# Post Tsunami Status of Coral Reef and Fish in Northern Aceh

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## ABSTRACT

The coral reefs of northern Aceh, located in western Indonesia, are productive marine ecosystems that are important for the economies of local communities. The catastrophic tsunami in December 2004 affected local communities, and ways in which they utilized marine resources, while impacts on reef resources were patchy. Limited data and information on coral reef condition prior to the tsunami has highlighted the need for regular long-term coral reef monitoring to assess reef recovery from the tsunami and from previous damage caused by destructive fishing and overfishing. The objectives of this study were to provide reliable data and information on scleractinian corals and reef fish in the northern Aceh region of Weh and Aceh Islands. Using line intercept transects (LIT) and underwater visual census techniques at 21 sites, we found that the mean coral cover in Weh Island was significantly higher (30.0%-fair condition) compared to Aceh Island (10.8%-poor condition). Coral reefs at Rubiah Island, Sumur Tiga and Benteng that were protected under the management of Panglima Laot of Sabang were in the best condition. On Weh Island reef fish abundance (32,505 $ha^{-1}$) and biomass (748 $kg.ha^{-1}$) were also significantly higher than on Aceh Island (9539 $ha^{-1}$ and 396 $kg.ha^{-1}$, respectively). Pomacentridae (damsel fish) had the highest abundance and biomass among fish families. Macro-invertebrates numbers, in particular sea urchins, were highest on Aceh compared to Weh Island, and in open access areas compared to marine managed areas. The potential for sea urchins to influence coral recruitment and coral reef recovery of Aceh Islands requires further investigation.

## INTRODUCTION

Northern Aceh on the Indonesian Island of Sumatra and the surrounding reefs in the Andaman Sea are well known for their extensive shallow reef flats that extend 200–500 m from the shore. The reefs are dominated by massive species (mainly Poritidae and Faviidae) intermingled by patches of branching *Acropora* and *Montipora* in sheltered areas, and mostly branching species at high-energy reefs (Brown 2005). Weh and Aceh Islands are the two main islands in northern Aceh, and also the westernmost reef areas in the Indonesian archipelago. The marine fauna and flora of north-west Sumatra, including the northern Acehnese reefs, are comprised of species from the Indian Ocean and the Pacific Ocean and make the region

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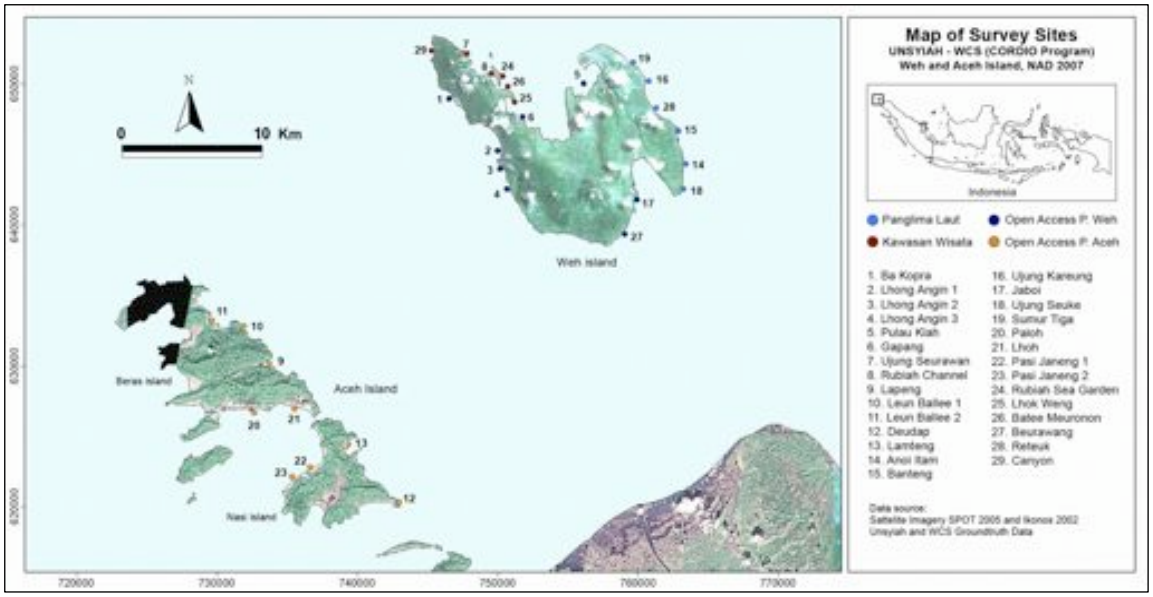



**Figure 1**. Map showing survey sites at Aceh and Weh Islands, Northern Sumatra, Indonesia.

biogeographically distinct from the eastern Indonesian coral reef fauna and flora.

