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Research Article

The shallow water hard corals of Pulau Weh, Aceh Province, Indonesia

[1]Andrew H. Baird, [2]Stuart J. Campbell, [3]Nur Fadli, [1,4]Andrew S. Hoey, [3]Edi Rudi

[1]ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, Australia; [2]Wildlife Conservation Society, Bogor, Indonesia; [3]Centre for Marine and Fisheries Studies, Syiah Kuala University, Banda Aceh, Aceh, Indonesia; [4]Red Sea Research Center, King Abdullah University of Science and Technology, Thuwal, Kingdom of Saudi Arabia.

Abstract. The corals reefs of Aceh, Indonesia, are one of the few areas of the world where the fauna, in particular the scleractinian corals, have yet to be described. The area is likely to be of high biogeographical significance due to its position at the northern tip of Sumatra on the boundary of three major water bodies, the Indian Ocean, the Andaman Sea and the Straits of Malacca. Here, we present the quantitative description of the assemblage structure of the shallow water scleractinian corals of Pulau Weh. Carbonate reefs are rare on the island, the exception being some fringing reef development in shallow water in at least two locations. Most colonies are attached to granite boulders which make up the ocean floor at most sites on the north and west coast, or rest in the sandy substrates that dominate the ocean floor on the east coast. Coral cover in February 2009 was over 40% at most sites, ranging from 21% ± 3.0 SE to 80% ± 2.4. Coral assemblage structure varied widely around Pulau Weh with assemblages from the western and northern sites being dominated by *Acropora* spp. in particular, species with digitate, encrusting-arborescent and tabular morphologies. In contrast, coral assemblages on the west coast were dominated by massive *Porites* spp. and *Heliopora*. The *Acropora* fauna is dominated by species with digitate and encrusting arborescent morphologies, very different from many other regions in Indonesia. This unusual species composition plus the presence of a high proportion of endemics indicates that the region should be a high priority for conservation efforts. Further taxonomic studies at depth and further afield are required to fully describe this unique fauna that supports a small diving industry and a number of fisheries.

Key Words: biodiversity, conservation, coral reefs, coral triangle, Andaman Sea.

Corresponding Author: A. Baird, andrew.baird@jcu.edu.au

Introduction

The province of Aceh occupies the northern third of the island of Sumatra, Indonesia. The province supports three main reefs areas: fringing reefs lining the eastern and western coast of the Sumatra mainland; the island groups of Simeuleu and Pulau Banyak in the south west of the province and the islands of Pulau Weh and Pulau Aceh forming the northern most part of Indonesia approximately 16 km off the tip of Sumatra (Figure 1). The region is likely to be of high biogeographical significance due to its position on the border of three large bodies of water: the Andaman Sea, The Indian Ocean and the Straits of Malacca (Brown 2007).

The reefs of Aceh remain one of the last areas in the world where the marine flora and fauna have yet to be documented (Brown 2007), largely as a results of a turbulent history. Aceh was the last region of modern Indonesia to be incorporated into the Dutch East Indies after 30 years of war (Reid 2005). In 1948, Aceh joined the Republic of Indonesia, however, the province was soon in rebellion, which has flared sporadically until a memorandum of understanding was signed in 2006 (Aspinall 2009). Consequently, the area has been off limits to foreigners for much of its recent history (Brown 2007). Furthermore, the rebellion and the distance from the national capital, Jakarta, discouraged Indonesian scientists from visiting the region. Local capacity has also been limited; the Marine Science Department at Syiah Kuala University was only established in 2003. To the best of our knowledge the reefs of Aceh have not been visited by a coral taxonomist since Buitendijk collected at least four fungiids on Pulau Weh between 1905 and 1927; specimens now housed at the Zoological Museum of Amsterdam (Hoeksema pers. comm.). Veron *et al* (2009) list 339 species in the Andaman Sea including 69 *Acropora* species. Based on records from the two nearest sites in Wallace (1999) (Thailand and West Sumatra) we estimate that 52-58 *Acropora* species are likely to occur on Pulau Weh. However, neither Veron (2000) nor Wallace (1999) examined any material from Aceh, indeed, Veron (2000) did not examine any material from Sumatra. Allen & Adrim (2003) describe the reef fish fauna of northern and western Sumartra as one of eight local centers of diversity within Indonesia and list six species as endemic to Pulau Weh. The only other internationally published research on the reefs of Aceh describes the effects of the Indian Ocean Tsunami on these reefs (Baird *et al* 2005; Campbell *et al*

