# Technical Report

## The coral reefs of northern Aceh: an ecological survey of Weh and Aceh islands, April 2006

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MARINE PROGRAM

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## The coral reefs of northern Sumatra: an ecological survey of Weh and Aceh Islands, April 2006

Report no. REP/XVII/EXT/01/07/ENG

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*Composition and layout: Yudi Herdiana*
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# 1. EXECUTIVE SUMMARY

The aim of this survey was to assess the condtion of coral reefs in 3 management regions of Weh and Aceh Islands, situated on the western coast of Nangroe Aceh Darussalam province. Data on coral reef condition including hard coral cover, algal cover, invertebrate densities and fish biomass and abundance was collected in both government and traditional marine protected areas and open access fisheries utilization areas. Hard coral cover and diversity was highest in marine protected areas compared with open access sitess, while algal cover was highest in open access areas. Coral recruit density was highest in open access sites, especially on the Aceh islands.

The fish composition was dominated by herbivores and there was no difference in reef fish species richness was evident among management zones. Higher fish biomass and abudance was found in marine protected areas on Weh Island compared with open access sites on both Weh and Aceh islands. The density of clams and sea cucumbers was higher on Pulau Weh than on Pulau Aceh. No differences were found with densities of clams and sea cucumbers among management zones on Pulau Weh. In contrast the density of sea urchins was higher in open acces sites on Pulau Aceh and Weh compared with densities in marine protected areas.

The higher abundance of urchins and algae and lower abundance of corals, fish and other invertebrates may be attributed to a long history of disturbance from destructive and unregulated fishing in open access areas. Although compliance with regulations in marine protected areas was not measured as part of the present study the use of nets from boats, a prohibited activity in both marine protected areas, was observed in both Kawasan Wisata and Panglima Laut sites. No evidence of blast fishing was observed in any of the management zones studied.

The health of reefs in the region, including coral cover, diversity and reef fish would appear to be affected mostly by management or fishing practices. The relatively high hard coral recruitment at sites on Weh and Aceh Island shows a propensity for natural recovery from past destructive fishing practices. Given the positive effects of existing MPAs on reef health such management needs support to strengthten enforcement of regulations and community empowerment in decision making processes. A full evaluation of sites for MPA inclusion is needed using MPA selection criteria which should include: ecosystem representation, replication of critical habitats, areas that have high potential for recovery, areas of high connectivity to be sources and sinks of coral and fish recruitment and socio-economic characteristics. Regulatory management controls including no take areas, periodic closures and species controls require evaluation on the basis of these criteria.

# 2. METHODS

The Aceh Islands lies between 95°00'40" - 95°11'40" E and 5°45'04" - 5°35'30" N, and Weh Island lies between 95°12'55" - 95°22'40" E dan 5°54'25" - 5°46'15" N. The Aceh Islands and Weh Island lie at the nothern sides of Sumatera. The distance from Banda Aceh to Balohan port on Weh Island and Lambaro port on Aceh Islands are approximately 15 nautical miles.

Survey sites were chosen based on management type and grouped into 4 areas (Figure 1), i.e:

1. *Aceh Open Access (9 sites) (all fishing allowed, except for destructive fishing methods including blasting and cyanide)*
   a. Eastern sides (Deudap, Lampteng, Lapeng, Leun Balee 1, Leun Balee 2)
   b. Western sides (Lhoh, Paloh, Pasi Janeng 1, Pasi Janeng 2)
2. *Weh Open Access (8 sites) (all fishing allowed, except for destructive fishing methods including blasting an cyanide)*
   a. Western coast of Weh (Ba Kopra, Lhong Angin 1, Lhong Angin 2, Lhong Angin 3)
   b. Northern side of Weh (Gapang, Pulau Klah)
   c. Southern sides of Weh (Beurawang, Jaboi)
3. *Kawasan Wisata/Tourism Area (5 sites) (prohibited use of all fishing nets from boats and destrcitve fishing methods since 1999)*
   a. Situated on the northern coast of Weh (Batee Meuronon, Lhok Weng, Rubiah Channel, Rubiah Sea Garden, Ujung Seurawan)
4. *Panglima Laut (8 sites)/local tenure (prohibited use of all fishing nets from boats and destrcitve fishing methods since 1998)*
   a. Situated on eastern coast of Weh (Anoi Hitam, Benteng, Sumur Tiga, Ujung Kareung, Ujung Seuke); *panglima laut* or literally means admiral is a local figure that regulate fishing boundary and gear restriction. This figure also has charismatic influence to community in their livelihood.

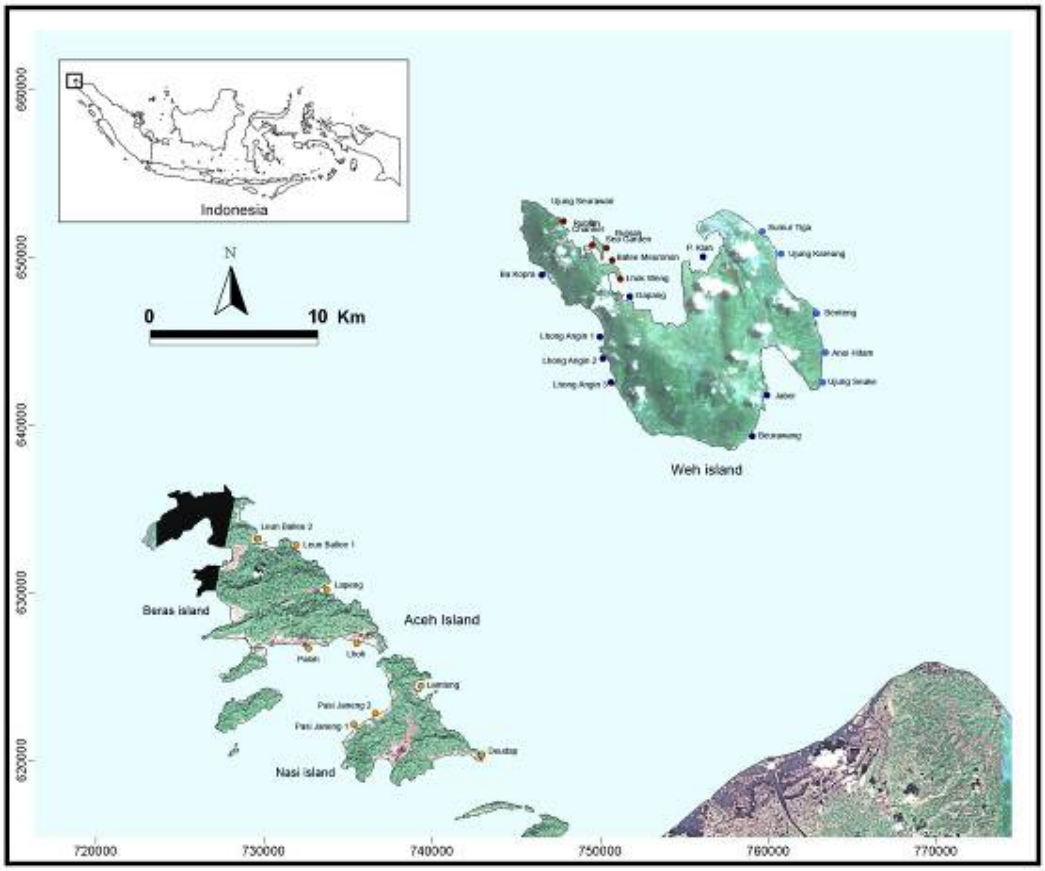


Figure 1. Survey locations in February 2006. Coloured dots show the status of different sites within each management type (Yellow: Open access Aceh, Dark blue: Open access Weh, Red: Kawasan Wisata, Light blue: Panglima laut).

**1. Hard coral cover**

At each site, observations were conducted at 2 depths, shallow transect (at 1 – 3 metres) and deep transect (at 6 – 8 metres), 4 transect each of 50 metre length were surveyed. Replicate transects were set at a minmum of 5 metres aprt from each other. A point intercept transect method was chosen to estimate the percentage cover of benthic features including corals, algae, rock and sand. Each transect was divided into 100 points with 50 cm intervals between each point. Substrate and lifeform were identified and recorded under every point. Hard coral genera identified using guideline from Veron (2000).

**2. Hard coral genera diversity**

Diversity of hard coral was recorded as the cumulative number of hard coral genera along the distance of the transect. The number of genera vs. distance of transects were $\log_{10}$ transformed, converting the curves to straight lines of number of genera vs. $\log_{10}$(distance), passing through the origin (Edinger et.al, 1998). The slope of each line was calculated using linear regression and used as an index of genera diversity for each transect and each site (Edinger et.al, 1998).

**3. Hard coral genera richness**

The hard coral genera abundance value was obtained from total number of hard coral recorded for each sites and overall location.

**4. Hard coral recruitment**

Hard coral recruitment data were collected by counting the numebre of corals < 4mm within a 50x50 cm quadrat transect at each 10 metres along the 4 x 50m transects. Recruitment data were collected at 2 depths of 1-3m and 6-8m.

**5. Reef fish species richness**

Reef fish were separated into 6 families: Acanthuridae, Chaetodontidae, Labridae, Pomacanthidae, Pomacentridae, dan Scaridae. All 6 families are most commonly seen in coral reef area. Based on these families, species diversity in every site was counted using Coral Fish Diversity Index (CFDI) that developed by Allen (1998).

*Species richness of single area = 3.39 x CFDI – 20.595*

**6. Reef fish biomass and abundance**

Within each site, observations were conducted at 2 depths, shallow transect (1 – 3 meters) and deep transect (6 – 8 meters), along 2 x 50 metre transects, placed 5 metres apart Species, number and fish length were recorded within a 5 metre wide belt transect for fish sizes larger than 10 cm, and within a 2 metre belt for fish sizes less than 10 cm. Fish species identification source from Myers (1999), and Allen and Steene (1999).