The reefs ecosystems support a local artisanal fishery as well as a primarily pelagic commercial fishery. The area also has a tourism industry with snorkeling and SCUBA diving and other recreational activities as the main attractions. These activities contribute income to coastal communities, in addition to farming, business, and government sectors (Baird *et al.* 2005b). Although these reefs were subject to substantial disturbance from the tsunami, initial claims that northern Aceh reefs were destroyed or greatly impacted by the tsunami in 2004 (Brown 2005, UNEP 2005) were unfounded (Baird *et al.* 2005a and b). Nevertheless damage to coastal communities was severe with five of thirteen villages in Weh Islands heavily affected by the earthquake and tsunami; mostly on the northern and southern coasts (Baird *et al.* 2005b). Damaged houses, boats, fishing gears, and loss of life paralyzed the northern Aceh fisheries, including destructive fishing activities. However, overfishing and destructive fishing practices had caused serious damage and significantly degraded coral reef ecosystems in Aceh Islands prior to the tsunami (Baird et al. 2005a and b).

The status of reefs of Northern Aceh range from very poor to good condition, but have overall been well documented only recently (Baird *et al.* 2005a and b, Campbell *et al.* 2005, Ardiwijaya *et al.* 2006). Coral reefs of Weh Island are known to be generally in better condition than those on Aceh Island because of past differences in management between these two. To improve the management of these reefs and prevent damaging, unsustainable, and illegal fishing practices from returning, investment is required to implement management practices and strategies that help rehabilitate, restore and protect marine resources through programs of regular monitoring, education, coastal management and establishment and maintenance of marine protected areas. The aim of this research project was to provide reliable data and information on coral reef resources of northern Aceh that will be useful for local people, scientists, tourists, and other stakeholders to evaluate the condition of the reefs, make recommendations for management and be used to evaluate the effectiveness of future coastal management. This report focuses on overall reef condition (benthic, invertebrates and fish) while a

more detailed analysis of fish biomass and fishery implications is presented in Campbell et al. (2007).

# METHODS

## Survey Sites

Coral reef and invertebrate surveys were conducted in 2006 and 2007 at 21 sites, 13 on Weh Island and 8 on Aceh Island (comprising Beras and Nasi islands), while coral reef fish surveys were conducted at 29 sites, 19 on Weh and 10 on Aceh Island (Fig. 1). Sites were selected to represent the reefs of the region and the types of site management, including Marine Protected Areas (consisting of Panglima Laot and Tourism Reserve) where fishing restrictions are in place, as well as areas with unrestricted fishing or open access areas, on both islands.

## Survey Techniques

Methods used were manta tow and Line Intercept Transect (LIT) for benthic cover, under water visual census technique (UVC) for reef fishes, and belt transect for invertebrates (English *et al*. 1997, Hill and Wilkinson 2004). In order to obtain representative data of the reef, transects were laid at two depths at 2-3 m (shallow) and 6-8 m (deep).

### *Coral reefs*

Manta tows were used to obtain general descriptions of reef areas, estimating percent cover of hard coral, soft coral, dead coral and sand. Two divers were towed along the reef edge using a boat at a constant speed of 2 knots, with regular stops every 2 minutes to record data on substrate cover. The number of tows varied between locations depending on reef and environmental conditions. Two replicate 30 meter LIT transects were recorded at each site and depth. Reef condition was assessed using percent cover of live hard coral was based on Gomez and Yap (1998): excellent, 75-100%; good, 50-74%; fair, 25-49%; and poor, 0-24%.

### *Reef fish*

Abundance and biomass of reef fishes were recorded using Underwater Visual Census, recorded along the lines used for LIT, plus one additional transect. Data were collected at the species level and 9 size classes visually estimated (0 cm, 5-10cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm and >40 cm). Transect size was 5x50 m for fish >10cm and 2x50 m for fish <10cm. Data is presented as abundance, in number of individuals per hectare ($ha^{-1}$), as well as biomass, in kilograms per hectare ($kg.ha^{-1}$), estimated using standard length-weight relationships for fish species (FishBase 2000).