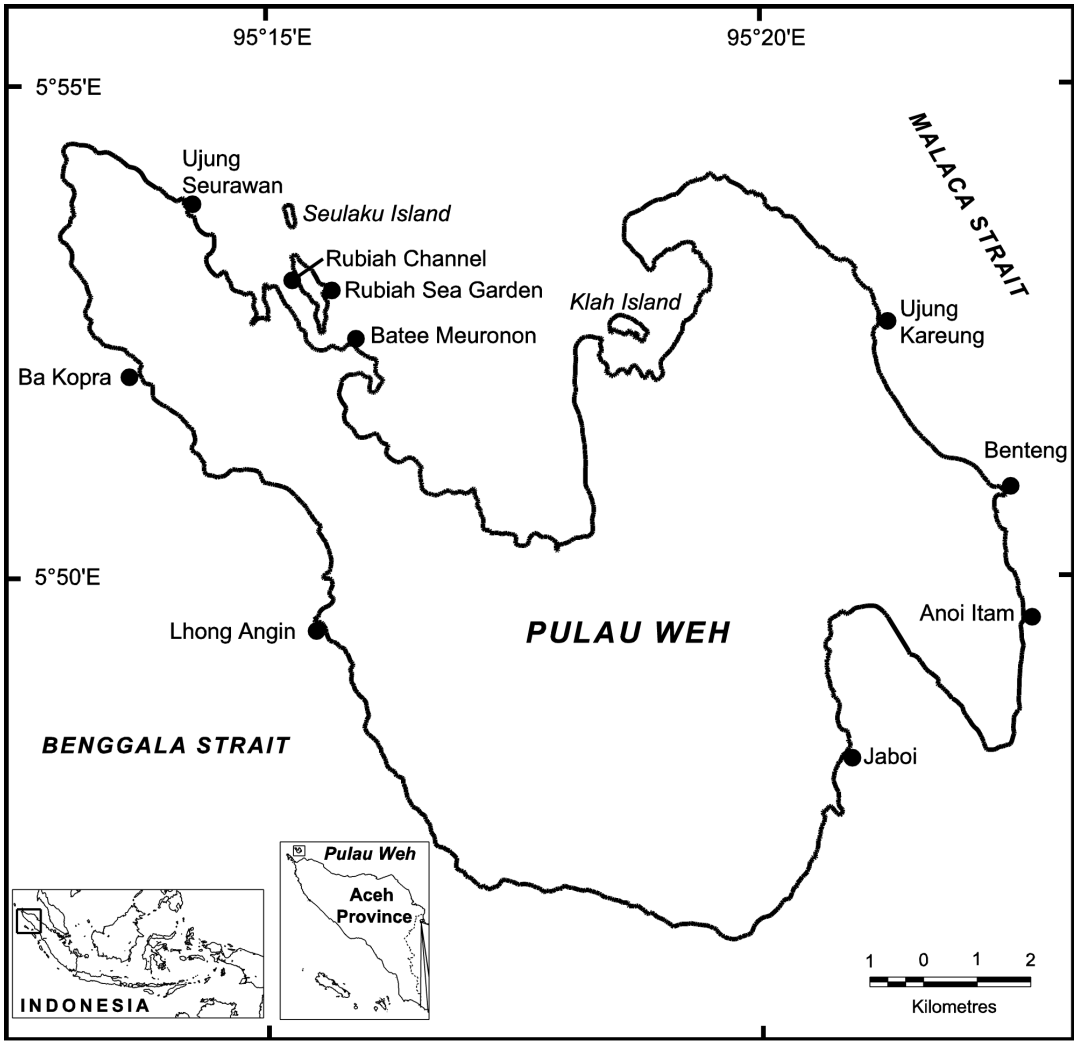

Figure 1. Map of Pulau Weh, northern Aceh, Indonesia showing the location of the ten sites used to quantify the shallow hard coral assemblages in February 2009.