**7. Macro invertebrate abundance**

Macro-invertebrate abundance was recorded for economically and ecologically important species. Macro-invertebrate species recorded were clam (Family Tridacnidae), sea-cucumber (Family Holothuridae), sea-urchin (Class Echinoidea), starfish (Class Asteroidea, especially *Acanthaster planci* = crown-of-thorn starfish). Data collection used 2x100 meters length belt transect with 1 meter width. Each transect were divided into 5 sub-transect (1 m x 20 m). Macro-invertebrate species were recorded at all sub-transect, except for sea-urchin which were recorded at 2 sub-transect considering their relatively high abundance to decrease the data collection time. The shell length of clam species was measured to estimate length distribution. Identification of macro-invertebrates was based on Colin and Arneson (1995).

**8. Statistical analysis**

ANOVA multivariate statistical analyses were used to measure difference between areas or depth.

# 3. RESULTS

The Aceh Islands are characteized by a low % cover of hard corals. Based on interviews with several local sources in the Aceh and Weh Island, habitat destruction occurred during the 1980's by destructive fishing methods. Along the western coast this condition has been worsened by physical factors (waves action) that accur throughout the year, causing turbid waters from sand and other particles. This turbidity lessens the opportunity for coral to settle and grow. There are no marine protected areas or fishing gear management practices within Aceh Island.

Aceh Islands located to the west of Weh Island provides a protective barrier to Weh Island from wave action generated from the Indian Ocean. The relatively high water visibility of Weh Island provides abundant sunlight for coral reef to grow.

The western side of Weh Island is characterised by steeply sloping (50-70$^{o}$) fringing reefs, while on the eastern side the reef slope is relatively gentle (20-30$^{o}$). The coral reefs are found in depths up to 10 metres.

**1. Hard coral cover**

The cover of coral recorded at each depth and site are shown and grouped by management zone (Figure 2). Coral reef cover on Aceh Islands was low compared with Weh Island reefs with mean coverage at shallow and deep sites 11.7% and 1.8% respectively. On Aceh slands the majority of corals grow in shallow waters. At deep sites the substrate is predominanatly composed of sand (12.3%) and dead coral (79.6%), which is are unfavourable for coral growth.

Marine protected areas (MPAs) on Weh Island had higher hard coral cover compared to sites within open access fishing areas. The mean hard coral cover at Panglima Laut sites were relatively similar at shallow and deep sites (53.1% and 53.6%), and higher than in the Kawasan Wisata (*tourism area*) where the mean hard coral cover was 30.9% (deep) and 44.9% (shallow). The mean hard coral cover in open access sites on Weh Island was 23.5% (deep) and 28.5% (shallow).

There was a significant difference ($F=97.85$, $P<0.05$) in the percentage cover of hard corals among management zones, with the mean coral cover in Panglima Laut (53.3%) and Kawasan Wisata (37.9%) higher than Weh open access (26%), and Aceh open access (6.5%) sites (Figure 2). There was also a significant difference ($F=8.91$, $P<0.05$) in the mean cover of coral between depths, with the mean cover at shallow sites (30.9%) higher compared with the deep sites (23.1%). The corals of Aceh Islands generally are true calcareous reefs whereas on both Aceh and Weh Islands shallow and deep corals are found growing on bedrock. The deeper sites on Aceh and at some Weh sites are dominated by sand, and at other locations – (eg. The western side of Weh Island) – the substrate is volcanic rock with limited hard coral attachment.

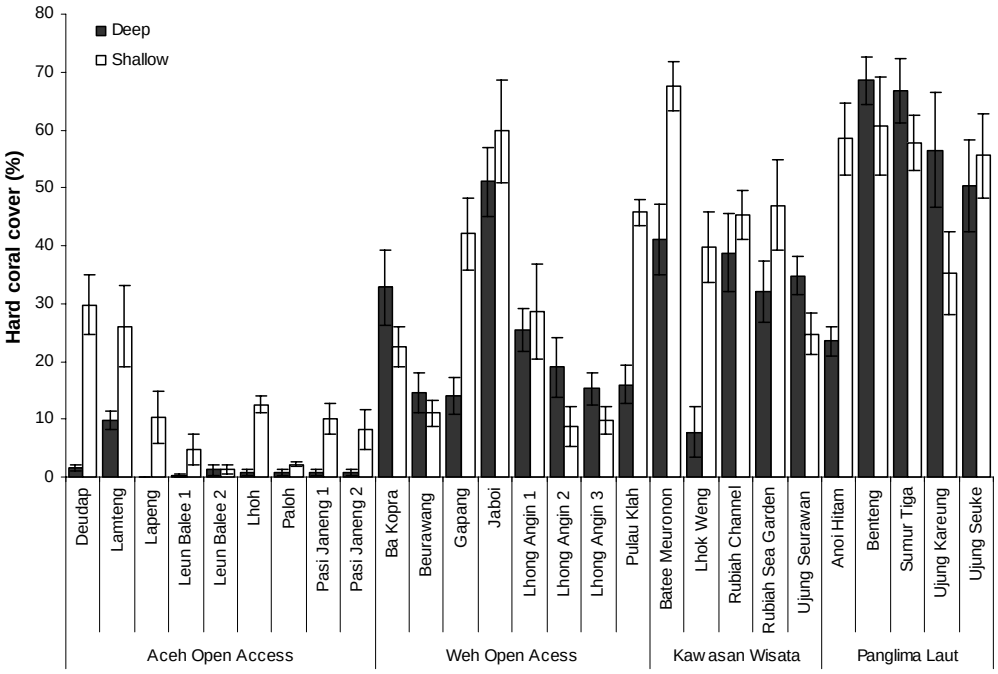


Figure 2. Mean (±SE) hard coral cover (%) within 27 survey sites within 4 management zones.

The cover of algae recorded at each depth and site are shown and grouped by management zone (Figure 3).The mean algal cover within the Aceh Islands was 76.9% at deep sites and 82.3% at shallow sites. The mean algal cover of Weh open access sites was 53.3% (deep) and 64.9% (shallow), within Panglima Laut MPA it was 33.5% (deep) and 41.8% (shallow), and in Kawasan Wisata MPA was 51.1% (deep) and 47.7% (shallow) (Figure 3).

There was no significant difference in algae coverage ($F=3.124$, $P=0.079$) between depths, but there was a significant difference ($F=48.847$, $P<0.05$) between management areas. The mean algae cover was lowest in Panglima Laut (37.6%), intermediate in Kawasan Wisata (49.4%), and highest in open access sites in Weh (59.1%) and Aceh Islands (79.6%).

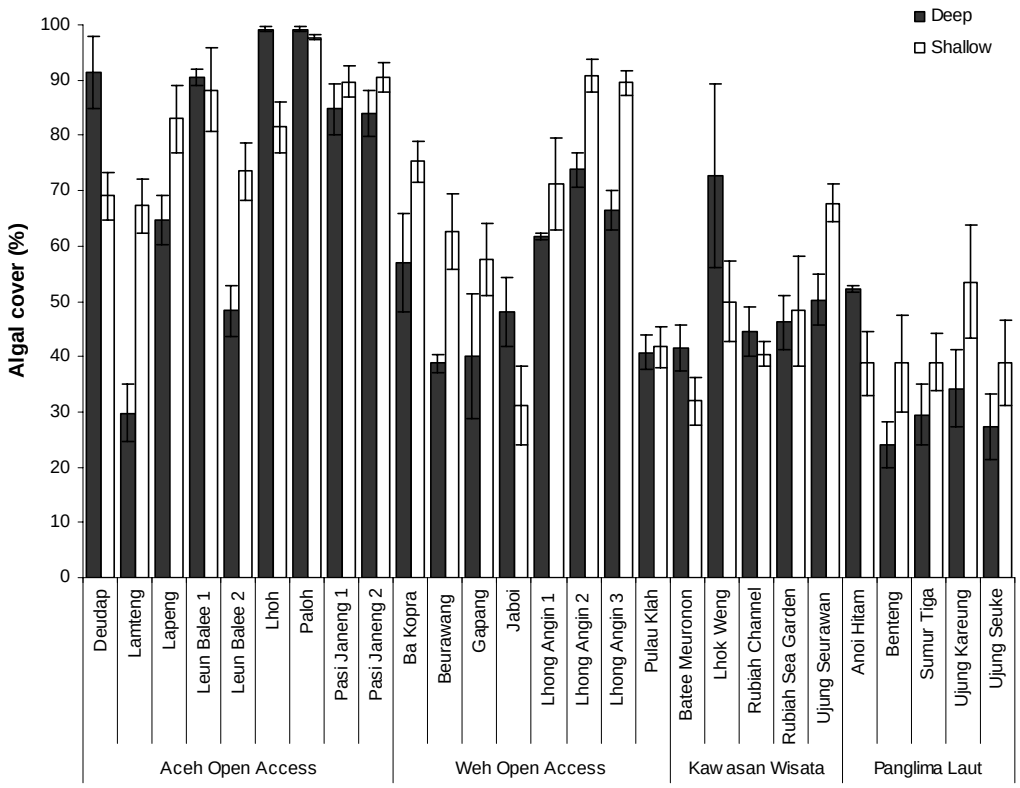


Figure 3. Mean (±SE) of mixed algae cover (%) within 27 survey sites within 4 management zones.

The cover of sand recorded at each depth and site are shown and grouped by management zone (Figure 4).There was a significant difference in mean sand cover ($F= 37.702$, $P<0.05$) between depths. The deeper coral reef habitats within Aceh Islands and Weh Island were commonly dominated by sand, for example at Lamteng (57%), Leun Balee 2 (47.8%), Beurawang (41.8%), Gapang (44.3%), and Pulau Klah (40.8%). The mean sand cover within Aceh Islands was 19.3% (deep) and 5.6% (shallow) similar to mean sand cover at Weh open access sites at 20.4% (deep) and 5.8% (shallow). These means were higher than mean sand cover in the Panglima Laut MPA sites with 7.2% (deep) and 4.3% (shallow), and in Kawasan Wisata MPA sites with 14.8% (deep) and 2.6% (shallow).