### *Macro-invertebrates*

Macro-invertebrates were counted using 2 replicate 5x50 $m^2$ belt transects at the two depths. Invertebrates were identified to species level and data converted to numbers per unit area ($ha^{-1}$). Species diversity was analyzed using the Shannon-Wiener index (H') (Krebs 1989), with the following ranges used in this study: H'<1 : low diversity; 1<H'<3 : medium diversity; H'<3 : high diversity

## Statistical Analyses

Using two-way nested analysis of variance (ANOVA) we examined the effect of time (fixed; 2 levels, 2006 and 2007) and management areas (fixed; 4 levels, Panglima Laot, Kawasan Wisata, open access Aceh Islands, open access Weh Islands) on mean fish biomass and mean fish abundance. In order to understand the variation in reef fish biomass and abundance between sites within management areas (among sites) and among management areas data from each transect (n = 6) at each site (random; 6 - 9 levels) were nested within each management area. Significance among factors was tested at the $P<0.05$ levels. Biomass and abundance of reef fish were log transformed prior to ANOVA analyses to improve homogeneity and normality. All analyses were completed using SPSS v11.5.

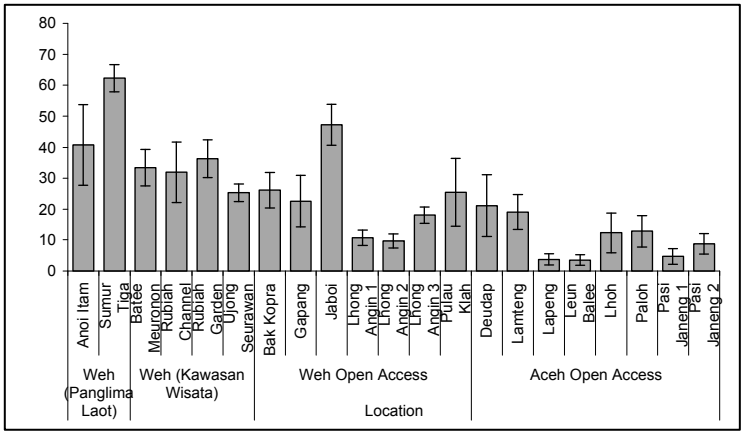



**Figure 2**. Mean percent cover of hard coral (± SE) at study sites at Weh and Aceh Islands, based on LIT surveys.

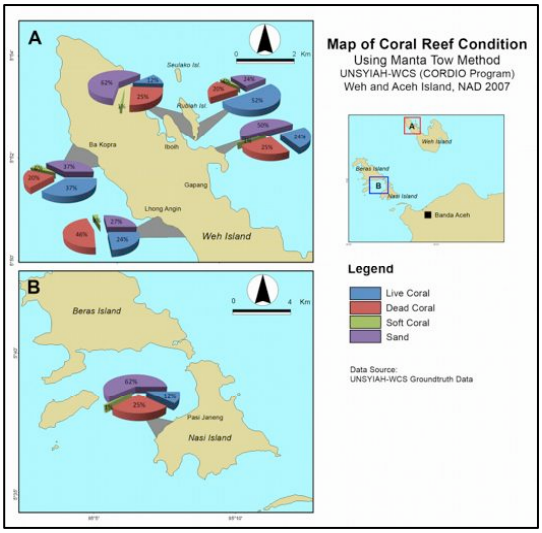



**Figure 3.** Percent cover of major benthic cover categories at study sites at Weh Islands (A) and Aceh Islands (B), based on Manta Tow surveys.

## RESULTS AND DISCUSSION

### Coral Reefs

The health of coral reefs varied considerably within the region, with the hard coral cover (pooled for both depths) being higher on Weh Island (30.0% ± 2.4 (standard error of the mean)) than Aceh Island, (10.8% ± 4.0). Hard coral cover on Weh Island was higher on reefs with fishing restrictions, i.e. Panglima Laot (51.5% ± 10.8), and inside the Tourism Reserve (31.7% ± 2.3) compared with open access areas on Weh Islands (22.8% ± 4.8). Using Gomes and Yap (1998) categories to estimate reef condition one site managed by the Panglima Laot authority, Sumur Tiga (site no 19) was categorized as in "good condition" with a coral cover of 62.3% ± 4.4, while 8 sites were in "fair condition" (25.3-47.2%) and 12 sites in "poor condition" (3.6-22.5%, Fig. 2). Results from manta tow surveys indicate that the benthic habitats are dominated by sand and that mean live coral on Weh Islands, ranging between 12 and 52%, was higher than in Aceh Islands (12%) (Fig. 3). These results support findings from the LIT surveys that reefs inside managed areas were in better condition than those in open access areas.