2007; Hagan *et al* 2007) and limited information on reproductive seasonality in the *Acropora* (Baird *et al* 2009).

The scleractinian fauna of Pulau Weh is also of interest for economic reasons. The reefs support a small but growing dive industry and a number of fisheries. The aim of this study was to provide a quantitative description of the hard coral assemblages surrounding Pulau Weh.

Material and Method

Total coral cover and the assemblage structure of coral assemblages were determined at 10 sites spread around Pulau Weh in February 2009 (Figure 1) using 8 replicate 10 m line intercept transects (LIT) at between 0.5 and 2 m depths. The cover in cm of each hard coral colony (i.e. all scleractinians plus *Heliopora* and *Millepora*) was recorded. *Acropora* colonies were categorized into one of five morphological groups following Wallace (1999). Remaining scleractinian colonies were categorized as *Isopora*, *Montipora*, Pocilloporidae, Poritiidae or "other scleractinia". Cover was then expressed as the percentage of 10 m covered by each group on each transect. Principal component analysis (PCA) was used to investigate the differences in the assemblage structure among sites using these 12 taxa. All data were collected on snorkel, restricting the surveys to depths generally less than 4 m. Taxonomic references used were Wallace (1999), Veron (2000) and Veron (2004).

Results and Discussion

Carbonate reefs are rare on the island, the exception being some fringing reef development in very shallow water in at least two locations, Benteng (Figure 1; Figure 2a) and Rubiah Sea Garden (Figure 1; Figure 2b). Most colonies are attached to granite boulders which make up the ocean floor at most sites on the north and west coast (Figure 2d), or rest in the sandy substrates that form the ocean floor on the east coast (Figure 2e). Total hard coral cover ranged from 21% ± 3.0 at Batee Meuronon to 80% ± 2.4 at Benteng and was greater than 40% at all but four sites (Batee Meuronon, Ujung Seurawan, Ba Kopra and Lhong Angin; Figure 3). Coral cover was consistently high at sites on the western side of Pulau Weh, ranging from 41% ± 3.7 at Anoi Itam to 80% ± 2.5 at Benteng (Figure 3). Coral cover was variable among the north western sites, all situated within a government gazetted marine reserve centred on the village of Ipoih, ranging from 21% ± 3.0 at Batee Meuronon to 57% ± 5.4 at Rubiah