There was a significant difference in sand composition ($F= 2.674$, $P<0.05$) between management areas, where the mean composition of sand within Aceh Island (12.3%) was higher compared to the Panglima Laut MPA (5.7%).

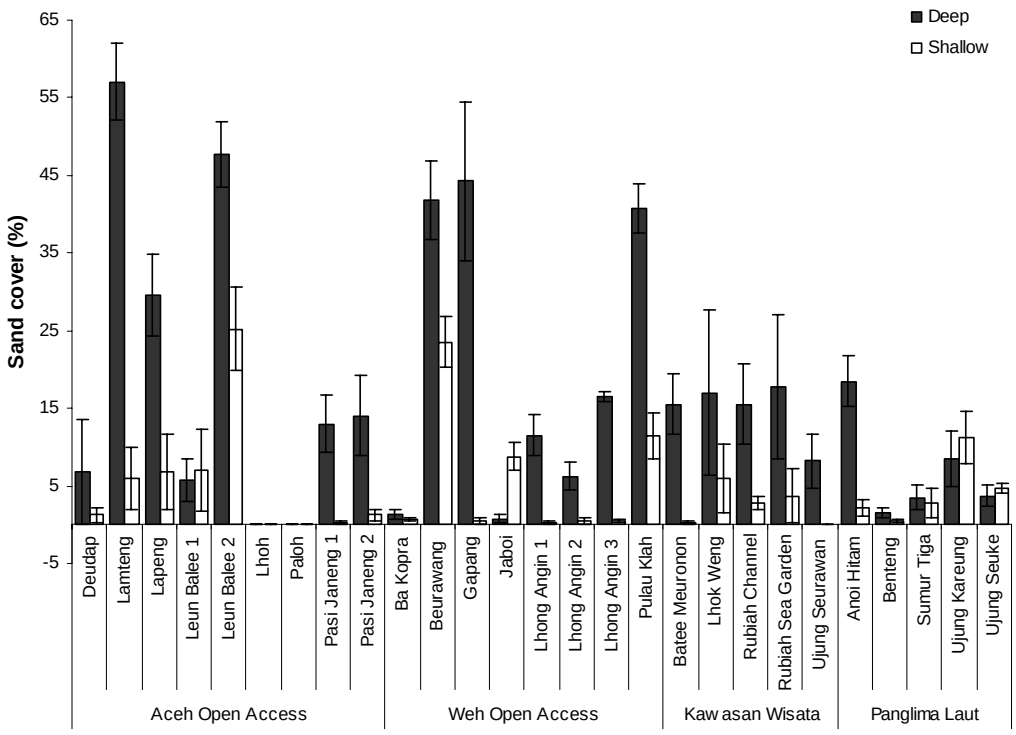


Figure 4. Mean (±SE) of sand cover (%) within 27 survey sites within 4 management zones.

**2. Hard coral genera diversity**

The diversity of hard coral genera recorded at each depth and site are shown and grouped by management zone (Figure 5).There was no significant difference in hard coral diversity between depths ($F=0.222$, $P=0.638$), however there was significant difference ($F=15.335$, $P<0.05$) among management zones, with lower mean diversity in Aceh Islands (2.52) compared to other management areas. However there was no difference between areas within the Weh Islands (open access 4.41, Panglima Laut 4.85, and Kawasan Wisata 4.73) (Figure 5).

The mean hard coral diversity within Aceh Islands was 2.04 (deep) and 3.39 (shallow). The mean diversity within Weh open access sites was 4.75 (deep) and 4.04 (shallow), in Panglima Laut sites was 5.03 (deep) and 4.67 (shallow), and in Kawasan Wisata 5.27 (deep) and 4.18 (shallow) (Figure 5).

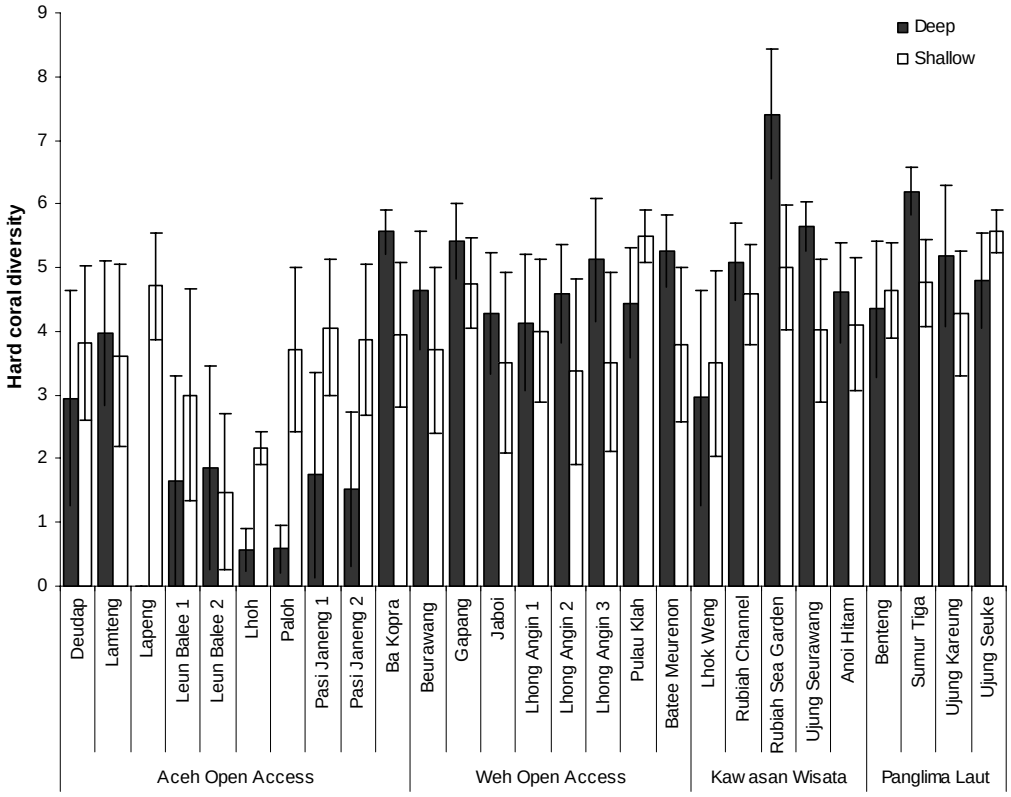


Figure 5. Mean (±SE) of hard coral diversity 27 survey sites within 4 management zones. Diversity measured as the slope of the log transformed area coral genera diversity curve (*slope of the genus-log (area) regression line*).

### 3. Hard coral genera richness

Hard coral genera richness within at all sites were dominated by the genus Porites (37%), Acropora (30%) and Heliopora (11%), while the remaining 39 genera were 10% (Figure 6).

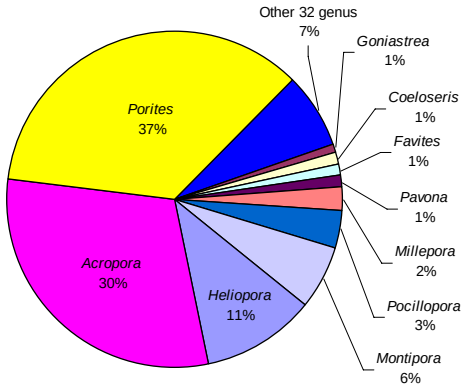


Figure 6. Total hard coral composition within all observation areas.

There were 45 hard coral genera recorded during the WCS survey in Aceh; the 2005 survey recorded 30 genera while in 2006 a total of 42 genera were recorded at sites with 30 genera of hard coral recruits. Figure 7 shows the total number of hard coral genera recorded in at each depth and site. The highest number of hard coral genera recorded on deep transects was found at Rubiah Sea Garden and Ujung Seurawan, with 21 genera each.

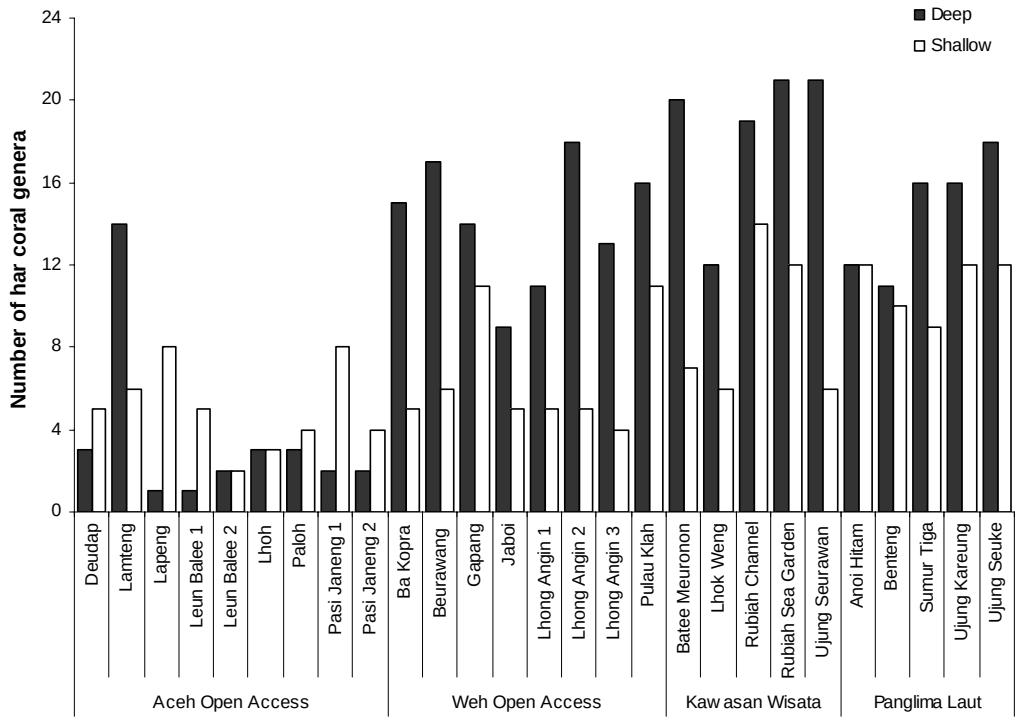


Figure 7. Total number of har coral genera within 27 survey sites: comparison between protected and utilization areas.

