Rondo showed some tsunami damage, specifically overturned

Acropora spp. tables, both alive (Fig. 15) and dead (Fig. 16a and b) and overturned *Porites* spp., but the majority of the reef was unaffected (Fig. 17). Live coral cover was 39%, although this figure was equalled by the proportion of rubble along the transect line.

Figure 15. Overturned live *Acropora* sp. table at 10 m water depth at Pulau Rondo, October 29, 2005.

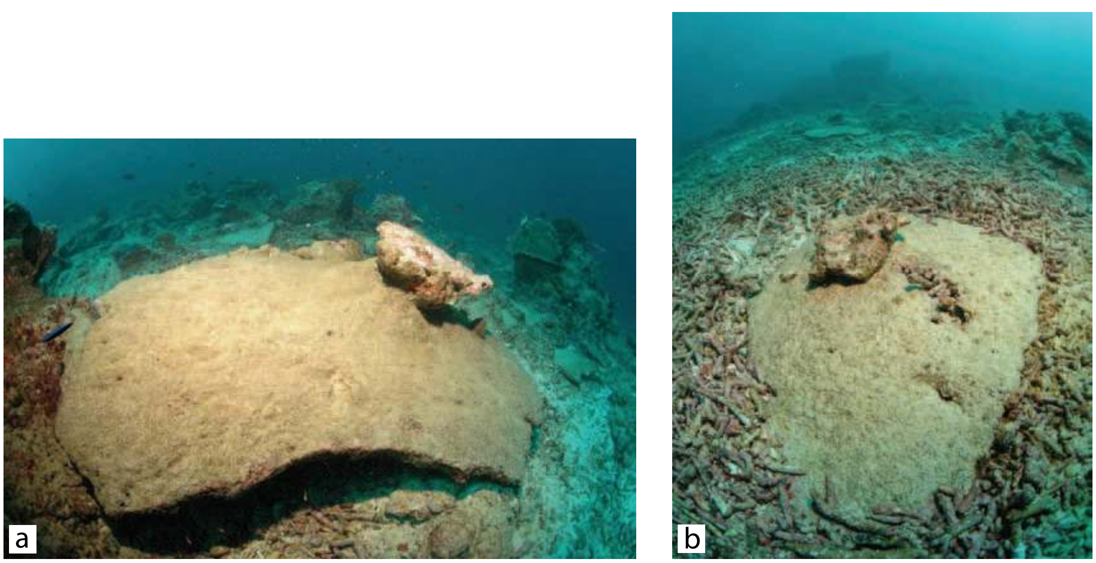

Figure 16. (a) Overturned dead *Acropora* spp. tables at 10 m water depth at Pulau Rondo, October 29, 2005. (b) overturned dead table coral surrounded by branching coral rubble.

Figure 17. Healthy reef communities at 10 m water depth at Pulau Rondo, October 29, 2005.

On the east side of Pulau Rondo the shallow survey was dominated by rock (50% cover) with rubble representing 30% of the substrate and live coral cover only 17%. The deep survey was dominated by rubble (70% cover), with little live coral cover (18%). Tsunami damage was observed in this area; specifically overturned dead *Acropora* spp. tables and a large tree trunk (over 6 m in length) had been deposited on the reef between 15 m and 18 m water depth (Fig. 18).

Figure 18. Tree trunk on reef at water depth of 18 m, Pulau Rondo, October 29, 2005.

At Pulau Bunta (Fig. 1, site 14), Manta Tows were conducted around the entire circumference of the island. The results suggested very high tsunami damage, with the reef being littered with small cylindrical branching coral fragments and a few overturned dead *Acropora* spp. tables being observed. Rock was estimated to account for 56% of the substrate observed and rubble 31%, with only 4% of the substrate being represented by live coral. Five coconut palm trunks were observed on the reef at depths of between 4 and 6 m. While conducting the Manta Tows, observations on the island confirmed that there had been significant tsunami impact here. Many coconut palms had fallen and much of the low-lying vegetation had been killed. Although this island is small (0.16 km x 0.38 km), approximately seven buildings were observed. Clearly these buildings were very new and piles of building debris were observed, indicating that the tsunami wave must have destroyed the buildings which previously stood there. Pulau Bunta would have been one of the first islands off the north coast of Aceh Province to be hit by the tsunami wave as it progressed northwards from the epicenter (Fig. 1).