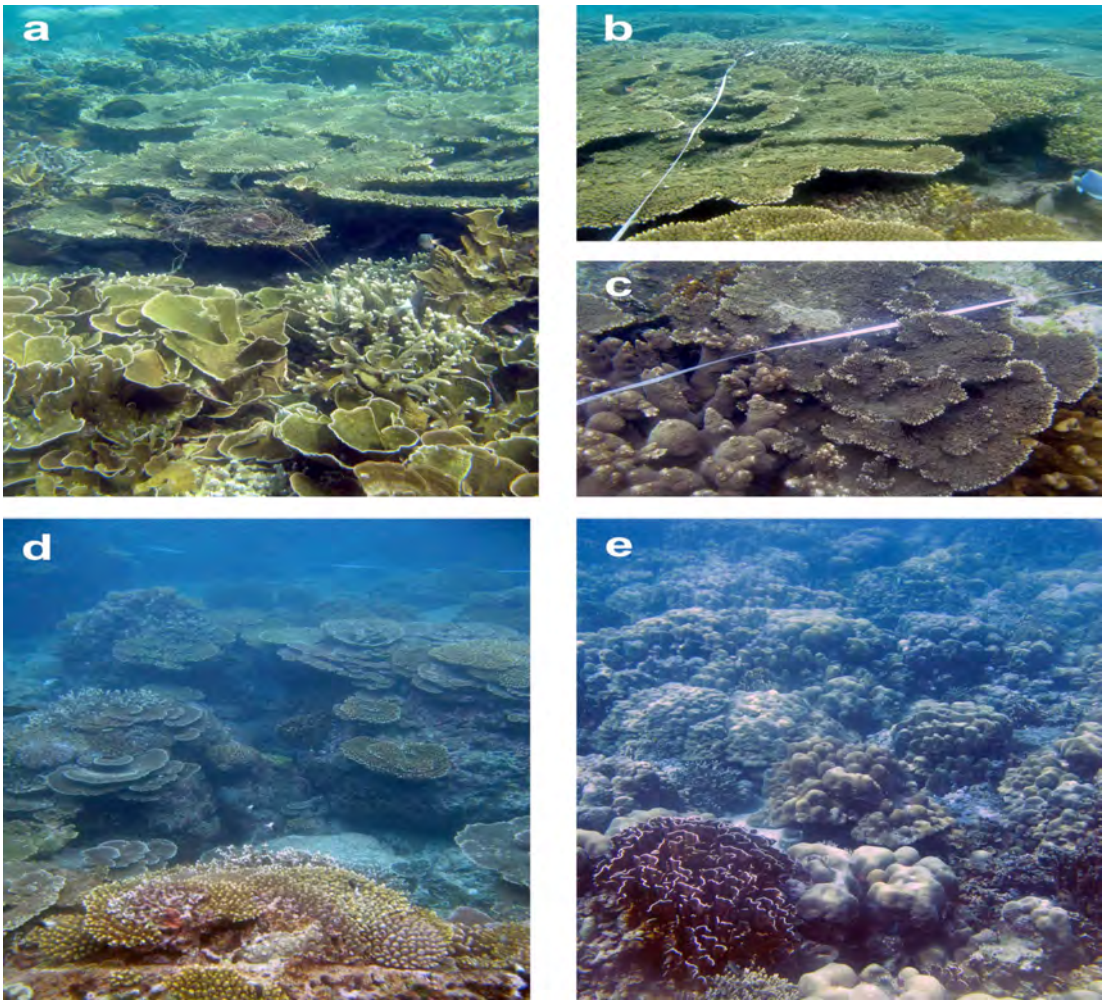

Figure 2. Representative coral assemblages from various sites on Pulau Weh. (a) Fringing reef dominated by tabular *Acropora* and foliose *Montipora* at Benteng on the eastern side of P. Weh; (b) Fringing reef dominated by tabular and digitate *Acropora* at Rubiah Sea Garden; (c) Tabular and encrusting-arborescent *Acropora* dominate coral assemblages at Ujung Seurawan on the north coast of P. Weh; (d) Diverse hard coral assemblages growing on granitic boulders at Lhong Angin on the west coast of P. Weh; (e) Coral assemblages on the east coast of P. Weh are typically dominated by massive *Porites* and *Heliopora* resting on sandy substrates, such as this assemblage at Jaboi.

Sea Garden (Figure 3). Coral cover was lower on the eastern side of the island ranging from 24% ± 2.5 at Lhong Angen to 34% ± 2.6 (Figure 3).

The principal component analysis showed clear variation in the coral assemblages among sites, with two main clusters forming along the first principal component (Figure 4). Eastern and northern sites were dominated by *Acropora* spp. colonies with digitate, encrusting-arborescent and tabular morphologies (Figure 4; Figure 2b-d). Assemblages on the west coast, were generally dominated by massive *Porites* spp. and *Heliopora* (Figure 4; Figure 2e). Within each of these clusters, sites were distinguished by differences in the relative abundance of arborescent *Acropora*, *Montipora* and Pocilloporidae (Figure 4). For example, *Montipora* and arborescent *Acropora* were abundant at Benteng (Figure 4; Figure 2a) and Pocilloporidae were relatively abundant at Lhong Angin (Figure 4).

The reefs of Pulau Weh were in good condition in February 2009 with coral cover typically over 40% (Figure 2). Indeed, two of the sites with lower than 40% cover, Ujung Seurawan and Batee Meuronron, both had cover over 40% in surveys conducted in 2005 (Baird *et al* 2005). Recent *Acathaster planci* activity was evident at both sites and outbreak densities of the starfish were recorded at Batee Meuronron in February 2008 (A. Baird per obs; Figure 5a). Other sources of recent coral mortality include isolated cases of Black Band Disease (Figure 5b) and the