**4. Hard coral recruitment**

Hard coral recruitment abundance (ind.m$^{-2}$) was measured at each site to gain information on the possible recovery potential of disturbed (Figure 8). There was a significant difference ($F= 58.015$, $P<0.05$) in the mean number of coral recruits between depths with higher numbers in deep sites (mean = 8.1 ind.m$^{-2}$) compared with shallow sites (mean = 3.8 ind.m$^{-2}$). Among management zones, there was a significant difference in recruitment ($F=11.306$, $P<0.05$), with the mean abundance of recruits at open access sites on Aceh Islands (8 ind.m$^{-2}$) was higher compared with Weh open access (4.5 ind.m$^{-2}$) and Panglima Laut (4.3 ind.m$^{-2}$), but not significant to Kawasan Wisata (6.2 ind.m$^{-2}$).

The mean abundance of coral recruits within the Aceh Island open access zone was 10 ind.m$^{-2}$ (deep) and 5 ind.m$^{-2}$ (shallow), higher than the mean number of recruits within the Weh open access zone of 7 ind.m$^{-2}$ (deep) and 2 ind.m$^{-2}$ (shallow). The mean abundance of

coral recruits within the protected areas of Kawasan Wisata were 9 ind.m$^{-2}$ (deep) and 3 ind.m$^{-2}$ (shallow), and within Panglima Laut sites means were 4 ind.m$^{-2}$ for each depth.

The high hard coral recruitment at Aceh Island was associated with low hard coral cover, and avaibility of dead substrate favorable for hard coral larvae settlement.

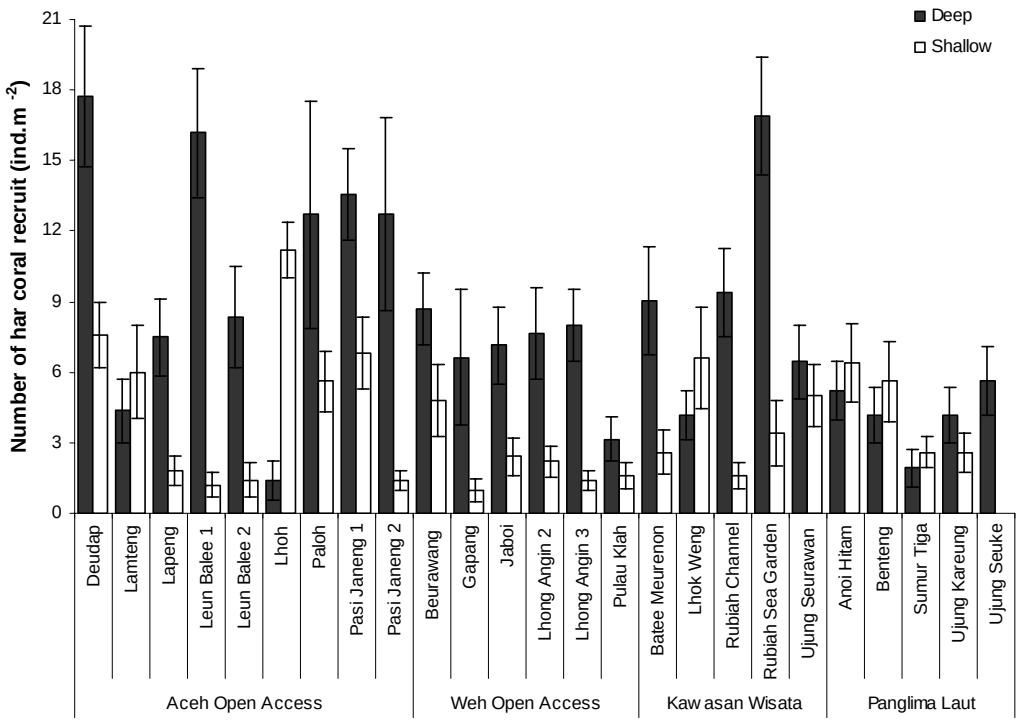


Figure 8. Mean abundance (±SE) of hard coral recruitment within 27 survey sites within 4 management zones.

## 5. Reef fish species richness

The number of reef fish (species richness) recorded at each site within the 4 management zones is shown (Figure 9). There was a significant difference ($F= 8.749$, $P<0.05$) in mean species richness among management zones, with lower richness recorded in Aceh Islands (159 ind.) compared with Panglima Laut (242 ind.), Kawasan Wisata (276 ind.) and Weh open access (214 ind). There was no significant difference in the richness of reef fish species among management zones within Weh Island.

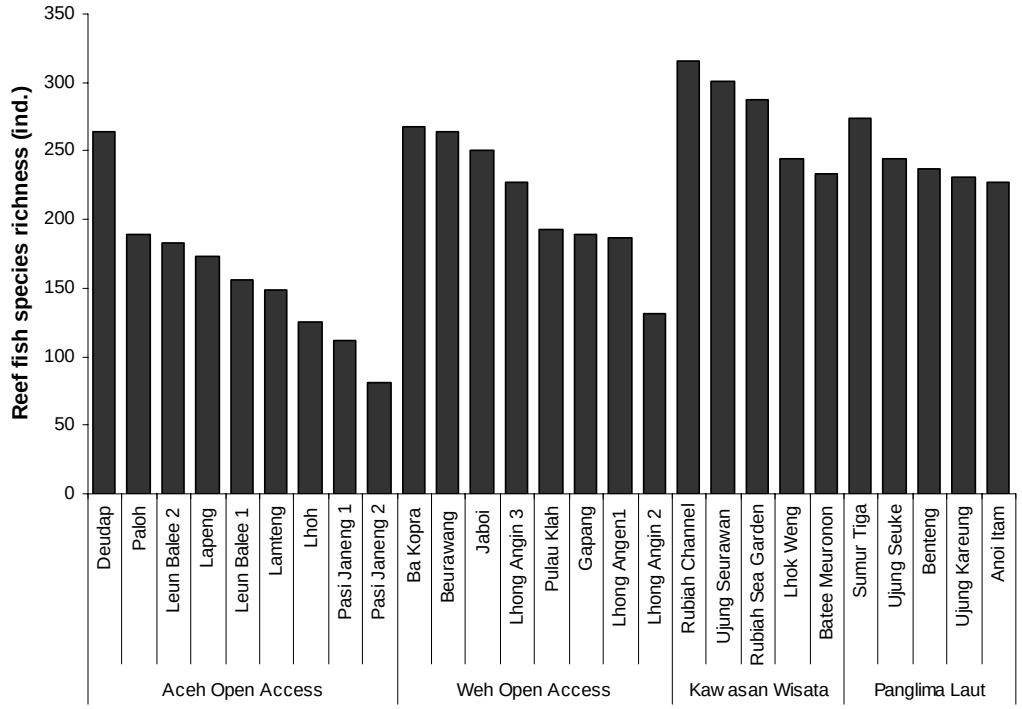


Figure 9. Reef fish species richness within 27 survey sites within 4 management zones.

## 6. Reef fish biomass and abundance

The mean biomass of reef fish recorded at each site within the 4 management zones is shown (Figure 10). There was no significant difference (F= 0.002, P= 0.967) in the mean biomass (kg.ha$^{-1}$) of reef fish between deep and shallow areas. While, there was significant difference (F= 17.029, P<0.05) diffrences among between management zones, with the mean biomass within open access areas (Aceh Island 399 kg.ha$^{-1}$ and Weh Island 460 kg.ha$^{-1}$) lower compared with biomass of fishes within protected areas (Kawasan Wisata 942 kg.ha$^{-1}$ and Panglima Laut 1346 kg.ha$^{-1}$).

The mean biomass of reef fish on Aceh Islands of 461 kg.ha$^{-1}$ (deep) and 337 kg.ha$^{-1}$ (shallow) was comparable with that in open access areas on Weh Island of 471 kg.ha$^{-1}$ (deep) and 450 kg.ha$^{-1}$ (shallow). Considerably higher was the mean biomass of reef fish in the Panglima Laut (1638 kg.ha$^{-1}$ deep; 1054 kg.ha$^{-1}$ shallow) and Kawasan Wisata (711 kg.ha$^{-1}$ deep; 1173 kg.ha$^{-1}$ shallow).

The mean reef fish biomass in Aceh Islands was 461 kg.ha$^{-1}$ (deep) and 337 kg.ha$^{-1}$ (shallow), and in open access Weh Island was 471 kg.ha$^{-1}$ (deep) and 450 kg.ha$^{-1}$ (shallow). The mean reef fish biomass in the protected areas of Panglima Laut were 1638 kg.ha$^{-1}$ (deep) and 1054 kg.ha$^{-1}$ (shallow), and in Kawasan Wisata 711 kg.ha$^{-1}$ (deep) and 1173 kg.ha$^{-1}$ (shallow).

The highest mean biomass of reef fish within sites was recorded at Sumur Tiga

(Panglima Laut) with 3105 kg.ha$^{-1}$. Optimal reef fish biomass for tropical coral reefs have been recorded at 1200 kg.ha$^{-1}$ and the majority of sites where biomass exceeded this value (eg. Leun Balee 1, Pulau Klah, Rubiah) were mainly from within the Panglima Laut (Figure 10).