DISCUSSION

Regional Reef Characteristics

Reefs of the Banyak region and northern islands displayed very similar benthic characteristics, with combined values of rock, hard coral and rubble contributing to between 85-90% of the overall benthos. Highest amounts of rubble were recorded in the northern islands, which may suggest that these offshore islands are exposed to a high energy environment due to oceanic swell generated thousands of kilometers away in the Indian Ocean (Tomascik et al., 1997). The reefs of the north coast of Aceh were typified by bare coral pavement with little rubble, and these reefs displayed a soft coral community that was not observed at any other site.

Evidence of boat anchor damage and dynamite fishing was observed at nearly all survey sites, suggesting that continuously high levels of anthropogenic stress on the reefs of Sumatra is having a more significant impact on coral reef health than that which resulted from the December 2004 tsunami.

Earthquake Damage

Earthquake damage resulted in three major alterations to the reef environment. Firstly, extensive mortality of reef-flat corals occurred due to uplift at Pulau Bangkaru. The corals that were uplifted and subsequently killed through subaerial exposure were those on the shallow reef-flat, and due to the naturally harsh nature of the reef-flat environment these corals would have been more resistant to natural environmental stress (e.g. higher water temperatures and solar radiation) than other corals further down the reef slope. Large (> 2 m diameter) microatolls, massive corals typically with a dead, flat upper surface surrounded by a living margin (Scoffin and Stoddart, 1978), were uplifted approximately 1.5 m above sea-level on the southwest coast of Simeulue island (Sieh, 2005) and smaller raised microatolls were observed at Pulau Bangkaru. As the upward growth of microatolls is constrained by sea level through prolonged exposure at low spring tides, microatolls act as natural recorders of sea level (Scoffin and Stoddart, 1978; Woodroffe and McLean, 1990; Zachariasen et al., 1999). In regional terms it has been suggested that a 1,000 km stretch of reef along the plate boundary from the Andaman and Nicobar islands to Sumatra has suffered uplift or submergence as a result of the December 2004 earthquake (Bilham, 2005). Consequently a huge number of reef-flat corals and microatolls have been killed in this region. There are few coral species that are common to both reef-flat areas and reef slope areas in this region, the most dominant being *Porites lutea* (Brown, 2005, pers. comm.; Phongsuwan and Brown, 2007), and the loss of so many other reef-flat coral species is likely to have serious implications for the re-population of the reefs of the region.

Secondly, reef uplift at Pulau Bangkaru has brought reef-front corals into the reef-flat zone. The corals that once thrived at deeper depths on the reef have now been uplifted to within a few meters of the surface and only time will tell how well these corals will survive after experiencing such a radical vertical shift in environments. Although it is conceivable that these corals will adapt to their new, warmer water temperature and associated increased solar radiation, typically, such adaptations are only successful through gradual change over long time periods. However, it must also be considered that some species may be more able to adapt than others, which may alter the coral community composition.

Thirdly, moving further north, effects of the earthquake were observed at the islands of Pulau Baleh and Bagu, but unlike at Pulau Bangkaru where the reefs had been uplifted, these islands, and thus the surrounding reefs, had been submerged as a result of the earthquake. Although little structural damage was observed as a result of the tsunami on the reefs of these islands, the displacement of shallow reefs to deeper zones due to this tectonic plate shift may, over time, have implications for the reef ecosystem. Corals are extremely sensitive and very susceptible to variations in temperature. Consequently, a vertical shift of even as little as a meter could have severe consequences for the coral community.

