

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



Syiah Kuala  
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INDONESIA  
MARINE PROGRAM

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

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## ABSTRACT

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Northern Acehese reefs, which are 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. Impacts on reef resources were patchy although limited data and information on coral reef condition before the tsunami has obviated the need for regular long-term coral reef monitoring to assess their recovery from tsunami impacts and from previous damage caused by destructive fishing and overfishing. The objectives of this study were to provide reliable data and information on benthic hard 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 around Weh Island and Aceh Islands, we found that the mean coral reef cover in Weh Island was significantly higher (29.98%-fair condition) compared to Aceh Islands (10.76%-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. Reef fish abundance in Weh Island ( $32505 \text{ no. ha}^{-1}$ ) and biomass ( $748 \text{ kg. ha}^{-1}$ ) were also significantly higher than in Aceh Islands (abundance= $9539 \text{ no. ha}^{-1}$ ; biomass= $396 \text{ kg. ha}^{-1}$ ). Fish species from the family Pomacentridae (damselfish) were highest in abundance and biomass. Higher numbers of macro-invertebrates, in particular sea urchins, were found in Aceh Islands compared to Weh Island, and in open access areas compared with marine managed areas. The potential for sea urchins to influence coral recruitment and coral reef recovery of Aceh island requires further investigation.

Key Words: Coral reef, reef fish, tsunami, Acehese reef

## MANAGEMENT POLICY STATEMENT

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Banda Aceh, December 2007

In February 2007 the Marine and Fisheries Study Centre - Syiah Kuala University collaborated with the Wildlife Conservation Society (WCS) - Marine Program Indonesia to survey coral reefs of Aceh and Weh (Sabang) islands as part of ongoing monitoring of these reefs in the aftermath of the 2005 tsunami. The activity was an integrated coral reef monitoring after previous 2006 monitoring by Unsyiah and WCS separately.

The aim of the monitoring was; 1) to provide knowledge on the condition and recovery of coral reefs in the region and to provide information that can support and underpin sustainable reef management, and 2) promote collaboration between institutions and organizations involved in coral reef management in Aceh.

The key finding of the 2007 survey is that the condition of coral reefs in terms of coral cover and reef fish abundance in marine managed areas is considerably better than in areas open to unregulated fishing activity on Weh Island. The low cover of live corals in the Aceh Islands indicates that the coral reefs of these islands have been heavily degraded by destructive fishing activities. These reefs also contain high numbers of macro-invertebrates, in particular sea urchin populations, that may have been caused by the removal of predators by overfishing, and also from nutrient runoff from poorly located and managed agricultural development.

Nevertheless the reduction in dynamite and cyanide fishing since 2005 has allowed the reefs in Aceh Island to begin to recover as evidenced by high numbers of coral recruits and the abundance of both herbivorous and carnivorous fish in some locations.

Recommendations from this study:

- 1) A network of marine managed areas with community support is required to protect representative marine habitats in the region, increase the abundance and biomass of reef fish and allow coral reefs to recover from poor management practices

- 2) Fisheries management should consider implementation of suite of controls including no take areas, restrictions on the use of some gears (e.g. nets) in some areas and the banning of destructive/unsustainable fishing methods
- 3) Decisions on the design of new management controls and strengthening of existing marine managed areas requires input from traditional fishery management institutions, local government agencies and communities
- 4) A monitoring program that investigates the health of reefs is required to identify the rate of coral reef recovery and evaluate the success of management controls
- 5) Identification of reef fish spawning aggregation sites and other habitat for manta ray, whaleshark, dolphin and turtle are important factors to be considered in the design of management controls for a marine managed area network

Further information on the survey is attached.

Sincerely,

Dr. Edi Rudi, M.Sc.  
Team Leader

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# 1. INTRODUCTION

## ***Background***

Northern Aceh and the surrounding reefs in 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* species in sheltered areas and mostly branching species at high-energy reefs (Brown 2005). Weh Island and Aceh Islands are the two main islands in northern Aceh and also the western most reef areas in the Indonesian archipelago. The marine fauna and flora of north-west Sumatra, including the northern Aceh reefs are comprised of species from the Indian Ocean and the Pacific Ocean and make the region biogeographically distinct from eastern Indonesian coral reef fauna and flora.

Coral reefs of Weh Island are known to be generally in better condition than those on Aceh islands because of past differences in management between these two regions of northern Aceh (Baird *et al.* 2005a and b). The reefs are important for fisheries with a range of artisanal gears used and mainly pelagic commercial fisheries. The area is known for its 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).

Coral reefs habitats and their associated fauna and flora are therefore important marine ecosystems with important ecological functions and services in the region. 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 Island heavily affected by the earthquake and tsunami; mostly the northern and southern coasts (Baird *et al.* 2005b). Damaged houses, boats, fishing gears, and loss of life paralyzed the economic state of northern Aceh's fisheries, including the 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 reefs of Northern Aceh range from those are very poor to those in good condition but generally have only been recently well documented (Baird *et al.* 2005a, Baird *et al.* 2005b, Campbell *et al.* 2005, Ardiwijaya *et al.* 2007). 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.