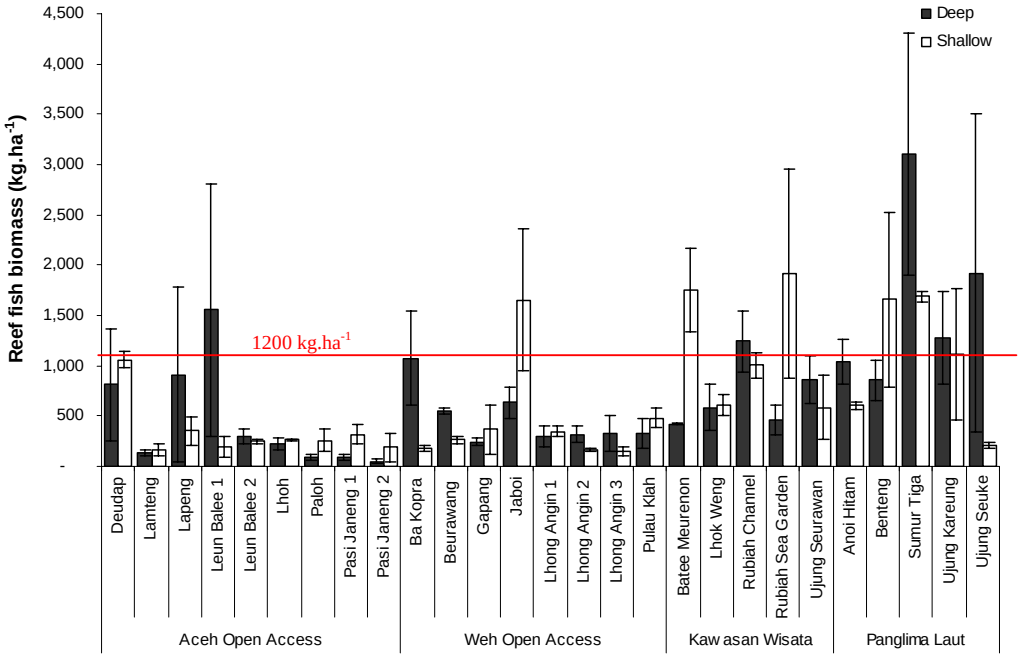


Figure 10. Mean (±SE) of reef fish biomass (kg.ha$^{-1}$) within 27 survey sites within 4 management zones.

The mean abudance of reef fish recorded at each site within the 4 management zones is shown (Figure 11). The mean abundance (ind.ha$^{-1}$) of reef fish did not show significant difference ($F=0.216$, $P=0.643$) between depths. There were significant difference ($F=24.425$, $P<0.05$) in reef fish biomass among management zones with the mean abundance in the Aceh Islands open access zone (10771 ind.ha$^{-1}$) lower compared with the Weh open access zone (22135 ind.ha$^{-1}$), and the mean abundance in Weh open access zone lower compared with protected areas (Kawasan Wisata 51735 ind.ha$^{-1}$; 70517 ind.ha$^{-1}$), however there was no difference in reef fish biomass between protected zones.

The mean abundance of reef fish within Aceh Islands was 12142 ind.ha$^{-1}$ (deep) and 9400 ind.ha$^{-1}$ (shallow). In Weh open access areas it was 21094 ind.ha$^{-1}$ (deep) and 23175 ind.ha$^{-1}$ (shallow). The mean biomass in the Kawasan Wisata zone was 36934 ind.ha$^{-1}$ (deep) and 66536 ind.ha$^{-1}$ (shallow), and in Panglima Laut mean fish abundance was 81680 ind.ha$^{-1}$ (deep) and 59354 ind.ha$^{-1}$ (shallow).

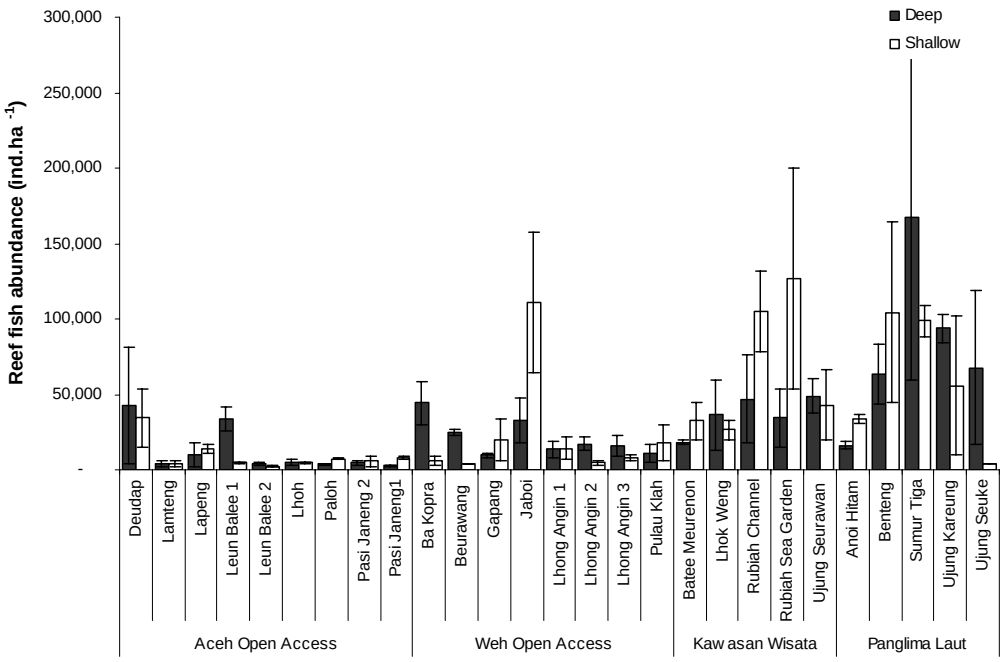


Figure 11. Mean (±SE) of reef fish abundance (ind.ha$^{-1}$) within 27 survey sites within 4 management zones.

## 7. Macro-invertebrate abundance

The abundance of economically important clams, sea-cucumbers and sea urchins at all sites within the 4 management zones are shown (Figures 12-14). Three species of clam from the family Tridacnidae were recorded among all sites including *Tridacna crocea*, *T. maxima* and *T. squamosa* and their total abundance was recorded (Figure 12).

There was a significant difference ($F= 13.678$, $P<0.05$) in mean clam abundance between depths with abundance at deep sites (1.4 ind.100m$^{-2}$), lower compared to shallow sites (3.6 ind.100m$^{-2}$). This difference could be explained by the abundance of *Tridacna crocea* and *T. maxima* on shallow reef flats, even though *T. squamosa* was more abundant at deep sites and had the largest shell size.

There were significant differences ($F= 20.137$, $P<0.05$) in clam abundance among management zones with the mean clam abundance within the Aceh Islands open access zone (0.5 ind.100m$^{-2}$) lower compared with all management zones within Weh Island (open access 3.2 ind.100m$^{-2}$, Panglima Laut 2.9 ind.100m$^{-2}$, Kawasan Wisata 4.5 ind.100m$^{-2}$).

The mean abundance of clams within Aceh Islands was 0.4 ind.100m$^{-2}$ (deep) and 0.6 ind.100m$^{-2}$ (shallow) whilst in Weh open access sites it was 1.8 ind.100m$^{-2}$ (deep) and 4.6 ind.100m$^{-2}$ (shallow). The mean abundance of clam within Kawasan Wisata was 2.2 ind.100m$^{-2}$ (deep) and 6.7 ind.100m$^{-2}$ (shallow), while in the Panglima Laut zone mean abundances of 2 ind.100m$^{-2}$ (deep) and 3.7 ind.100m$^{-2}$ (shallow) were recorded. The highest mean abundance was recorded at the shallow site of Batee Meurenon with 14 ind.100m$^{-2}$.

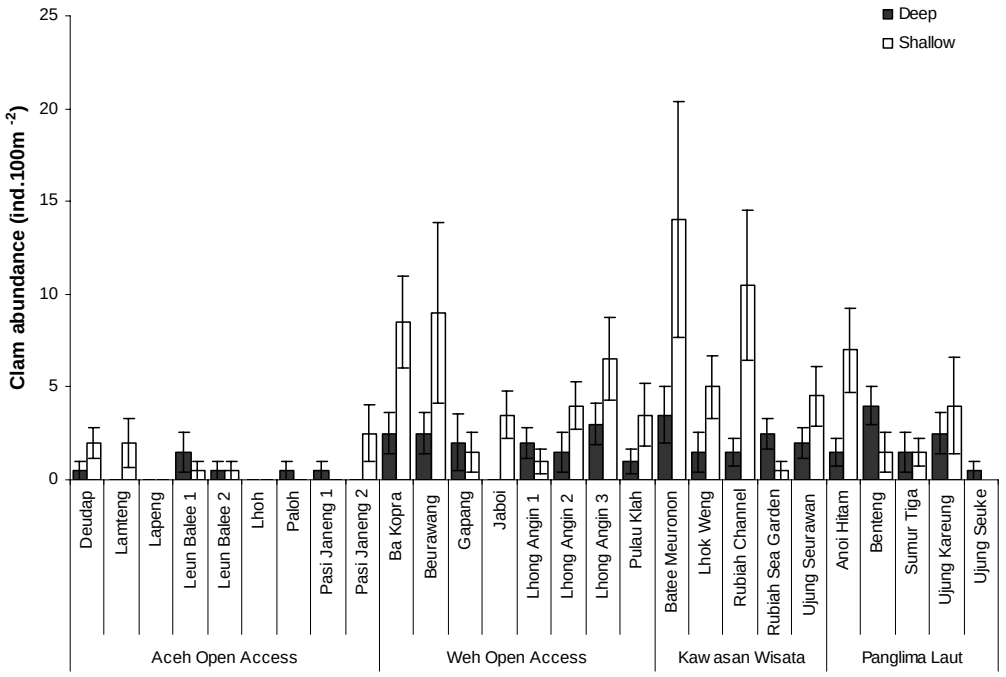


Figure 12. Mean (±SE) abundance (ind.100m$^{-2}$) of clam (Tridacnidae) within 27 survey sites and within 4 management zones.