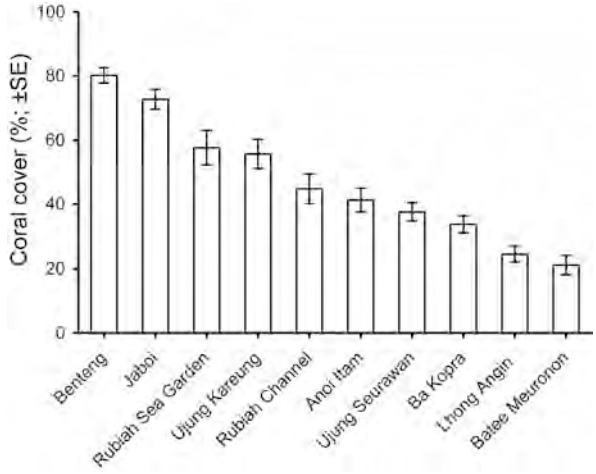

Figure 3. Variation in the cover of live hard coral (mean % ± SE) among ten sites on Pulau Weh, northern Aceh. Each mean is based on eight 10-m line intercept transects. Locations of the ten sites are given in Figure 1.

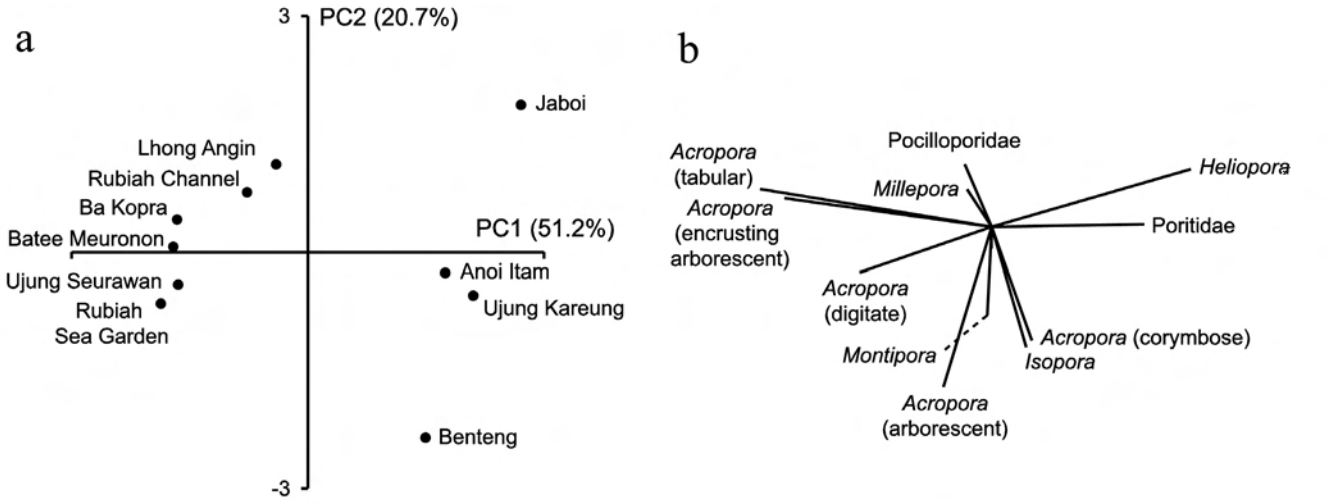

Figure 4. Principal component analysis showing the relationships among hard coral assemblages on Pulau Weh. (a) Ordination plot showing the relationship between the ten sites. Each site is based on eight 10-m line-intercept transects. (b) Coral taxa loadings indicating the relative contributions of each of the hard coral taxa to the observed differences in assemblage structure.

corallivorous snail *Drupella* sp. (Figure 5c) and a moderate incidence of disease affecting *Pocillopora* spp. (Figure 5d) at sites on the west coast, which has potentially contributed to a decline in coral cover at Lhong Angen since 2005 (Baird *et al* 2005). Nonetheless, the high coral cover at most of these sites suggests local management has been relatively effective at controlling destructive fishing practices that have damaged nearby reefs in the region (Baird *et al* 2005; Campbell *et al* 2007; Campbell *et al* in press). Unfortunately, this success in managing reef biodiversity was abruptly halted by a rapid rise in sea temperatures that caused dramatic decline in coral cover at all sites around Pulau Weh with up to 100 % mortality of some sensitive species, such as *Isopora palifera* in May 2010 (unpublished data). This event highlights the challenges associated with conserving coral reefs and local habitats in the face of global threats, such as climate change (Hughes *et al* 2003; Bellwood *et al* 2004, Rodder 2009, Fadli *et al* 2012).