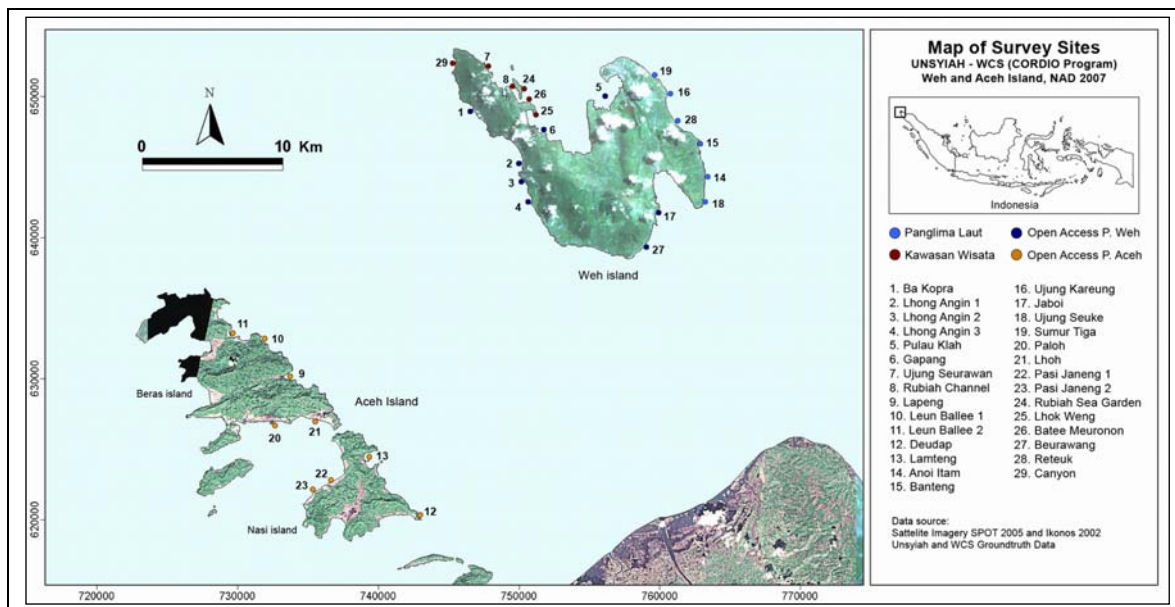
***Aim of the research***

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.

## 2. METHODS

### Survey Sites

Coral reef and invertebrate surveys were conducted at 21 sites; consisting of 13 sites on Weh Island and 8 sites on Aceh Islands. Coral reef fish surveys were conducted at 29 sites; consisting of 19 sites on Weh Island and 10 sites on Aceh Islands (**Figure 1**). Sites were selected to represent the reefs of the region and the types of site management including: Marine Protected Area (MPA, consisted of Panglima Laut and Tourism Reserve) where fishing restrictions are in place and unrestricted fishing or open access areas. Description of each site is presented in **Table 1**.



**Figure 1.** Map showing of survey sites at northern Acehese coral reef ecosystem

### Survey Techniques

The methods used in this research were Manta Tow, Line Intercept Transect (LIT) for benthic cover, under water visual census technique (VCT) 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).

**Table 1.** Description of each study site. LIT = Line Intercept Transect for benthic cover estimates; VCT = Underwater visual census technique for reef fishes; Manta Tow was used for broad benthic cover estimation and Belt transects were used for invertebrates

Site	Site Name	Data Collected/ Methods	Location	Management Type
1	Ba Kopra	LIT, Manta Tow, VCT, Invertebrate	Weh Island	open access
2	Lhong Angin 1	LIT, Manta Tow, VCT, Invertebrate	Weh Island	open access
3	Lhong Angin 2	LIT, VCT, Invertebrate	Weh Island	open access
4	Lhong Angin 3	LIT, VCT, Invertebrate	Weh Island	open access
5	Pulau Klah	LIT, VCT, Invertebrate	Weh Island	open access
6	Gapang	LIT, VCT, Invertebrate	Weh Island	open access
7	Ujung Seurawan	LIT, VCT, Invertebrate	Weh Island	MPA
8	Rubiah Channel	LIT, Manta Tow, VCT, Invertebrate	Weh Island	MPA
9	Lapeung	LIT, VCT, Invertebrate	Aceh Islands	open access
10	Luen Balee 1	VCT	Aceh Islands	open access
11	Luen Balee 2	LIT, VCT, Invertebrate	Aceh Islands	open access
12	Deudap	LIT, VCT, Invertebrate	Aceh Islands	open access
13	Lamteng	LIT, VCT, Invertebrate	Aceh Islands	open access
14	Anoi Itam	LIT, VCT, Invertebrate	Weh Island	MPA
15	Benteng	VCT	Weh Island	MPA
16	Ujung Kareung	VCT	Weh Island	MPA
17	Jaboi	LIT, VCT, Invertebrate	Weh Island	open access
18	Ujung Seuke	VCT	Weh Island	MPA
19	Sumur Tiga	LIT, VCT, Invertebrate	Weh Island	MPA
20	Paloh	LIT, VCT, Invertebrate	Aceh Islands	open access
21	Lhoh	LIT, VCT, Invertebrate	Aceh Islands	open access
22	Pase Janeng 1	LIT, VCT, Invertebrate	Aceh Islands	open access
23	Pase Janeng 2	LIT, Manta Tow, VCT, Invertebrate	Aceh Islands	open access
24	Rubiah Sea Garden	LIT, Manta Tow, VCT, Invertebrate	Weh Island	MPA
25	Lhok Weng	VCT	Weh Island	MPA
26	Bate Meuronon	LIT, Manta Tow, VCT, Invertebrate	Weh Island	MPA
27	Beurawang	VCT	Weh Island	open access
28	Rateuk	VCT	Weh Island	open access
29	Canyon	VCT	Weh Island	MPA

### **Benthic fauna**

Line intercept transect were used to assess morphological descriptions of the reef benthic community in life form level. Data were recorded with 2 replicate 30 metre transects. The interpretation of reef condition using percent coverage of live hard coral was based on Gomez and Yap (1998); excellent (75-100%); good (50-74,9%); fair (25-49,9%), and poor (0-24,9%).

Manta Tow was used to obtain general descriptions of some reef areas by estimating percent cover of hard coral, soft coral, dead coral and sand. This method involved towing two divers using a boat at a constant speed (2 knots) and regular stops to record data every 2 minutes of substrate cover between reef flat and reef edge. The number of tows varied between locations and was depended on reef and environmental conditions. Conducting the Manta Tow technique in addition to the LIT coral surveys aimed to provide a broader assessment of benthic fauna cover and health over a larger scale than LIT surveys and measure broad changes in coverage and composition of benthic categories (Hill and Wilkinson 2004).