The Aceh Islands suffered severe catastrophic damage from the tsunami in 2004, but many reefs were already dead or in poor condition prior to the tsunami because of a history of destructive fishing including dynamite and cyanide use (Baird *et al.* 2005, Campbell *et al.* 2005). Enormous dead colonies of coral and rubble beds covered with a thick growth of filamentous algae remain common on Aceh Island reefs. However, there was also little evidence of recent coral mortality. To the contrary, an increase in the mean coral cover in Aceh Island from 2006 (8.2% ± 1.8: Ardiwijaya et al. 2006) to 2007 (10.8% ± 2.4: this study), suggests that recruitment of corals is occurring, as has been previously suggested (Ardiwijaya *et al.* 2006, Fig. 4). It is possible that the reduction in fishing effort, and particularly destructive fishing, following the tsunami have allowed reefs on Aceh Island to start to recover from the misuse of the past. Nevertheless, recent reports in 2007 of the use of cyanide fishing show it is starting up again. Sediment run-off from inappropriate and poor agricultural practices also highlights the need for an ecosystem-based approach to these problems, where land use and

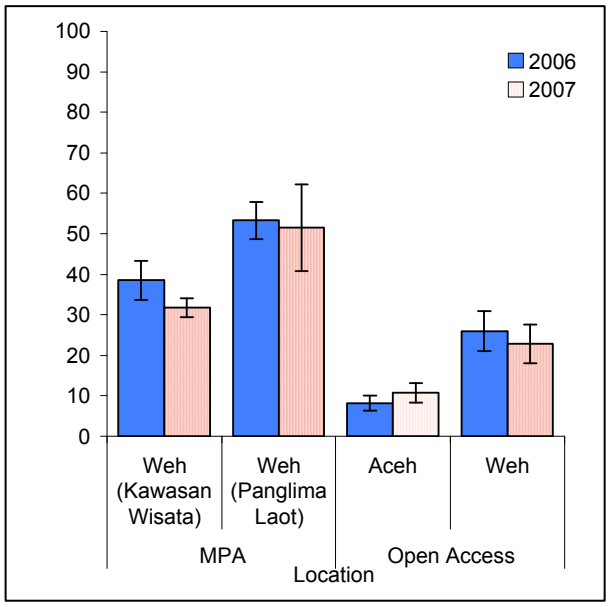



**Figure 4**. Mean coral cover (± SE) (%) on coral reefs in 4 management areas, in 2006 and 2007.

marine resource use practices are considered in the design and implementation of regulatory controls.

## Reef Fishes

In 2006, reef fish abundance was highest in Sumur Tiga (133,050 $ha^{-1}$), while in 2007 it was highest at Benteng (83,770 $ha^{-1}$) (Fig. 5). Both sites are located within Panglima Laot management areas, and in an ANOVA (Table 1) both abundance and biomass of fish were significantly highest in management areas in both 2006 and 2007 (Fig. 6). After management type, the abundance and biomass of reef fishes was significantly affected by site characteristics (nested within management) shown by the lower F ratio for site as a factor (Table 1). There was a considerable decrease in fish biomass and abundance in protected areas from 2006 to 2007, while both were stable in fished areas (Fig. 6). However this did not result in a statistically significant difference in the ANOVA of management type by site interaction. There was no significant difference in reef fish biomass between 2006 and 2007 (F= 0.160 p=0.716).

Biomass of reef fishes in 2006 ranged from 118 to 2399 $kg.ha^{-1}$, with the highest biomass recorded at Sumur Tiga and the lowest at Pasi Janeng 2. In 2007, biomass of reef fishes ranged from 149 to 1562 $kg.ha^{-1}$, the highest recorded in Canyon and the lowest in