The scleractinian fauna of Pulah Weh is unique, being a composite of Indian Ocean species, widespread Indo-Pacific species, Pacific Ocean species plus locally abundant species found mainly in Indonesia (Rudi *et al*, in press). In addition, the abundance of species with digitate morphologies (e.g. *A. digitifera* and *A. gemmifera*), and encrusting arborescent morphologies (e.g. *A. pinguis* and *A. roseni*) distinguishes this fauna from most other sites surveyed by Wallace in Indonesia (Wallace &

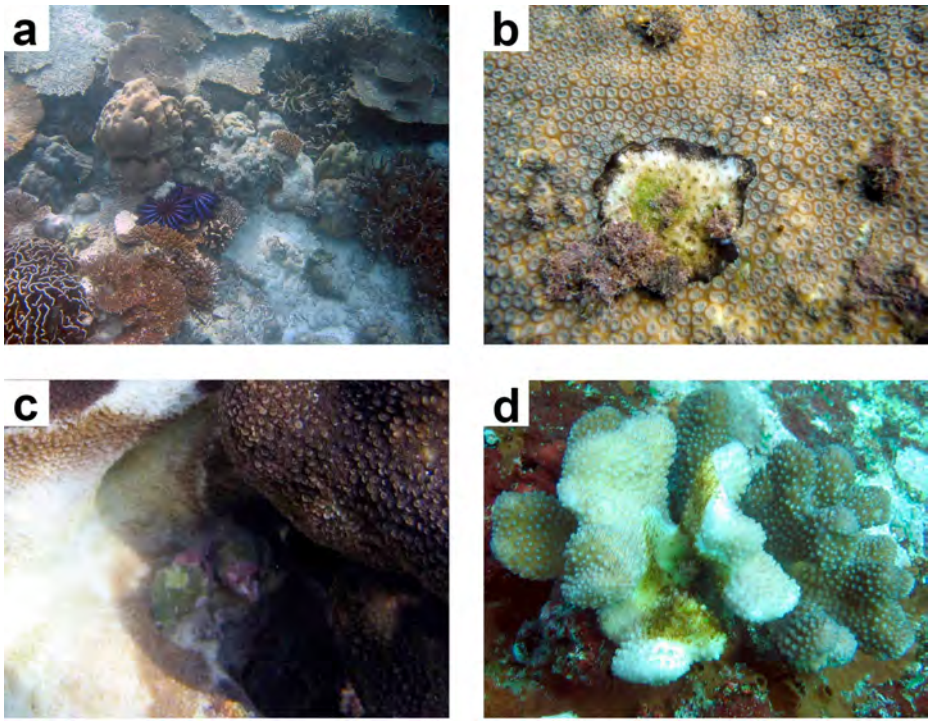

Figure 5. Agents of coral mortality on Pulau Weh. (a) *Acanthaster planci* at Batee Meuronon; (b) Black Band Disease on a *Montastrea colemani* colony at Ujung Seurawan; (c) *Drupella* sp. on *Acropora robusta* at Rubiah Sea Garden; (d) unidentified disease on *Pocillopora verrucosa* at Lhong Angin.