### **Reef Fish**

Abundance and biomass of reef fishes were recorded using Underwater Visual Census using the same transects for LIT plus an 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) along 3 replicate 5x50 m<sup>2</sup> belt-transects for fish >10cm and 3 replicate 2x50 m<sup>2</sup> area for fish <10cm. Data was converted to number of individuals per hectare (no.ha<sup>-1</sup>) (fish abundance) and also kilograms per hectare (kg.ha<sup>-1</sup>) (fish biomass) using length-weight relationships for fish species using the following equation:

$$W = a L^b,$$

W = weight (kg)

a and b = constant (taken from FishBase 2000)

L = length (cm)

### **Macro-Invertebrates**

Abundance of macro-invertebrates were collected using 2 replicate 5x50 m<sup>2</sup> belt transects (50 m in length and 2.5 m wide on each side) at the two depths. All individuals were identified to species and data converted to numbers per unit area (no.ha<sup>-1</sup>). Species diversity was analyzed using Shannon-Wiener index (H') according to Krebs 1989):

$$H' = -\sum_{i=1}^s P_i \text{Log}_2 P_i$$

$$P_i = \frac{n_i}{N}$$

H' = diversity index

$n_i$  = number of individual species-i

N = number of total individual

Note: H' < 1 : low diversity

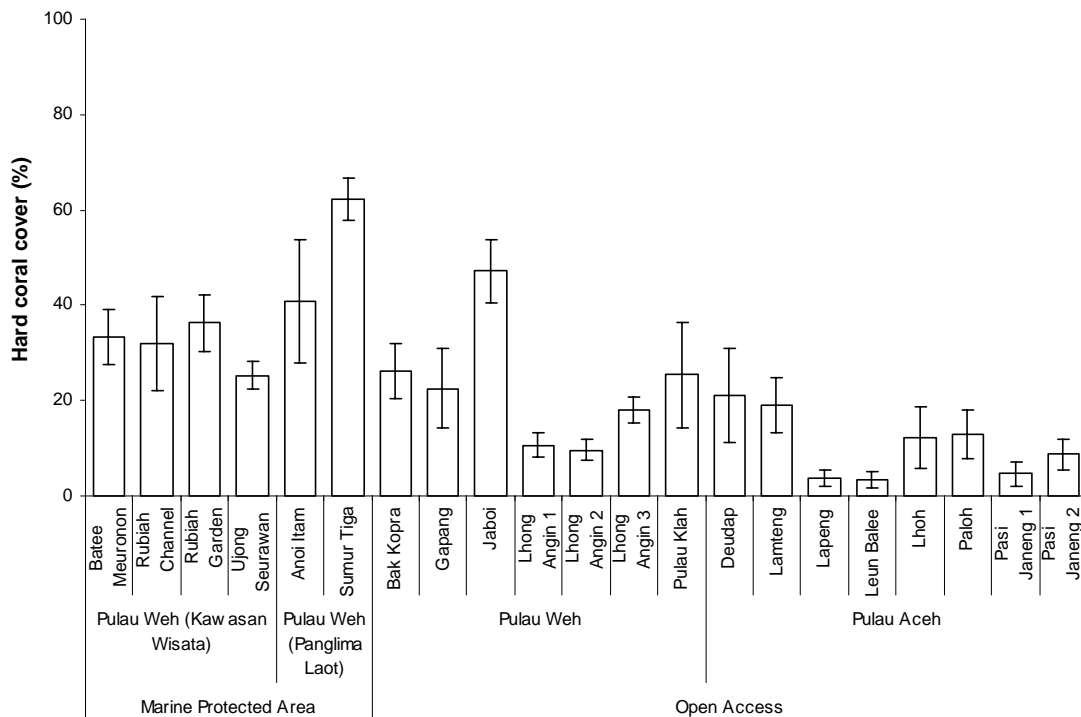
1 < H' < 3 : medium diversity

H' > 3 : high diversity

### 3. RESULTS AND DISCUSSION

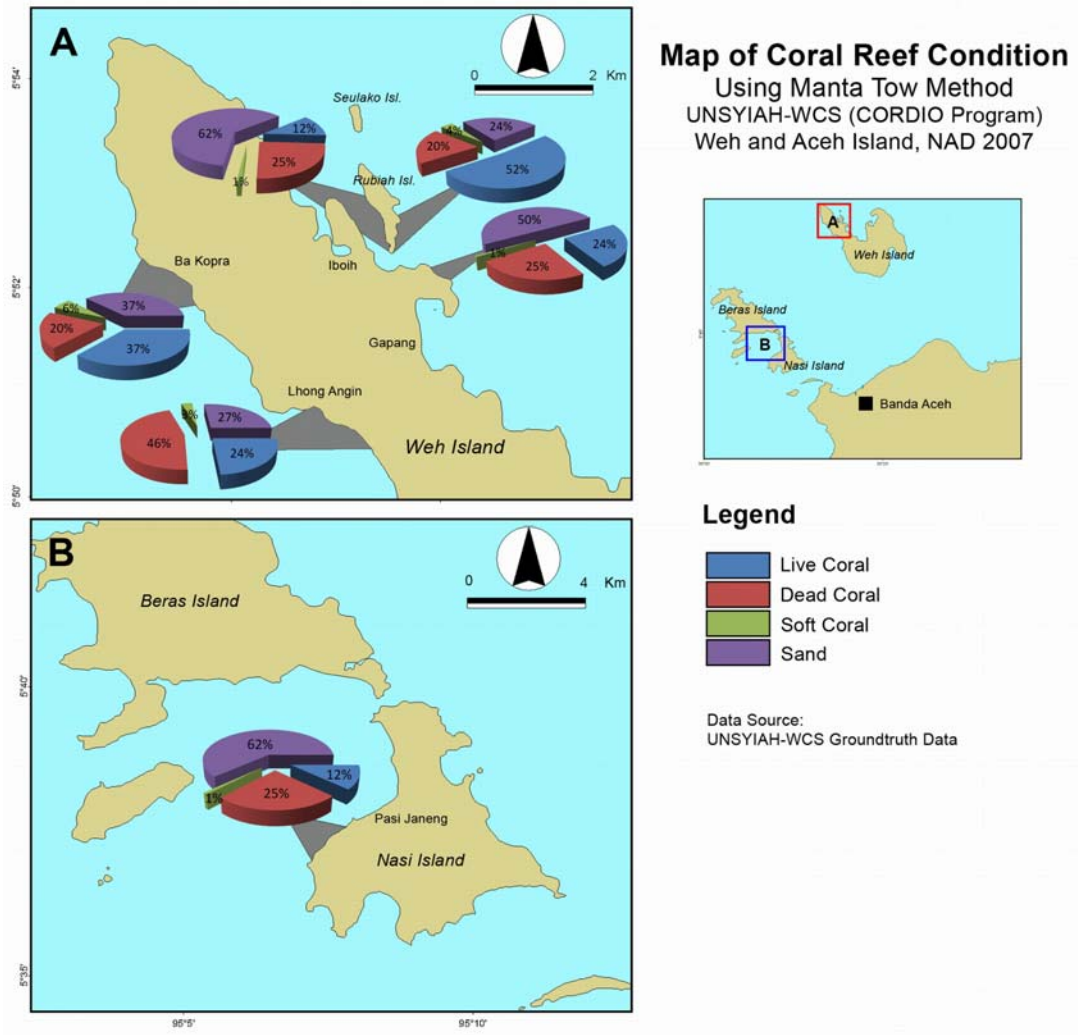
#### *Coral Reefs*

The health of coral reefs varied considerably within the region with overall mean hard coral cover pooled for both depths higher on Weh Island ( $29.98\% \pm 2.41SE$ ) than Aceh Island, ( $10.76\% \pm 4.04SE$ ). Hard coral cover was higher