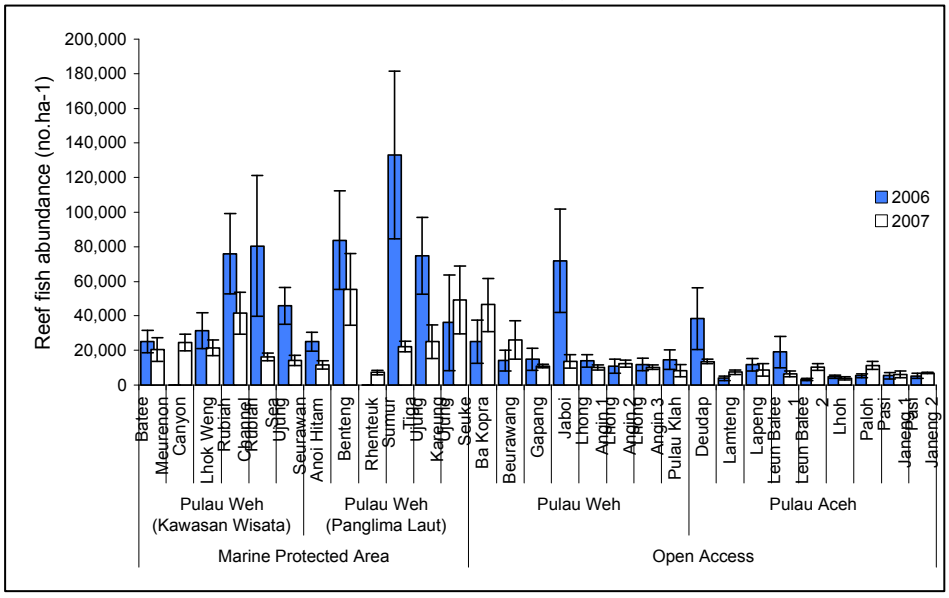
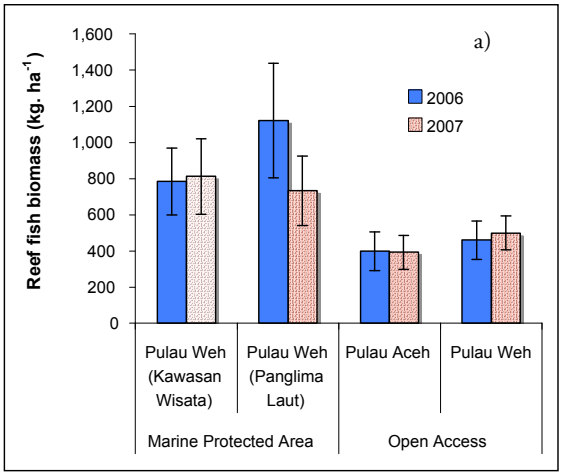



**Figure 5**. Mean abundance (± SE) ($no.ha^{-1}$) of reef fishes at study site in 4 management areas, in 2006 and 2007.



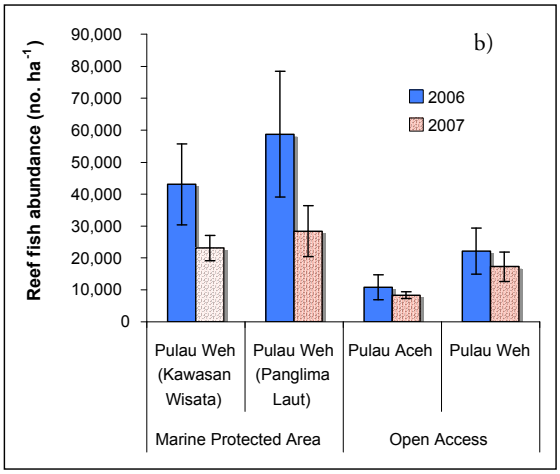




**Figure 6**. Mean biomass (a)(± SE) (kg.ha$^{-1}$) and abundance (b) of reef fishes in each management area, in 2006 and 2007.

Lapeng (Fig. 7). Sumur Tiga and Canyon are protected under the authority of Panglima Laot while Pasi Janeng 2 and Lapeng are open access areas on Aceh Islands.

However there were changes in the size class structure of fish from 2006 to 2007 (Table 2) and in the family composition. The number of small size fishes (5-10 cm) decreased, mainly due to a decrease in the number of Pomacentrids, in parallel with an increase in mid-sized fish (15-25 cm), mostly of groupers, snappers, and jacks. Pomacentrids are the most abundant reef fish present on these reefs and a major prey item for large carnivorous fishes, such as groupers, snappers, and jacks. This suggests that predation may be responsible for the overall decrease in fish abundance. Reduced fishing pressure following the tsunami in 2005 may have contributed to the increased numbers of large carnivorous fish. Excluding Pomacentrids, Acanthuridae comprised the largest portion of the biomass (Fig. 7), at all sites.