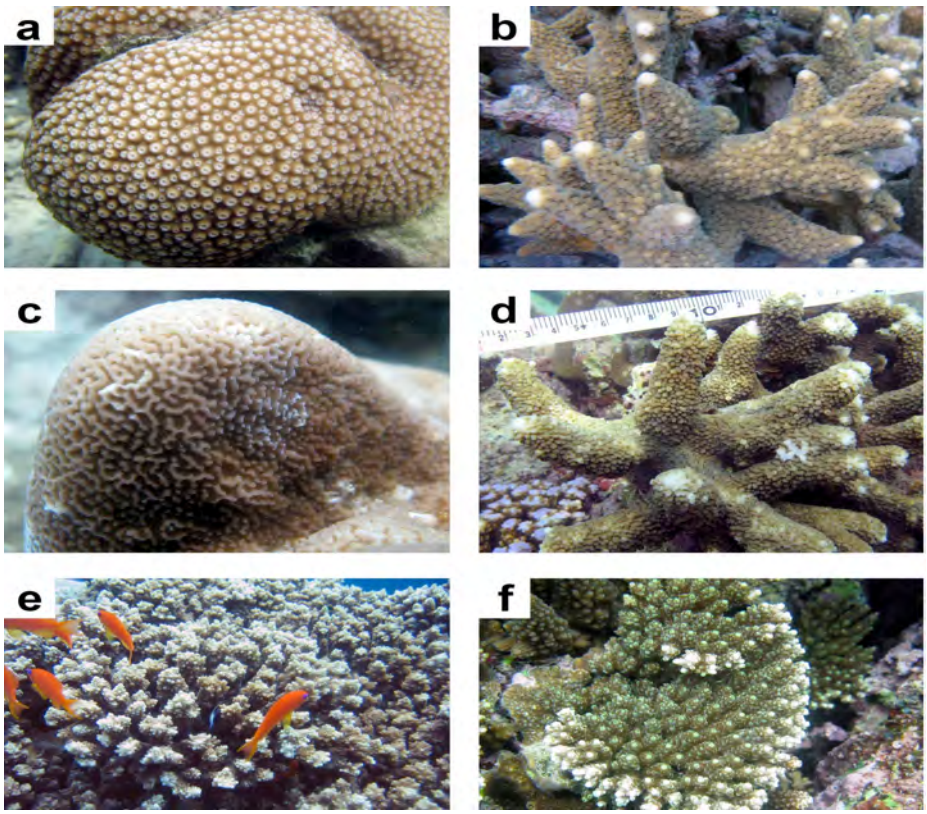

Figure 6. Possible new species of scleractinian coral from Pulau Weh. (a) *Astreopora* sp. nov. (b) *Acropora* sp. nov.1 (c) *Montipora* sp. nov. (d) *Acropora* sp. nov.2 (e) *Acropora dodenti* (f) *Acropora* sp. nov.

Wolstenholme 1998). The diversity of the scleractinian fauna is comparable with regions in the Coral Triangle (Rudi *et al*, in press), which is typically regarded as the centre of diversity for scleractinian corals (Briggs 2005). For example, surveys with a larger geographical scale but similar sampling intensity in the Kayoa Islands, Halmahera in the heart of the Coral Triangle (Veron *et al* 2009) recorded 130 scleractinian species (Ardiwijaya *et al* 2008) compared to the 133 recorded on Pulau Weh (Rudi *et al*, in press). Levels of endemism are also high. Rudi *et al* (in press) suggest at least five of the 133 species recorded in their surveys were new to science (Figure 6), a level of endemism (4%) double that of most of the 135 coral ecoregions identified by Veron *et al* (2009).

Conclusions

The shallow water coral reefs of Pulau Weh were in good condition in February 2009. Low incidences of disease and predation were evident, however, only at two sites was there any suggestion that these threats were affecting coral cover. The composition of the scleractinian fauna of Pulau Weh is distinct from other regions in Indonesia. In addition, the number of potentially new species discovered with relatively little effort suggests the reef of Aceh should be given a high conservation priority in order to protect this unique fauna and the industries, such as dive tourism and fishing that these reefs support.

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References

Allen, G. R., Adrim, M., 2003. Coral reef fishes of Indonesia. Zoological Studies 42:1-72.

Ardiwijaya, R. L., Kartawijaya, T., Setiawan, F., Prasetia, R., Yulianto, I., Herdiana, Y., Baird, A. H., Campbell, S. J., 2008. An assessment of the coral reefs of Kayoa Islands, Halmahera Seascape, Coral Triangle, Indonesia Wildlife Conservation Society-Marine Program Indonesia, Bogor, Indonesia.

Aspinall, E., 2009. Islam and Nation: Separatist rebellion in Aceh, Indonesia. Stanford University Press, Stanford.

Baird, A. H., Campbell, S. J., Anggoro, A. W., Ardiwijaya, R. L., Fadli, N., Herdiana, Y., Kartawijaya, T., Mahyiddin, D., Mukminin, A., Pardede, S. T., Pratchett, M. S., Rudi, E., Siregar, A. M., 2005. Acehnese reefs in the wake of the Asian tsunami. Current Biology 15:1926-1930.