on reefs with fishing restrictions on Weh Island; Panglima Laot ( $51.50\% \pm 10.78SE$ ) and inside the Tourism Reserve ( $31.73\% \pm 2.31SE$ ); compared with open access areas in Weh Island ( $22.83\% \pm 4.77SE$ ). Using Gomes and Yap (1998) categories to estimate reef condition, only at one site (Sumur Tiga -site 19), managed by the Panglima Laot authority, was categorized as “good condition” ( $62.28\% \pm 4.44SE$ ), while at 8 sites ( $25.32-47.21\%$ ) were in “fair condition” and at 12 sites were in “poor condition” ( $3.55-22.54\%$ ) (**Figure 2**).



**Figure 2.** Mean percent cover of hard coral ( $\pm SE$ ) in each study site at Weh Island and Aceh Island based on LIT

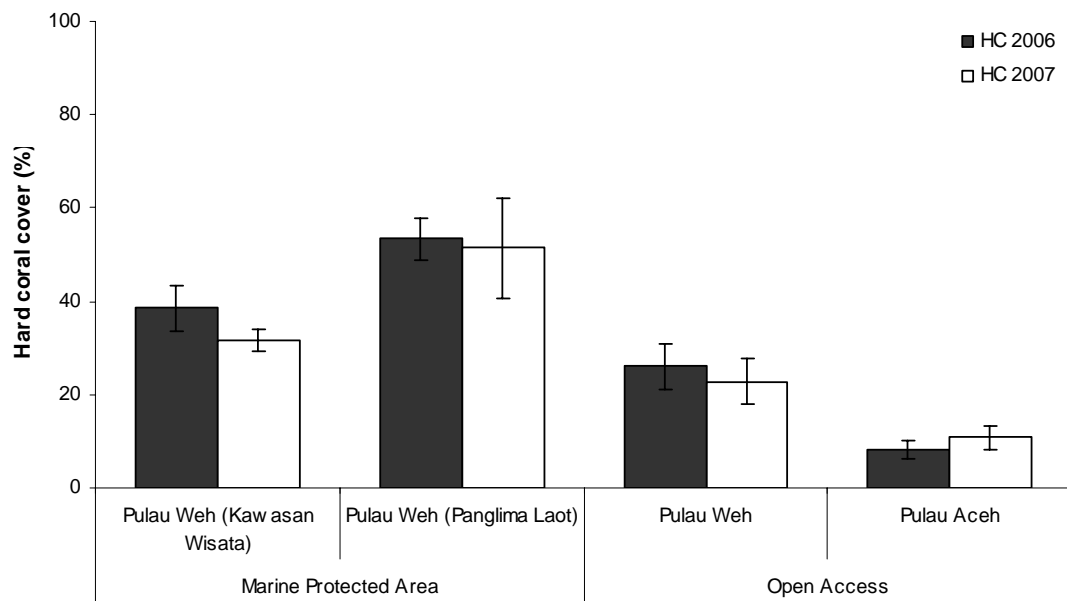
Results from broad scale surveys (i.e. manta tow surveys) indicate that the benthic habitats are dominated by sand and that mean live coral on Weh Island (12-52%) was in better condition than in Aceh Islands (12%) (**Figure 3**). The results support findings from the small scale LIT surveys that reefs inside managed areas were in better condition than those inside open access areas.



**Figure 3.** Percent cover of benthic communities in each study sites at Weh Island (A) and Aceh Island (B) based on Manta Tow Technique

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, yet there was also little evidence of recent coral mortality. To the contrary, an increase in the mean coral cover in Aceh Islands from 2006 (8.16%  $\pm$  1.83SE: Ardiwijaya et al. 2007) to 2007 (10.76%  $\pm$  2.41SE: this study), suggests that recruitment of corals is occurring as has been previously suggested (Ardiwijaya et al. 2007) (**Figure 4**).