Sea-cucumbers from the family Holothuridae are a highly valued macro-invertebrate that is collected for consumption. This family was generally low in abundance, except at some shallow sites at Lhong Angin 3 (13 ind.100m$^{-2}$) and Gapang (7.5 ind.100m$^{-2}$) (Figure 13). There were no sea-cucumbers recorded within Aceh Islands. There was no significant difference in mean sea-cucumber abundance between depth (F= 1.084, P=0.298) or among management zones (F= 1.551, P=0.200). The mean abundance of sea-cucumbers within the Weh open access zone was 0.7 ind.100m$^{-2}$ (deep) and 3 ind.100m$^{-2}$ (shallow). In Kawasan Wisata the mean abundance was 1 ind.100m$^{-2}$ (deep) and 0.2 ind.100m$^{-2}$ (shallow), while in the Panglima Laut zone they were found at deep sites only (mean = 1 ind.100m$^{-2}$).

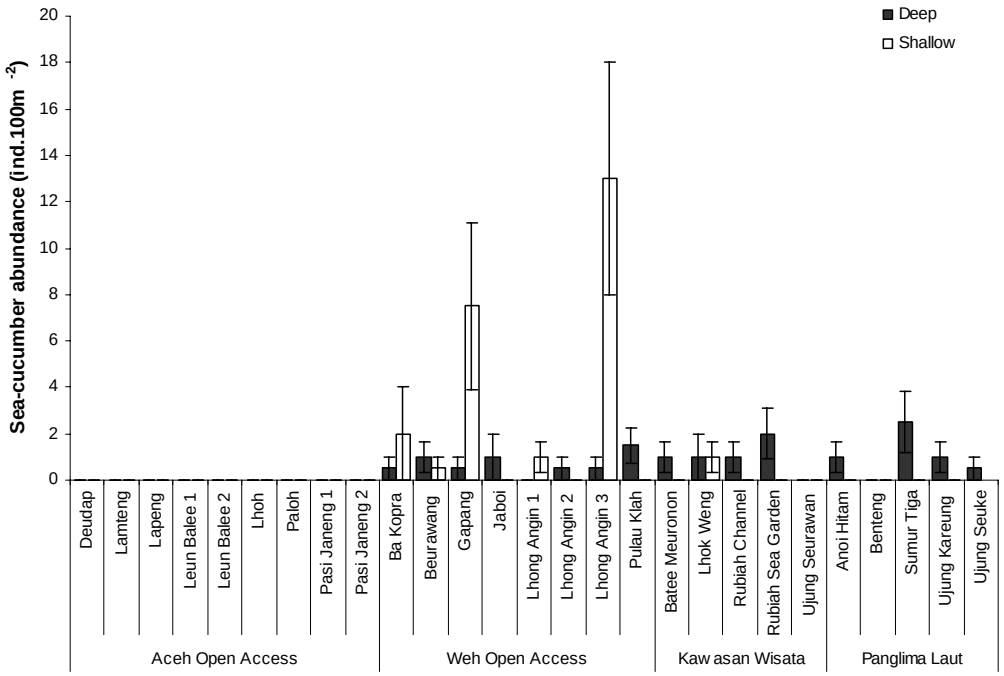


Figure 13. Mean (±SE) abundance (ind.100m$^{-2}$) of sea-cucumber (Holothuridae) within 27 survey sites: comparison between protected and utilization areas.

Another important macro-invertebrate is the sea-urchin (Class Echinoidea), especially the family Diadematidae that can be used as an indicator of water quality as reefs which have high nutrient inputs are often dominated by a high abundance of sea-urchins. There was significant difference ($F=5.050$, $P<0.05$) in mean sea-urchin abundance (ind.100m$^{-2}$) between depths, where the deep sites (62 ind.100m$^{-2}$) had higher abundance compared to the shallow sites (41 ind.100m$^{-2}$) (Figure 14). There were also significant difference ($F=17.462$, $P<0.05$) in mean sea-urchin abundance among management areas, with the mean abundance in open access zones (Aceh Island 73 ind.100m$^{-2}$ and Weh open access 84 ind.100m$^{-2}$) higher than the mean abundance in protected zones (Kawasan Wisata 9 ind.100m$^{-2}$ and Panglima Laut 5 ind.100m$^{-2}$).

The highest mean abundance of sea-urchins was recorded at the site of Leun Balee (deep = 413 ind.100m$^{-2}$; shallow = 356 ind.100m$^{-2}$) within the Aceh Islands (Figure 14). High abundance was also recorded at shallow sites of Lhong Angin (deep = 308 ind.100m$^{-2}$ ; shallow = 244 ind.100m$^{-2}$). The mean abundance of sea-urchins at Aceh Islands was 126 ind.100m$^{-2}$ (deep) and 15 ind.100m$^{-2}$ (shallow) while at Weh open access sites mean abundance was 58 ind.100m$^{-2}$ (deep) and 111 ind.100m$^{-2}$ (shallow). In the two MPAs mean abundance of sea urchins was 8 ind.100m$^{-2}$ (deep) and 10 ind.100m$^{-2}$ (shallow) for Kawasan Wisata and 6 ind.100m$^{-2}$ (deep) and 4 ind.100m$^{-2}$ (shallow) for Panglima Laut.

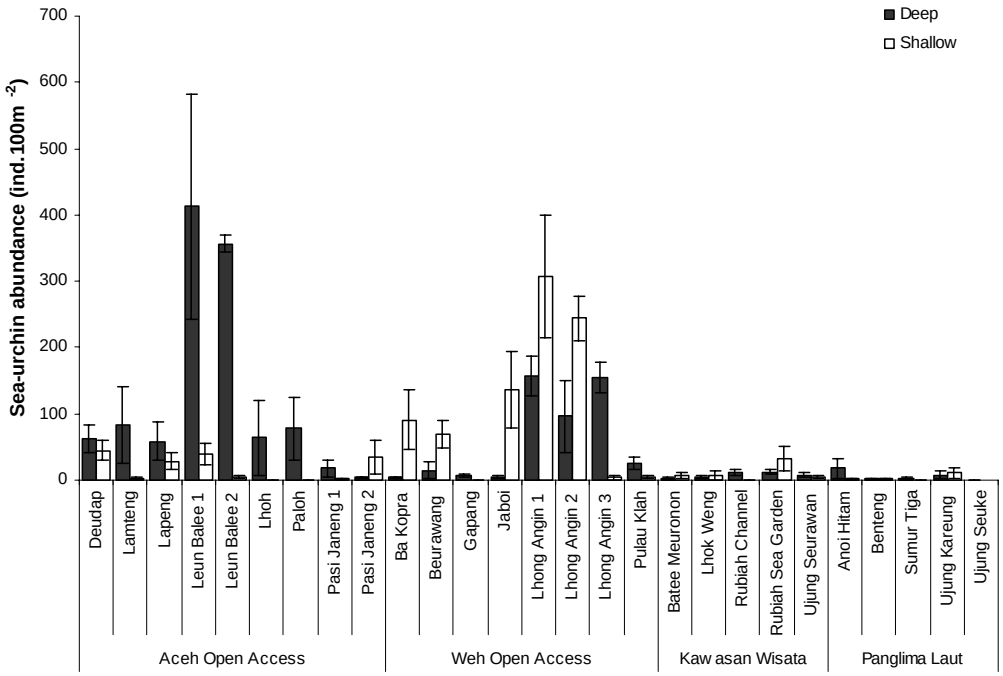


Figure 14. Mean (±SE) abundance (ind.100m$^{-2}$) of sea-urchin (Echinoidea) within 27 survey sites within 4 management zones.

# 4. CONCLUSIONS

1. Actual physical damage of coral reef by the tsunami was limited and very patchy and does not affect the broad scale ecological health of northern Aceh reefs (Baird *et.al*, 2005).

2. Successful hard coral recruitment at sites on Weh and Aceh Island shows a propensity for natural recovery from past destructive fishing practices.

3. Reef health including coral cover, diversity and reef fish are affected mostly by management regime (fishing practices) prior to the tsunami.
   a. Coral condition and health within the Panglima Laut and Kawasan Wisata marine protected areas is greater than in areas open to fishing on both Weh and Aceh islands.
   b. Reef fish abundance and biomass within Panglima Laut and Kawasan Wisata marine protected areas is greater than in areas open to fishing on both Weh and Aceh islands.
   c. Invertebrate abundance including clams and sea cucumbers are generally highest within Panglima Laut and Kawasan Wisata marine protected areas and very low or non-existent on Pulau Aceh.
4. The high biomass of fish within some areas suggest possible critical habitat for spawning or other form of aggregating behavior. Sites include Benteng, Deudap, Leun Balee 1.

5. Damaged reefs in proximity to mangrove areas (eg. Pulau klah, Lhok weng) were damaged prior to the tsunami and show limited signs of recovery. These areas are possible critical sites for fish nurseries.

# 5. RECOMMENDATIONS

1. The limited and very patchy damage to coral reefs from the tsunami and high hard coral recruitment at sites on Weh and Aceh islands suggest that management practices which allow natural recovery are best suited for long term improvements in coral reef health.

2. Coral transplant programs should have objectives that are closely linked with benefits to tourism, education and awareness programs at targeted sites. Given the high demand for resources, technical difficulty and capacity to re-habilitate areas at small scales (100's of metres) they are unlikely to provide benefits to broad scale ecological reef health and should not distract resources away from important sustainable management priorities, yet may provided opportunities for community empowerment and involvement in management.