The cause of the decline in fish in management areas is unknown. As it was found at many sites it is possible that non-anthropogenic factors such as migration, seasonal variation or predation may be responsible to any apparent decline in fish numbers. The decrease in Pomacentrid abundance and increase in the numbers of large fishes requires further investigation.

## Macro-Invertebrates

A high density of macro-invertebrates was found at almost all survey sites (Table 3). Sea urchins, worms, and ascidians comprised more than 86% of all invertebrates (Fig. 8). The density of shells, shrimps, cephalopods, and jellyfishes were surprisingly low. The low density of cephalopods and jellyfishes was most likely due to seasonal variation. High economic value species, such as clams, oysters, and sea cucumbers were abundant, which contrasts with the depletion associated with high levels of exploitation of these species in other parts of Indonesia.

The number of species and the abundance of macro-invertebrates were highly variable among sites (Table 3). The highest number of species was found at Lhong Angin 3 and Ba Kopra (25 species), while the highest abundance of invertebrates was found at Paloh (25,600 individuals.ha$^{-1}$). The diversity index of invertebrates (Krebs 1989) in Rubiah Channel, located within the government tourism reserve, was highest of all sites, (H'=3.89). Most sites within marine managed areas had a medium level of diversity (1<H'<3). In contrast to corals and fish, sites within the open access areas both in Weh Islands and Aceh Islands generally

**Table 1**. Nested two-way ANOVA of the effects of time, management and site (nested within management) on fish abundance (no.ha$^{-1}$) and fish biomass (kg ha$^{-1}$). Data was log transformed prior to analysis.

| Source | df | MS | F | P |
|---|---|---|---|---|
| **Abundance** | | | | |
| Time | 1 | 9.730 | 0.335 | 0.603 |
| Management | 3 | 29.021 | 10.630 | 0.042 |
| Management*Time | 3 | 2.730 | 1.426 | 0.261 |
| Site (within Management Type) | 23 | 1.915 | 2.736 | <0.001 |
| Error | 251 | 0.700 | | |
| **Biomass** | | | | |
| Time | 1 | 2.970 | 0.160 | 0.7159 |
| Management | 3 | 18.540 | 13.572 | 0.030 |
| Management*Time | 3 | 1.366 | 0.676 | 0.576 |
| Site (within Management Type) | 23 | 2.020 | 2.763 | <0.001 |
| Error | 251 | 0.731 | | |