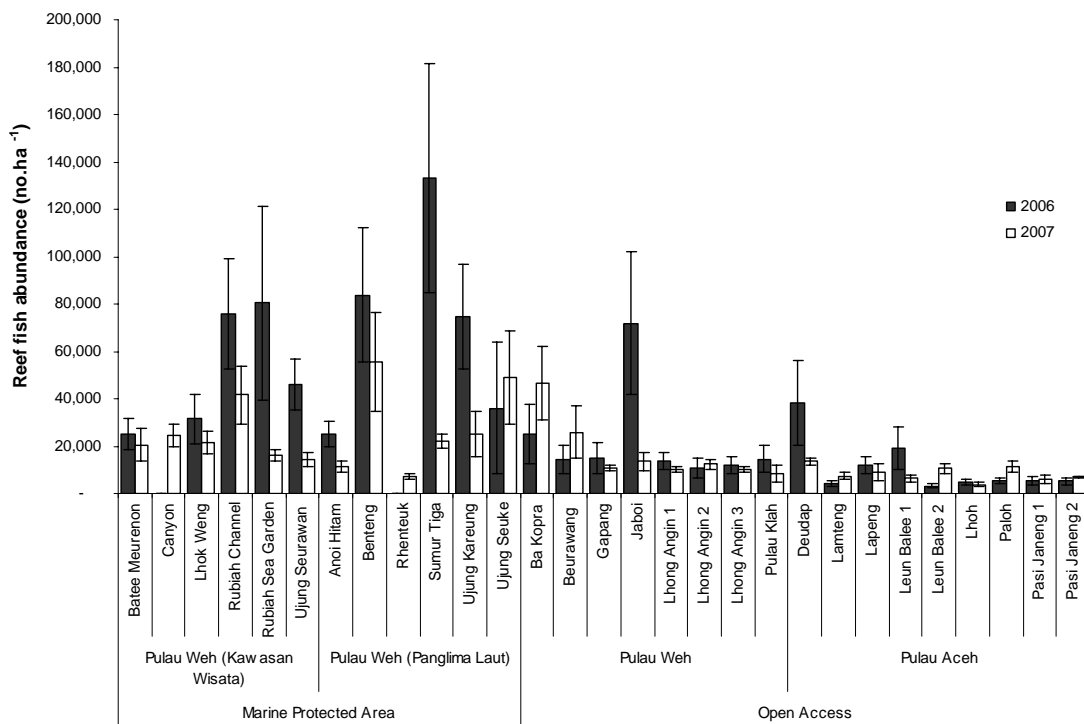


**Figure 4.** Mean coral cover ( $\pm$  SE) (%) of coral reef in 2006 and 2007 in each of 4 management areas

It is possible that reductions in fishing effort following the tsunami, in particular a reduction in destructive fishing have allowed reefs on Aceh islands to start to recover from the human misuse of the past. Nevertheless, recent reports in 2007 of the use of cyanide fishing are of considerable concern and highlight the urgent need for marine resource management on these islands. 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 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 (133050 no.ha<sup>-1</sup>), while in 2007 it was highest at Benteng (83770 no.ha<sup>-1</sup>) (**Figure 5**). Both sites were located within Panglima Laot management areas. Although the abundance of reef fishes was significantly affected by site (nested within management) ( $F=2.586$ ;  $P<0.05$ ) the effects of management had a greater influence of fish abundance (ie. Higher F ratios;  $F=37.671$ ;  $P<0.005$ ) (**Table 2**) because of more fish within marine managed areas within Panglima Laot sites than open access sites.

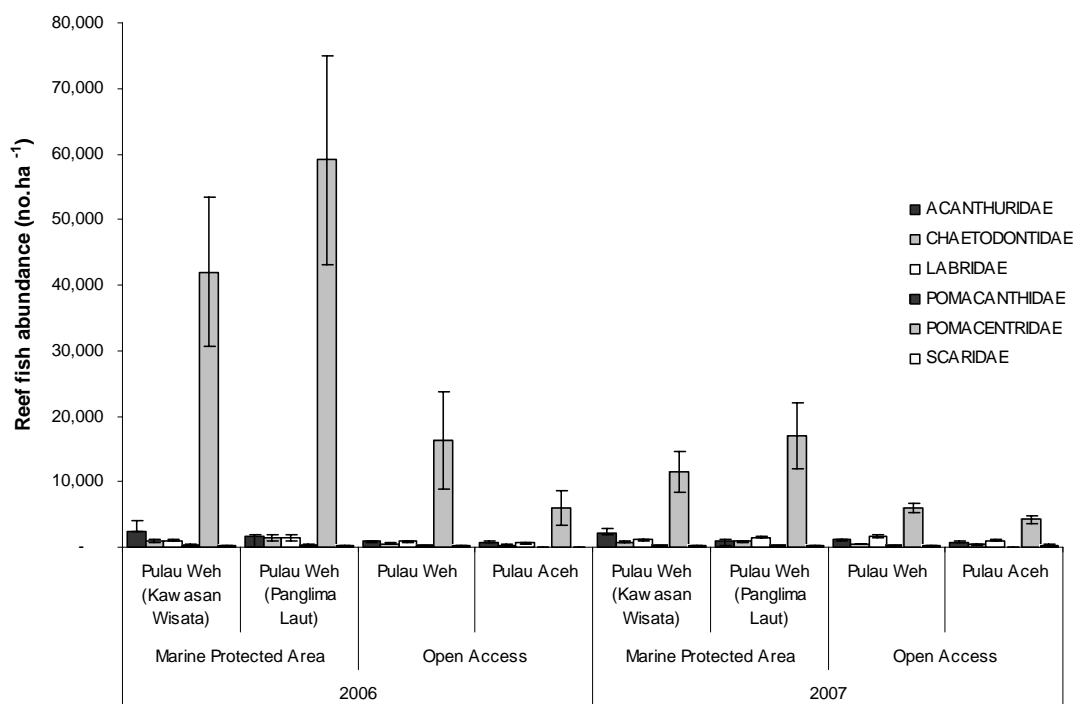


**Figure 5.** Mean abundance ( $\pm$  SE) (no.ha<sup>-1</sup>) of reef fishes in 2006 and 2007 at each study site and in 4 management areas

The significant effect of time ( $F=8.210$ ;  $P<0.005$ ) on fish abundance was due to a decrease in overall fish numbers from 2006 (32788 no.ha<sup>-1</sup>  $\pm$  4313) to 2007 (17986 no.ha<sup>-1</sup>  $\pm$  1636). This decrease in fish abundance was due to lower numbers of Pomacentrids (**Figure 6**), which comprised much of the small size fishes (5-10 cm) that also decreased in numbers from 2006 to 2007 (**Table 3**).