Baird, A. H., Guest, J. R., Willis, B. L., 2009. Systematic and biogeographical patterns in the reproductive biology of scleractinian corals. Annual Review of Ecology, Evolution and Systematics 40:531-571.

Bellwood, D. R., Hughes, T. P., Folke, C. & Nystrom, M., 2004. Confronting the coral reef crisis. Nature 429(6994):827-833.

Briggs, J. C., 2005. The marine East Indies: Diversity and speciation. Journal of Biogeography 32:1517-1522.

Brown, B. E., 2007. Coral Reefs of the Andaman Sea - and integrated perspective. Oceanography and Marine Biology Annual Review 45:173-194.

Campbell, S. J., Baird, A. H., Cinner, J., Ardiwijaya, R. L. Herdiana, Y., Kartawijaya, T., Mukminin, A., 2012. Avoiding conflicts and protecting coral reefs: Customary management of fishing gear protects habitat and fish biomass in Aceh, Indonesia Oryx: in press

Campbell, S. J., Pratchett, M. S., Anggoro, A. W., Ardiwijaya, R. L., Fadli, N., Herdiana, Y., Kartawijaya, T., Mahyiddin, D., Mukminin, A., Pardede, S. T., Rudi, E., Siregar, A. M., Baird, A. H., 2007. Disturbance to coral reefs in Aceh, Northern Sumatra: impacts of the Sumatra-Andaman tsunami and pre-tsunami degradation. Atoll Research Bulletin 544:55-78.

Fadli, N., Campbell, S. J., Ferguson, K., Keyse, J., Rudi, E., Baird, A. H., 2012. Quantifying change in the community structure of an artificial reef. Oryx: in press.

Hagan, A. B., Foster, R., Perera, N., Gunawan, C. A., Silaban, I., Yaha, Y., Manuputty, Y., Hazam, I., 2007. Tsunami impacts in Aceh Province and North Sumatra, Indonesia. Atoll Research Bulletin 544:37-54.

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nystrom, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B., Roughgarden, J., 2003. Climate change, human impacts, and the resilience of coral reefs. Science 301(5635): 929-933.

Reid, A., 2005. An Indonesia Frontier: Acehnese and other histories of Sumatra. Sinapore University Press, Singapore.

Rodder, D., 2009. Sleepless in Hawaii – does anthropogenic climate change enhance ecological and socioeconomic impacts of the alien invasive Eleutherodactylus coqui Thomas 1966 (Anura: Eleutherodactylidae)? North-Western Journal of Zoology 5(1):16-25.

Rudi, E., Hoey, A. S., Campbell, S. J., Fadli, N., Linkie, M., Baird, A. H., 2012. The Coral Triangle Initiative: What are we missing? A case study from Aceh, Indonesia. Oryx: in press.

Veron, J. E. N., 2000. Corals of the World. AIMS, Townsville.

Veron, J. E. N., 2004. New species described in Corals of the World. AIMS, Townsville.

Veron, J. E. N., DeVantier, L., Turak, E., Green, D. H., Kinnmonth, S., Stafford-Smith, M., Peterson, N., 2009. Delineating the Coral Triangle. Galaxea 11:91-100.

Wallace, C. C., 1999. Staghorn Corals of the World. CSIRO, Collingwood.

Wallace, C. C., Wolstenholme J., 1998. Revision of the coral genus *Acropora* (Scleractinia: Astrocoeniina : Acroporidae) in Indonesia. Zoological Journal of the Linnean Society 123:199-384.

Authors

•Andrew H. Baird, ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland 4811, Australia, e-mail: andrew.baird@jcu.edu.au

•Stuart J. Campbell, Wildlife Conservation Society, Jl. Pangrango No. 8, Bogor 16151, Indonesia.

•Nur Fadli; Department of Marine Sciences, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh, Aceh, Indonesia, e-mail: ivad29@yahoo.com

•Andrew S. Hoey, Red Sea Research Center, King Abdullah University of Science and Technology, Thuwal, Kingdom of Saudi Arabia.

•Edi Rudi, Department of Biology, Faculty of Sciences, Syiah Kuala University, Banda Aceh 23111, Aceh, Indonesia, e-mail: edirudi@yahoo.com

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