3. Existing MPAs (Panglima Laut, Kawasan Wisata) should be strengthened through enforcement of regulations, community empowerment and integrated monitoring and evaluation of management practices.

4. Additional sites should be selected for MPA's and other regulatory controls based on information from ecological and socio-economic assessments using MPA selection criteria including:
   a. ecosystem representation, replication of critical habitats
   b. areas that have high potential for recovery (eg. Pulau Aceh)
   c. areas of high connectivity to be sources an sinks of coral and fish recruitment

5. A full evaluation of sites for MPA inclusion is required – initial assessments based on ecological criteria suggest that Anoi Hitam, Benteng (Weh island), Deudap, Leun Balee 1 (Aceh island) which have high reef fish biomass and represent possible critical habitat for spawning aggregations would benefit from MPA or management controls.

6. Additional surveys to identify and assess areas of critical habitats for fish spawning aggregations, fish nurseries in proximity to mangroves (eg. Pulau Klah, Lhok Weng) and turtle nesting locations (eg. Pasi Janeng) are required.

7. Regulatory management controls including no take areas, periodic closures and species controls (eg. size limits for lobster, invertebrates and fish) need to be evaluated for proposed managed areas and be based on ecological, fisheries and socio-economic criteria.

8. Information on human fishing patterns, fisheries gear usage and effort is lacking and is required for MPA management and decision making. Priority should focus on identification of destructive and unsustainable fishing practices (eg. cyanide, muroami) and poaching in existing managed areas.

9. Critical habitats for other high profile species including rays, shark and dolphin need to be identified through ecological and social surveys and will benefit selection of areas targeted for tourism management.

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## APPENDIX

Table 1. Ecological values of survey 2006

| Site name | Management type | Depth | Coverage (%) | | | Hard coral | | | Fish | | Macro-Invertebrates Abundance (ind.100m$^{-2}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hard coral | Algae | Sand | Diversity (slope)* | Number of genera | Recruitment (ind.100m$^{-2}$) | Biomass (kg.ha$^{-1}$) | Abundance (ind.ha$^{-1}$) | Sea-urchin | Clam | Sea-cucumber | COT | Starfish | Turban-shell |
| Deudap | Aceh Open Access | Deep | 1.5 | 91.5 | 6.75 | 2.95 | 3 | 17.7 | 813.2 | 42,510 | 62.5 | 0.5 | 0 | 0 | 1.5 | 0 |
| Deudap | Aceh Open Access | Shallow | 29.75 | 69 | 1.25 | 3.82 | 5 | 1.8 | 1,061.6 | 34,220 | 45 | 2 | 0 | 0 | 0 | 0 |
| Lamteng | Aceh Open Access | Deep | 9.75 | 29.75 | 57 | 3.98 | 14 | 4.3 | 136.8 | 4,020 | 82.5 | 0 | 0 | 0 | 0 | 0 |
| Lamteng | Aceh Open Access | Shallow | 26 | 67.25 | 6 | 3.62 | 6 | 1.2 | 164.0 | 3,830 | 2.5 | 2 | 0 | 0 | 0 | 0 |
| Lapeng | Aceh Open Access | Deep | 0 | 64.75 | 29.5 | 0.00 | 1 | 7.5 | 907.3 | 9,710 | 58.75 | 0 | 0 | 0 | 0 | 0 |
| Lapeng | Aceh Open Access | Shallow | 10.25 | 83 | 6.75 | 4.71 | 8 | 1.4 | 350.0 | 13,740 | 28.75 | 0 | 0 | 0 | 0 | 0 |
| Leun Balee 1 | Aceh Open Access | Deep | 0.25 | 90.5 | 5.75 | 1.65 | 1 | 16.2 | 1,552.9 | 33,510 | 412.5 | 1.5 | 0 | 0 | 0 | 0 |
| Leun Balee 1 | Aceh Open Access | Shallow | 4.75 | 88.25 | 7 | 3.00 | 5 | 11.2 | 191.5 | 4,530 | 38.75 | 0.5 | 0 | 0 | 0 | 0 |
| Leun Balee 2 | Aceh Open Access | Deep | 1.25 | 48.25 | 47.75 | 1.85 | 2 | 8.3 | 295.5 | 3,940 | 356.25 | 0.5 | 0 | 0 | 1.5 | 0 |
| Leun Balee 2 | Aceh Open Access | Shallow | 1.25 | 73.5 | 25.25 | 1.48 | 2 | 5.6 | 245.1 | 2,450 | 3.75 | 0.5 | 0 | 0 | 0 | 0 |
| Lhoh | Aceh Open Access | Deep | 0.75 | 99.25 | 0 | 0.57 | 3 | 1.4 | 225.5 | 4,990 | 63.75 | 0 | 0 | 0 | 0 | 0 |
| Lhoh | Aceh Open Access | Shallow | 12.5 | 81.5 | 0 | 2.16 | 3 | 6.8 | 261.4 | 4,660 | | | | | | |
| Paloh | Aceh Open Access | Deep | 0.75 | 99.25 | 0 | 0.58 | 3 | 12.7 | 88.2 | 3,510 | 77.5 | 0.5 | 0 | 0 | 0 | 0.5 |
| Paloh | Aceh Open Access | Shallow | 2.25 | 97.75 | 0 | 3.72 | 4 | 1.4 | 258.0 | 7,200 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pasi Janeng 1 | Aceh Open Access | Deep | 0.75 | 84.75 | 13 | 1.75 | 2 | 13.6 | 85.0 | 4,600 | 17.5 | 0.5 | 0 | 0 | 1 | 0 |
| Pasi Janeng 1 | Aceh Open Access | Shallow | 10 | 89.75 | 0.25 | 4.05 | 8 | 4.8 | 312.6 | 5,810 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pasi Janeng 2 | Aceh Open Access | Deep | 0.75 | 84 | 14 | 1.52 | 2 | 12.7 | 47.2 | 2,490 | 3.75 | 0 | 0 | 0 | 0 | 0 |
| Pasi Janeng 2 | Aceh Open Access | Shallow | 8.25 | 90.5 | 1.25 | 3.87 | 4 | 1.0 | 188.9 | 8,160 | 1.25 | 0 | 0 | 0 | 0 | 0 |
| Batee Meuronon | Kawasan Wisata | Deep | 41 | 41.5 | 15.5 | 5.26 | 20 | 9.4 | 416.3 | 17,970 | 2.5 | 3.5 | 1 | 2.5 | 10 | 0 |
| Batee Meuronon | Kawasan Wisata | Shallow | 67.5 | 32 | 0.25 | 3.79 | 7 | 5.0 | 1,752.1 | 32,220 | 3.75 | 3.5 | 0 | 0 | 1.5 | 0 |
| Lhok Weng | Kawasan Wisata | Deep | 7.75 | 72.75 | 17 | 2.96 | 12 | 16.9 | 580.3 | 36,390 | 3.75 | 1.5 | 1 | 0 | 5 | 0 |
| Lhok Weng | Kawasan Wisata | Shallow | 39.75 | 50 | 6 | 3.50 | 6 | 6.4 | 607.0 | 26,330 | 6.25 | 14 | 0 | 0 | 2.5 | 0 |
| Rubiah Channel | Kawasan Wisata | Deep | 38.75 | 44.5 | 15.5 | 5.09 | 19 | 6.4 | 1,242.3 | 47,020 | 11.25 | 1.5 | 1 | 0.5 | 7 | 0 |
| Rubiah Channel | Kawasan Wisata | Shallow | 45.25 | 40.5 | 2.75 | 4.58 | 14 | 5.6 | 1,009.0 | 104,960 | 7.5 | 5 | 1 | 0.5 | 2 | 0 |
| Rubiah Sea Garden | Kawasan Wisata | Deep | 32 | 46.25 | 17.75 | 7.41 | 21 | 5.2 | 461.5 | 34,360 | 12.5 | 2.5 | 2 | 0 | 11.5 | 0 |
| Rubiah Sea Garden | Kawasan Wisata | Shallow | 47 | 48.25 | 3.75 | 5.00 | 12 | 2.6 | 1,911.4 | 126,490 | 0 | 10.5 | 0 | 0 | 1 | 0 |
| Ujung Seurawan | Kawasan Wisata | Deep | 34.75 | 50.25 | 8.25 | 5.65 | 21 | 4.2 | 856.8 | 48,930 | 7.5 | 2 | 0 | 0 | 5 | 0 |
| Ujung Seurawan | Kawasan Wisata | Shallow | 24.75 | 67.75 | 0 | 4.01 | 6 | 2.6 | 586.1 | 42,680 | 32.5 | 0.5 | 0 | 0 | 0 | 0 |
| Anoi Hitam | Panglima Laut | Deep | 23.5 | 52.25 | 18.5 | 4.61 | 12 | 1.9 | 1,035.6 | 16,180 | 17.5 | 1.5 | 1 | 0 | 16.5 | 0 |
| Anoi Hitam | Panglima Laut | Shallow | 58.5 | 38.75 | 2.25 | 4.11 | 12 | | 605.4 | 33,780 | 3.75 | 4.5 | 0 | 0.5 | 13 | 0 |
| Benteng | Panglima Laut | Deep | 68.5 | 24 | 1.5 | 4.35 | 11 | 4.2 | 854.8 | 63,390 | 1.25 | 4 | 0 | 0.5 | 3 | 0 |
| Benteng | Panglima Laut | Shallow | 60.75 | 38.75 | 0.5 | 4.65 | 10 | | 1,659.3 | 104,150 | 1.25 | 7 | 0 | 0 | 1.5 | 0 |
| Sumur Tiga | Panglima Laut | Deep | 66.75 | 29.5 | 3.5 | 6.19 | 16 | 5.6 | 3,105.4 | 167,200 | 2.5 | 1.5 | 2.5 | 0 | 5 | 0 |
| Sumur Tiga | Panglima Laut | Shallow | 57.75 | 39 | 2.75 | 4.76 | 9 | | 1,691.7 | 98,900 | 1.25 | 1.5 | 0 | 0 | 2.5 | 0 |
| Ujung Kareung | Panglima Laut | Deep | 56.5 | 34.25 | 8.5 | 5.18 | 16 | 7.6 | 1,273.5 | 93,810 | 7.5 | 2.5 | 1 | 0 | 11 | 0.5 |
| Ujung Kareung | Panglima Laut | Shallow | 35.25 | 53.5 | 11.25 | 4.28 | 12 | | 1,113.9 | 55,710 | 0 | 1.5 | 0 | 0 | 0 | 0 |
| Ujung Seuke | Panglima Laut | Deep | 50.25 | 27.25 | 3.75 | 4.80 | 18 | 6.0 | 1,919.2 | 67,820 | 0 | 0.5 | 0.5 | 0 | 10 | 0 |
| Ujung Seuke | Panglima Laut | Shallow | 55.5 | 38.75 | 4.75 | 5.57 | 12 | | 201.4 | 4,230 | 11.25 | 4 | 0 | 0 | 3.5 | 0 |
| Ba Kopra | Weh Open Access | Deep | 32.75 | 57 | 1.25 | 5.56 | 15 | 8.7 | 1,074.9 | 44,140 | 3.75 | 2.5 | 0.5 | 0 | 0.5 | 0 |
| Ba Kopra | Weh Open Access | Shallow | 22.5 | 75.25 | 0.75 | 3.95 | 5 | 2.4 | 172.9 | 5,710 | 35 | 2.5 | 0 | 0 | 0.5 | 0 |
| Beurawang | Weh Open Access | Deep | 14.5 | 38.75 | 41.75 | 4.65 | 17 | 6.6 | 549.4 | 24,430 | 15 | 2.5 | 1 | 0 | 8.5 | 0 |
| Beurawang | Weh Open Access | Shallow | 11 | 62.5 | 23.5 | 3.71 | 6 | 2.2 | 265.7 | 3,770 | 91.25 | 8.5 | 2 | 0 | 0 | 0 |
| Gapang | Weh Open Access | Deep | 14 | 40 | 44.25 | 5.43 | 14 | 7.1 | 240.8 | 9,770 | 6.25 | 2 | 0.5 | 0 | 7.5 | 0 |
| Gapang | Weh Open Access | Shallow | 42 | 57.5 | 0.5 | 4.76 | 11 | 1.4 | 368.0 | 19,990 | 68.75 | 9 | 0.5 | 0 | 1 | 0 |
| Jaboi | Weh Open Access | Deep | 51 | 48 | 0.75 | 4.27 | 9 | 7.7 | 631.9 | 33,040 | 5 | 0 | 1 | 0 | 5.5 | 0 |
| Jaboi | Weh Open Access | Shallow | 59.75 | 31.25 | 8.75 | 3.51 | 5 | 1.6 | 1,653.4 | 110,830 | 0 | 1.5 | 7.5 | 0 | 0 | 0 |
| Lhong Angin 1 | Weh Open Access | Deep | 25.5 | 61.75 | 11.5 | 4.13 | 11 | 8.0 | 297.7 | 13,490 | 157.5 | 2 | 0 | 0 | 2.5 | 0 |
| Lhong Angin 1 | Weh Open Access | Shallow | 28.5 | 71.25 | 0.25 | 4.01 | 5 | 2.6 | 348.4 | 14,330 | 136.25 | 3.5 | 0 | 0 | 0.5 | 0.5 |
| Lhong Angin 2 | Weh Open Access | Deep | 19 | 73.75 | 6.25 | 4.60 | 18 | 3.1 | 317.8 | 17,070 | 96.25 | 1.5 | 0.5 | 0 | 2 | 0 |
| Lhong Angin 2 | Weh Open Access | Shallow | 8.75 | 90.75 | 0.5 | 3.37 | 5 | 6.6 | 165.2 | 4,710 | 307.5 | 1 | 1 | 0 | 0 | 0 |
| Lhong Angin 3 | Weh Open Access | Deep | 15.25 | 66.5 | 16.5 | 5.12 | 13 | 9.0 | 322.7 | 15,670 | 155 | 3 | 0.5 | 0 | 7.5 | 0.5 |
| Lhong Angin 3 | Weh Open Access | Shallow | 9.75 | 89.5 | 0.5 | 3.52 | 4 | 1.6 | 147.3 | 8,080 | 243.75 | 4 | 0 | 0 | 0 | 0.5 |
| Pulau Klah | Weh Open Access | Deep | 16 | 40.75 | 40.75 | 4.44 | 16 | 4.2 | 328.8 | 11,140 | 26.25 | 1 | 1.5 | 0 | 8.5 | 0 |
| Pulau Klah | Weh Open Access | Shallow | 45.75 | 41.75 | 11.5 | 5.49 | 11 | 3.4 | 482.2 | 17,980 | 3.75 | 6.5 | 13 | 0 | 1.5 | 0 |