**Table 2.** Nested two-way ANOVA of the effects of time, management and site (nested within management) on fish abundance (no.ha<sup>-1</sup>) and fish biomass (kg.ha<sup>-1</sup>). Data was log transformed prior to analysis

Source	df	MS	F	P
<b>Biomass</b>				
Time	1	1.825	2.495	0.115
Management	3	18.934	25.878	0.001
Site (Management)	25	1.841	2.516	0.001
Error	252	0.732		
<b>Abundance</b>				
Time	1	5.981	8.210	0.005
Management Type	3	27.443	37.671	0.001
Site Name (Management Type)	25	1.884	2.586	0.001
Error	252	0.728		



**Figure 6.** Mean ( $\pm$ SE) of abundance (no.ha<sup>-1</sup>) of reef fishes of 2006 and 2007 at each study site and type of management based on six major families that commonly found

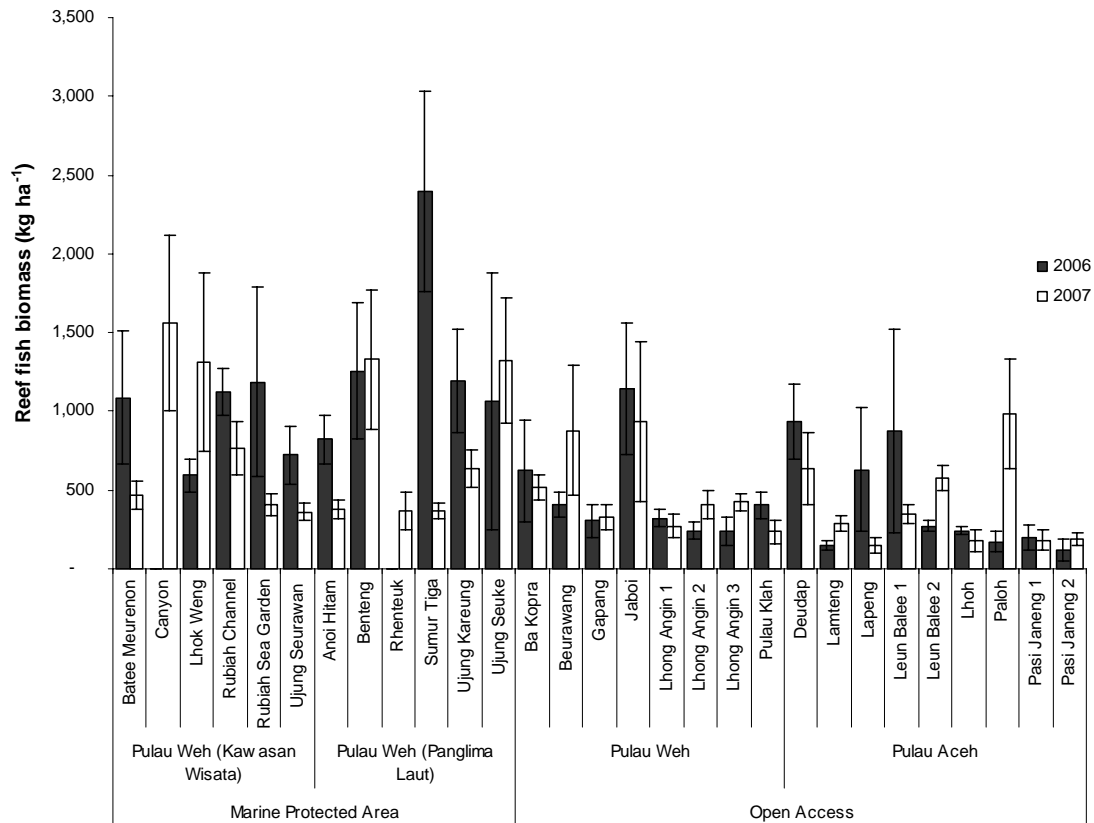
Pomacentrids are the most abundant reef fish present on these reefs and a major prey item for large carnivorous fishes, such as groupers, snappers, and jacks. The increasing numbers of carnivorous fish between 2006 and 2007 and increasing numbers of large size fishes (20-25 cm) which consisted mostly of groupers, snappers, and jacks (WCS unpublished data) 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.

**Table 3.** Mean abundance (no.ha<sup>-1</sup>) and biomass (kg.ha<sup>-1</sup>) of reef fishes in 2006 and 2007

Parameter	Category	2006	2007
<b>Trophic group</b>			
	Benthic invertebrate	1071.2963	1533.5632
	Carnivore	1861.2963	3652.6437
	Corallivore	712.0370	605.0575
	Detrivore		333.3333
	Herbivore	1703.1481	1674.4828
	Omnivore	25852.4074	9170.8046
	Planktivore	1863.9130	1687.2464
<b>Size</b>			
	0-5 cm	5312.0370	2848.2759
	5-10 cm	23196.2963	10947.1264
	10-15 cm	2050.3704	1652.1839
	15-20 cm	1834.4444	1581.6092
	20-25 cm	290.0000	827.1264
	25-30 cm	59.6296	89.1954
	30-35 cm	16.2963	17.2414
	35-40 cm	8.8889	6.6667
	>40 cm	20.0000	16.7816