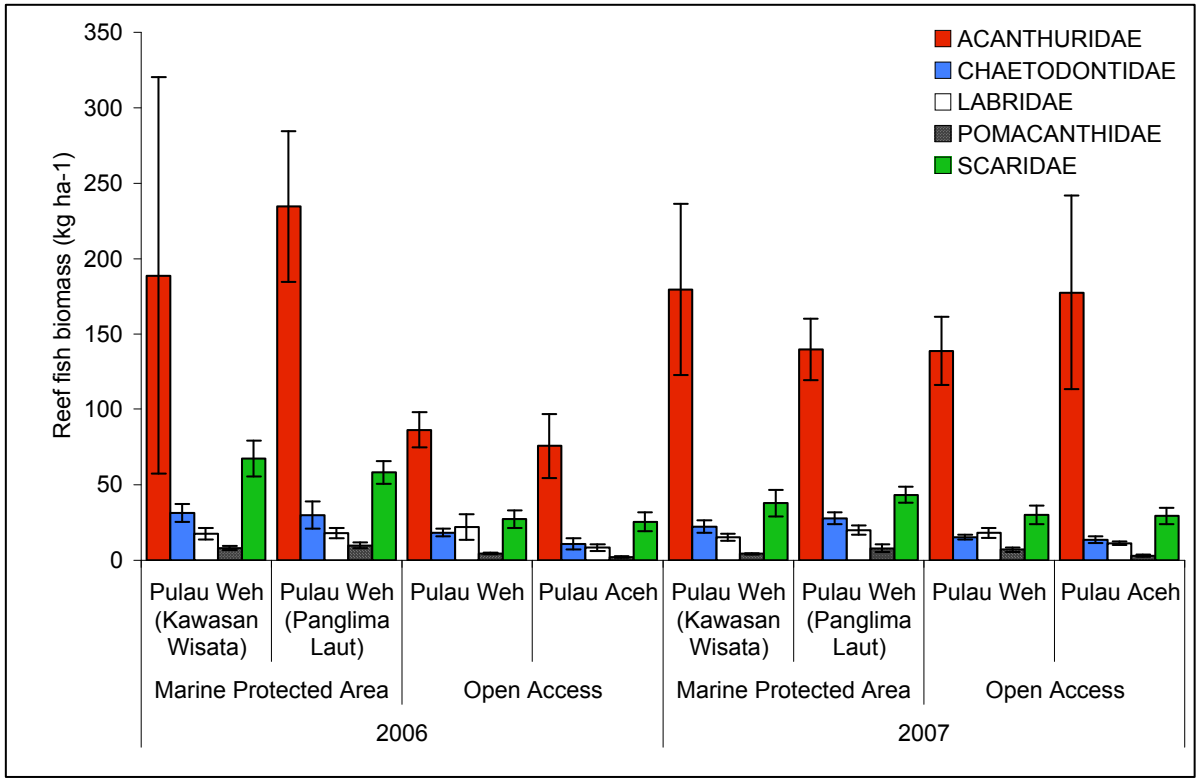



**Figure 7**. Mean biomass (± se) (kg.ha$^{-1}$) of the five major reef fish families excluding Pomacentridae, in each of the 4 management areas, in 2006 and 2007.

**Table 2**. Mean abundance (no.ha$^{-1}$) of reef fishes in 2006 and 2007.

| Parameter | Category | 2006 | 2007 |
|---|---|---|---|
| **Trophic group** | Benthic invert. | 1,071 | 1,534 |
| | Carnivore | 1,861 | 3,653 |
| | Corallivore | 712 | 605 |
| | Detrivore | | 333 |
| | Herbivore | 1,703 | 1,675 |
| | Omnivore | 25,852 | 9,171 |
| | Planktivore | 1,864 | 1,687 |
| **Size** | 0-5 cm | 5,312 | 2,848 |
| | 5-10 cm | 23,196 | 10,947 |
| | 10-15 cm | 2,050 | 1,652 |
| | 15-20 cm | 1,834 | 1,582 |
| | 20-25 cm | 290 | 827 |
| | 25-30 cm | 60 | 89 |
| | 30-35 cm | 16 | 17 |
| | 35-40 cm | 9 | 7 |
| | >40 cm | 20 | 17 |

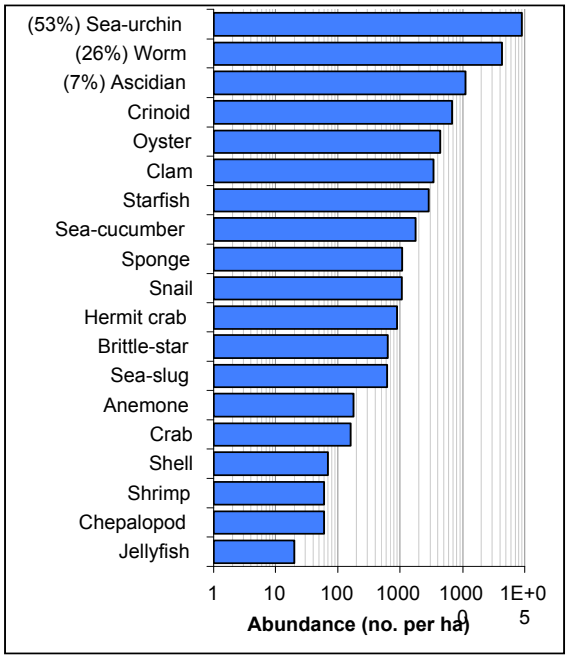



**Figure 8**. Composition of the macro-invertebrate community on reefs in Northen Aceh. Relative abundance of the top three is shown in parentheses).

had higher abundance of macro-invertebrates than sites within managed areas. These large numbers of invertebrates consisted mainly of sea urchins which are often an indicator of nutrient enrichment. Agricultural runoff is known to contribute nutrients to some areas in the Aceh Islands, although the tsunami would also have contributed high amounts of nutrients that led to the proliferation of turf algae on these reefs and a source of food for the sea urchin population. The high abundance of sea urchins may also be due to low predatory pressure from carnivorous fish. It would appear that on Acehnese reefs both urchins and herbivorous fish are highly abundant and impose high grazing pressure, reducing algal cover and currently creating space for coral recruits. Factors that reduce competition for food between urchins and fish (e.g. fishing) or increase the food supply for urchins (e.g. nutrient enrichment) may change this existing dynamic and enhance urchin population growth. In areas where coral cover and diversity are already at critically low levels, such as the Aceh Island, increases in urchin grazing pressure and space limitations arising from population growth of these and other invertebrates (e.g. *Acanthaster plancii*, *Drupella* spp.) may inhibit coral settlement and have negative consequences for coral recovery.