Tsunami Damage

A wide spectrum of tsunami damage was observed over a large distance (650 km) in a short period of time. Typically, it was only possible to survey one or two sites at each island visited, yielding only a snap-shot of the overall reef environment. Therefore, generalisations of the degree of tsunami impact at different sites must be regarded with due caution.

No discernable tsunami damage was observed on the reefs of Pulau Karang or Pulau Bangkaru, the most southerly islands (Fig. 1, sites 2 and 3). It is possible that the reefs of these islands were sheltered from the tsunami wave by the large island of Simeulue, which lies 44 km south of the earthquake's epicenter (Fig. 1). Some tsunami damage was observed on the reefs of the northern offshore islands and on the north coast of Aceh Province. The most frequently observed damage was overturned *Acropora* spp. tables, overturned massive *Porites* spp. colonies and tree debris on the reef. Tsunami impact was exhibited as pockets of damage (although larger areas than displayed as a result of dynamite fishing) as opposed to huge areas of the reef being completely destroyed. Due to the limited amount of surveys undertaken, it is not possible to discuss variations in tsunami damage with respect to depth or aspect. For example, at some sites tsunami damage was observed on the deep transect but not on the shallow transect and vice versa, and it is not clear why this may have been the case.

The reef area observed to be most affected by the tsunami was on the north coast of Aceh, a site in the centre of a large bay between two headlands. Although due to the random and dispersed nature of the surveys it is difficult to make any comment on the pattern of tsunami damage, it could be suggested that here the tsunami waves may have been refracted off the headlands either side of the bay and compounded in the centre of the bay causing extensive damage at this central bay site. Similar results have been reported elsewhere, for example, more extensive tsunami induced reef damage was observed in bay areas of Sri Lanka (Rajasuriya, 2005).

CONCLUSIONS

In summary, 54% of the sites surveyed showed no tsunami damage, 31% showed low to moderate damage and 15% showed high levels of damage. Although minimal coral recruitment subsequent to the earthquake and tsunami was observed, typically the reefs of Sumatra displayed between 30% and 65% live coral cover (Fig. 2). Some of the overturned corals observed in Sumatra were still alive but others were dead. However, some of these dead corals were well eroded, suggesting that they may have been dead but still standing prior to the tsunami event. Dead standing corals are far more susceptible to tsunami damage due to their weak attachment onto the substrate. It follows logic that reefs which are already subjected to high anthropogenic stress are likely to suffer the most as a result of tsunami impact (Baird et al., 2005).

So, how long will it take the reefs of these Aceh islands to recover from the tsunami impact? When talking about reef recovery, it is important to look at the type of damage observed. Many of the overturned corals that were observed contained live tissue. Although it is unreasonable to assume that the portion of live coral now resting on the seabed will survive, the colony should gradually spread across the bare substrate which was once the base area. The surviving parts of these colonies will also be an important larval source for re-populating the reef. The recovery rates are expected to take significantly longer in those areas where corals were killed as a result of the tsunami. For example, at Pulau Rondo some overturned *Acropora* spp. tables were already dead (Fig. 16a and b) and the amount of branching coral rubble on the eastern side of the island suggested that there was considerable tsunami damage here. However, it is important to note than even in areas where severe tsunami damage was observed and corals were killed as a result of the event, there were still large areas of healthy coral present, which will serve to repopulate the damaged reef.

Post-tsunami reef studies in Thailand found that 66% of the 174 sites surveyed showed no or very little damage, with only 13% exhibiting severe damage (> 50% of colonies affected) (Brown, 2005; Phongsuwan and Brown, 2007). It has been suggested that these reefs will recover from the tsunami event within the next 5-10 years (Brown, 2005; Phongsuwan and Brown, 2007). The reefs of Sumatra appear to have suffered similar levels of damage from the December 2004 tsunami to that reported from the surveys in Thailand. It can therefore be reasonably suggested that recovery times will be similar for the reefs of Sumatra, that is, the reefs are likely to recover within approximately 5 years and full recovery of even severely damaged reefs will occur within the next decade.

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