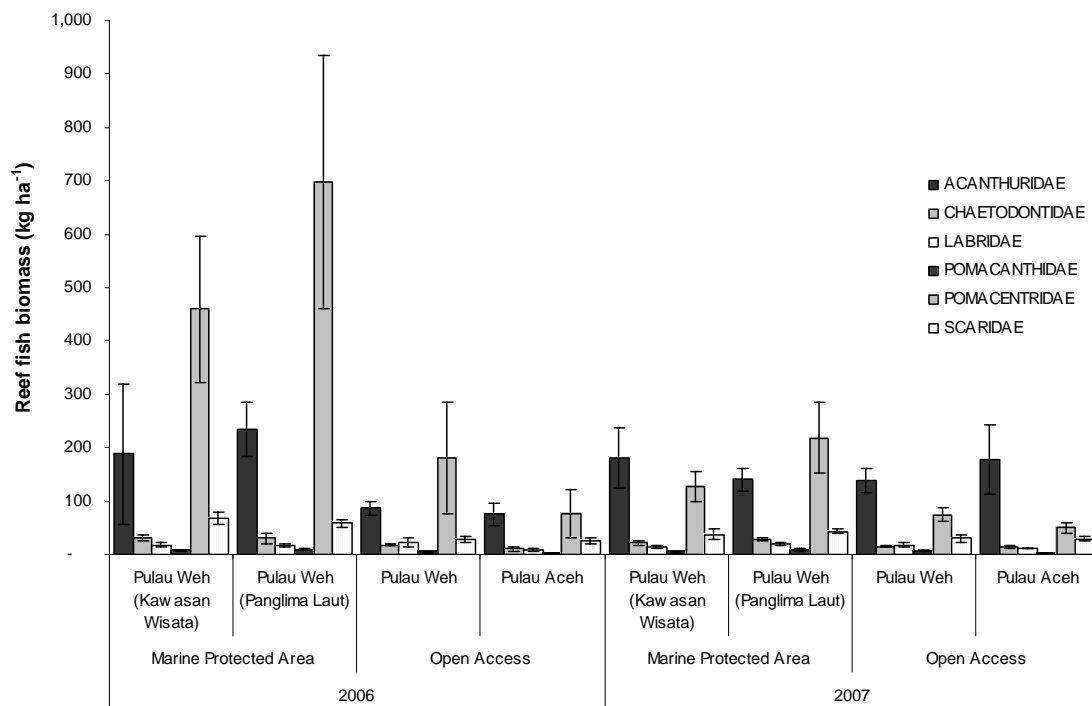
In contrast, there was no significant different in reef fish biomass between 2006 and 2007 ( $F= 2.495$ ;  $P>0.005$ ) (Table 3). Biomass of reef fishes in 2006 ranged from 118 to 2399 kg.ha<sup>-1</sup>. The highest was recorded in Sumur Tiga, and the lowest was in Pasi Janeng2. In 2007, biomass of reef fishes ranged from 149 to 1562 kg.ha<sup>-1</sup>, the highest was recorded in Canyon and the lowest in Lapeng (**Figure 7**). Sumur Tiga and Canyon were protected areas under the authority of Panglima Laot while Pasi Janeng 2 and Lapeng were open access areas in Aceh Islands. Fish from the family Pomacentridae had the highest biomass of all sites in 2006 (**Figure 8**), but no change between 2006 and 2007 occurred as Acanthuridae comprised a large portion of the biomass in 2007,

except within the areas under Panglima Laut where Pomacentridae was still dominant (Figure 8 and Figure 9).

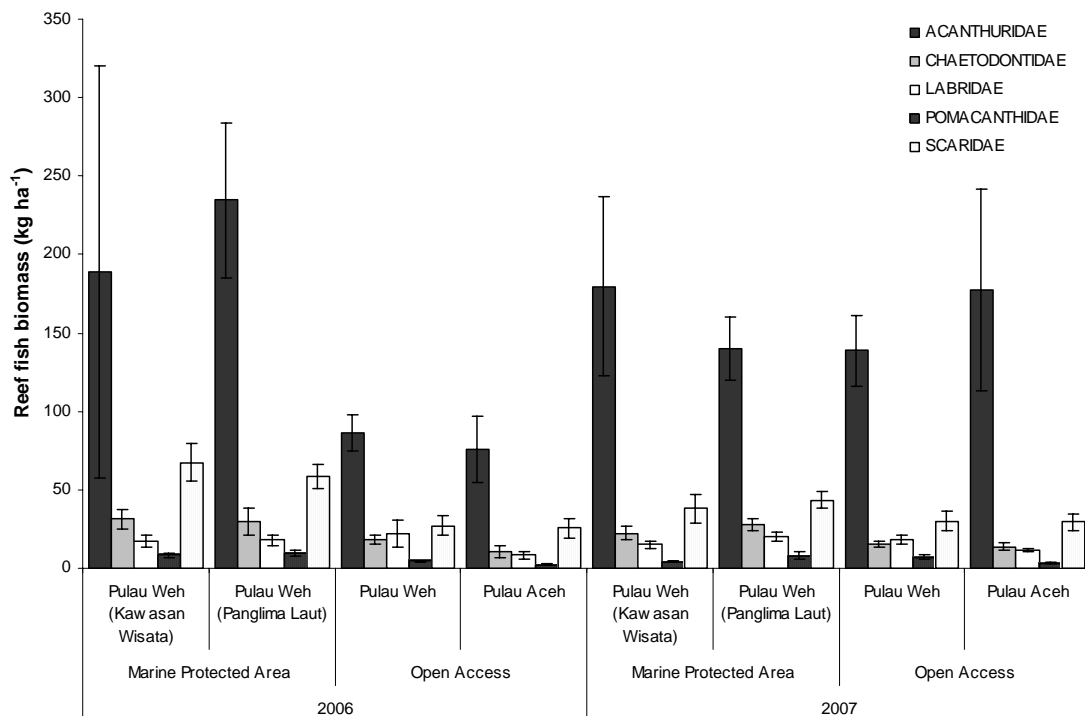


**Figure 7.** Mean ( $\pm$  SE) of biomass (kg.ha<sup>-1</sup>) reef fishes of 2006 and 2007 at each study site and 4 management areas

Overall the findings show that reef fishes abundance and biomass are highest within the areas where management controls are in place, suggesting that these controls should form a part of any future coral reef management strategies proposed for the region. Although the overall abundance of reef fish declined from 2006 to 2007, the cause of this is unknown. As it was occurring at many sites it is possible that non-anthropogenic factors such as migration, season or predation may be responsible, The decrease in Pomacentrid abundance and increase in the numbers of large fishes requires further investigation.