*Diversity (slope genus - log(area) line) (Edinger *et.al*, 1998)

Table 2. Coral genus list and propostion from point transect survey 2006

| no. | Genera | Propotion % |
|---|---|---|
| 1 | *Porites* | 35.58 |
| 2 | *Acropora* | 30.22 |
| 3 | *Heliopora* | 10.85 |
| 4 | *Montipora* | 6.04 |
| 5 | *Pocillopora* | 3.59 |
| 6 | *Millepora* | 2.32 |
| 7 | *Pavona* | 1.26 |
| 8 | *Favites* | 1.09 |
| 9 | *Coeloseris* | 0.99 |
| 10 | *Goniastrea* | 0.88 |
| 11 | *Favia* | 0.81 |

| no. | Genera | Propotion % |
|---|---|---|
| 12 | *Diploastrea* | 0.64 |
| 13 | *Leptastrea* | 0.62 |
| 14 | *Platygyra* | 0.48 |
| 15 | *Coscinaraea* | 0.45 |
| 16 | *Goniopora* | 0.36 |
| 17 | *Echinopora* | 0.36 |
| 18 | *Cyphastrea* | 0.36 |
| 19 | *Gardineroseris* | 0.33 |
| 20 | *Seriatopora* | 0.29 |
| 21 | *Hydnophora* | 0.28 |
| 22 | *Lobophyllia* | 0.26 |

| no. | Genera | Propotion % |
|---|---|---|
| 23 | *Galaxea* | 0.24 |
| 24 | *Fungia* | 0.21 |
| 25 | *Astreopora* | 0.19 |
| 26 | *Montastrea* | 0.17 |
| 27 | *Symphyllia* | 0.14 |
| 28 | *Psammocora* | 0.14 |
| 29 | *Pectinia* | 0.14 |
| 30 | *Merulina* | 0.14 |
| 31 | *Alveopora* | 0.10 |
| 32 | *Euphyllia* | 0.09 |
| 33 | *Pachyseris* | 0.07 |

| no. | Genera | Propotion % |
|---|---|---|
| 34 | *Stylophora* | 0.05 |
| 35 | *Plerogyra* | 0.05 |
| 36 | *Ctenactis* | 0.05 |
| 37 | *Acanthastrea* | 0.05 |
| 38 | *Turbinaria* | 0.02 |
| 39 | *Oulophyollia* | 0.02 |
| 40 | *Leptoria* | 0.02 |
| 41 | *Herpolitha* | 0.02 |
| 42 | *Echinophyllia* | 0.02 |

Table 3. Reef fish species richness using *Coral Fish Diversity Index* (CFDI) equation (Allen, 1998).

| Management type | Site | Total Species | CFDI | Species richness |
|---|---|---|---|---|
| Aceh Open Access | Deudap | **141** | **84** | **264.165** |
| Aceh Open Access | Lamteng | **87** | **50** | **148.905** |
| Aceh Open Access | Lapeng | **102** | **57** | **172.635** |
| Aceh Open Access | Leun Balee 1 | **95** | **52** | **155.685** |
| Aceh Open Access | Leun Balee 2 | **112** | **60** | **182.805** |
| Aceh Open Access | Lhoh | **56** | **43** | **125.175** |
| Aceh Open Access | Paloh | **97** | **62** | **189.585** |
| Aceh Open Access | Pasi Janeng 1 | **67** | **39** | **111.615** |
| Aceh Open Access | Pasi Janeng 2 | **53** | **30** | **81.105** |
| Weh Open Access | Ba Kopra | **138** | **85** | **267.555** |
| Weh Open Access | Beurawang | **132** | **84** | **264.165** |
| Weh Open Access | Gapang | **100** | **62** | **189.585** |
| Weh Open Access | Jaboi | **119** | **80** | **250.605** |
| Weh Open Access | Lhong Angen1 | **95** | **61** | **186.195** |
| Weh Open Access | Lhong Angin 2 | **81** | **45** | **131.955** |
| Weh Open Access | Lhong Angin 3 | **109** | **73** | **226.875** |
| Weh Open Access | Pulau Klah | **106** | **63** | **192.975** |
| Kawasan Wisata | Batee Meuronon | **118** | **75** | **233.655** |
| Kawasan Wisata | Lhok Weng | **124** | **78** | **243.825** |
| Kawasan Wisata | Rubiah Channel | **146** | **99** | **315.015** |
| Kawasan Wisata | Rubiah Sea Garden | **140** | **91** | **287.895** |
| Kawasan Wisata | Ujung Seurawan | **145** | **95** | **301.455** |
| Panglima Laut | Sumur Tiga | **127** | **87** | **274.335** |
| Panglima Laut | Anoi Itam | **103** | **73** | **226.875** |
| Panglima Laut | Benteng | **116** | **76** | **237.045** |
| Panglima Laut | Ujung Kareung | **110** | **74** | **230.265** |
| Panglima Laut | Ujung Seuke | **113** | **78** | **243.825** |