## CONCLUSIONS

Overall the condition of coral reefs in terms of coral cover and reef fish abundance in marine managed areas was considerably better than in open access areas. These areas have been protected from blasting and cyanide fishing while other reefs around Aceh Islands have been subject to unregulated fishing and destructive fishing. The low live coral cover in the Aceh Islands and high abundance of macro-invertebrates, in particular urchin populations, indicates that these reefs have been heavily impacted by a range of anthropogenic factors including overfishing, destructive fishing and eutrophication, undermining the recovery of the reefs. However, the reduction in dynamite and cyanide fishing since 2005

**Table 3**. Number of species, abundance and diversity index of macro-invertebrates at study sites.

| Island | Site Number | Site Name | Number of Species (S) | Abundance ($ha^{-1}$) | Diversity Index (H') |
|---|---|---|---|---|---|
| Weh (MPA) | 26 | Bate Meuronon | 19 | 5,090 | 3.13 |
| | 8 | Rubiah Channel | 21 | 1,660 | 3.89 |
| | 24 | Rubiah Sea Garden | 19 | 12,840 | 1.71 |
| | 7 | Ujung Seurawan | 14 | 3,190 | 2.39 |
| | 14 | Anoi Itam | 19 | 4,080 | 2.88 |
| | 19 | Sumur Tiga | 13 | 6,090 | 2.28 |
| Weh (Open Access) | 1 | Ba Kopra | 25 | 9,920 | 2.58 |
| | 6 | Gapang | 14 | 3,510 | 3.04 |
| | 17 | Jaboi | 15 | 2,230 | 3.25 |
| | 2 | Lhong Angin 1 | 21 | 15,570 | 2.06 |
| | 3 | Lhong Angin 2 | 20 | 9,370 | 1.96 |
| | 4 | Lhong Angin 3 | 25 | 13,360 | 2.50 |
| | 5 | Pulau Klah | 27 | 6,240 | 3.04 |
| Aceh (Open Access) | 12 | Deudap | 20 | 10,980 | 2.29 |
| | 13 | Lamteng | 17 | 3,530 | 2.75 |
| | 9 | Lapeung | 7 | 4,430 | 1.48 |
| | 21 | Lhoh | 15 | 15,150 | 1.91 |
| | 20 | Paloh | 14 | 25,600 | 1.24 |
| | 22 | Pase Janeng 1 | 10 | 1,030 | 1.94 |
| | 23 | Pase Janeng 2 | 18 | 6,070 | 2.65 |
| | 11 | Luen Balee 2 | 9 | 11,260 | 1.66 |

has allowed the reefs in Aceh Islands to begin to recover, with recent reports of high coral recruitment (Ardiwijaya *et al.* 2007). A reduction in destructive fishing activities was indicated by an increase in the number of carnivorous fish from 2006 to 2007, such as groupers, snappers, and jacks, which are target species for local fisheries. Management controls that reduce pressure particularly on carnivorous and herbivorous reef fish species are urgently required to maintain reef diversity, the existing balance between grazing pressure and coral recruitment, and to prevent sea urchin population growth from having negative impacts on coral reefs. Further studies and monitoring are required to examine if recovery of Aceh Islands reefs continues and compare these trends with nearby reefs where existing management controls on fisheries also require support and strengthening.

## RECOMMENDATIONS

-Gear restrictions on the use of netting, and enforcement of prohibited and/or destructive fishing methods, in particular blast fishing and cyanide, need consideration in the context of designing marine management areas in northern Aceh.

-Continued monitoring of reef fish, sea urchins and coral reef recovery within and outside of management zones is required for informing management options for the area and evaluating management success.

-The abundance and biomass of carnivorous fish needs to be maintained through effective management controls that reduce pressure and protect target species from overfishing.

-Identifying reef fish spawning aggregation sites of high economic value fish, such as groupers and

napoleon wrasse, is required to design MPAs and assist in marine conservation planning.

-Strong support from stakeholders, including the government, private sector, and local communities are required to maintain and strengthen existing Marine Protected Areas and build a network of marine managed areas that represents marine habitats, processes and functions of the region.

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