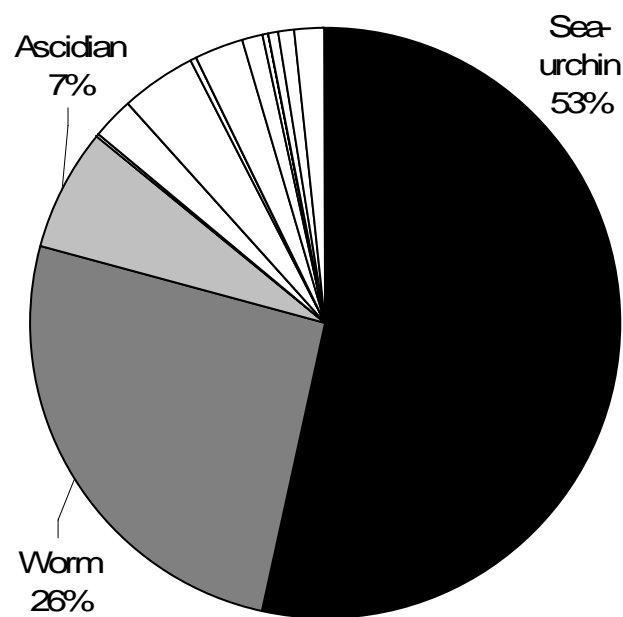
**Figure 8.** Mean biomass ( $\pm$  SE) ( $\text{kg}\cdot\text{ha}^{-1}$ ) of six major families reef fishes in 2006 and 2007 in each of 4 management areas



**Figure 9.** Mean biomass ( $\pm$  SE) ( $\text{kg}\cdot\text{ha}^{-1}$ ) of six major families reef fishes in 2006 and 2007 in each management area, excluding Family Pomacentridae

### **Macro-invertebrates**

A high density of macro-invertebrates was found at almost all survey sites (Appendix 1). Sea urchins, worms, and ascidians comprised more than 86% of all invertebrates at each site (**Figure 10**). The density of shells, shrimps, cephalopods, and jellyfishes were surprisingly low, even though the low density of cephalopods and jellyfishes was most likely seasonal factor. High economic value species, such as clams, oysters, and sea cucumbers were abundant, which contrasts with the levels of exploitation these marine animals in other locations in Indonesia.



**Figure 10.** Composition of macro-invertebrates in Northern Aceh

The number of species and the abundance of macro-invertebrates were highly variable among sites (Table 4). 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 (25600 individuals.ha<sup>-1</sup>). The diversity index of invertebrates (Krebs 1989) in Rubiah Channel, located within the government tourism reserve was highest of all sites, ( $H' = 3.89$ ), and 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 Island and Aceh Islands generally had higher abundance of macro-invertebrates than sites with marine 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.

**Table 4.** Number of species, abundance and index diversity of macro-invertebrate at each study sites

Island	Site Number	Site Name	Number of Species (S)	Abundance (ind.ha <sup>-1</sup> )	Diversity Index (H')
Weh (MPA)	26	Bate Meuronon	19	5090	3.13
	8	Rubiah Channel	21	1660	<b>3.89</b>
	24	Rubiah Sea Garden	19	12840	1.71
	7	Ujung Seurawan	14	3190	2.39
	14	Anoi Itam	19	4080	2.88
	19	Sumur Tiga	13	6090	2.28
Weh (Open Access)	1	Ba Kopra	25	9920	2.58
	6	Gapang	14	3510	3.04
	17	Jaboi	15	2230	3.25
	2	Lhong Angin 1	21	15570	2.06
	3	Lhong Angin 2	20	9370	1.96
	4	Lhong Angin 3	<b>25</b>	13360	2.50
	5	Pulau Klah	27	6240	3.04
Aceh (Open Access)	12	Deudap	20	10980	2.29
	13	Lamteng	17	3530	2.75
	9	Lapeung	7	4430	1.48
	21	Lhoh	15	15150	1.91
	20	Paloh	14	<b>25600</b>	1.24
	22	Pase Janeng 1	10	1030	1.94
	23	Pase Janeng 2	18	6070	2.65
	11	Luen Balee 2	9	11260	1.66

The high abundance of sea urchins may also be due to low predatory pressure from carnivorous fish. It would appear that on Aceh island reefs both urchins and herbivorous fish are highly abundant and impose high grazing pressure on the reefs, 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 sea-urchin population growth.

In areas where coral cover and diversity are already at critically low levels, such as the Aceh islands, increases in urchin grazing pressure and space limitations arising from population growth of these and other invertebrates (e.g. *Acanthaster planci*, *Drupella* spp.) may inhibit coral settlement and have negative consequences for coral recovery.

#### 4. 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 Aceh Islands' reefs have been subject 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 coral reefs of Aceh Island have been heavily impacted possibly by a range of anthropogenic factors including overfishing, destructive fishing and eutrophication that was not supporting the recovery of the reefs. However, the reduction in dynamite and cyanide fishing since 2005 has allowed the reefs in Aceh Island to begin to recover, with recent reports of high coral recruitment (Campbell *et al.* 2006). 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 prevent sea urchin population growth from having negative impacts on coral reefs. Further studies and monitoring are required to examine if recovery of Aceh island reefs continues and compare these trends with nearby reefs where existing management controls on fisheries also require support and strengthening.

## 5. RECOMMENDATIONS

- a. Gear restrictions on the use of netting and prohibition on destructive fishing methods, in particular blast fishing and cyanide need consideration in the context of designing marine management areas in northern Aceh.
- b. Continued monitoring of reef fish, sea urchins and coral reef recovery within and among management zones is required for informing management options for the area and evaluating management success.
- c. The abundance and biomass of carnivorous fish needs to be maintained through effective management controls that reduce pressure and protect target species from overfishing.
- d. Identifying spawning aggregation sites (SPAGS) of high economic value fish, such as groupers and napoleon wrasse, is required to design MPAs and assist in marine conservation planning.
- e. Strong support from stakeholders, including the government, private sectors, 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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