Temporal Variation and Comparison of the Status of Coral Reefs in Selected Sites in the Philippines

Clarissa T. Reboton and
Hilconida P. Calumpong
Silliman University-Institute of Environmental and Marine Sciences,
Dumaguete City, Philippines

This study investigates the temporal changes on the condition of coral reefs based on baseline surveys conducted as early as 1995 in two sites from each of three regions in the Philippines (V-Masbate), VII-Negros Oriental, and XI-Davao Oriental). Results showed a significant increase in coral cover in the southern side of Baladingan, Masbate from poor (14±4%) in 2009 to fair (33±3%) in 2013 . Comparatively, coral cover in Guang-guang, Davao Oriental showed no significant difference despite the seeming increase from 27±10% in 2010 to 42±3% in 2013 while the northern side of Pujada I. experienced a decline from 75±3% to 40±6%. In Negros Oriental, a long-term study of Apo Chapel revealed a significantly increasing trend over a 15-year period from 19±8% in 1999 to 60±19% in 2005 and since then, has remained in good condition. This site also has the highest species diversity. No change was observed in Bantayan marine sanctuary, Dumaguete for over 19 years with only 18±15% in 1995 to 20±10% in 2013. A comparison of current data between sites in each region showed statistically similar coral cover in Masbate and Davao Oriental. In Negros Oriental, Apo Chapel has significantly higher coral cover than Bantayan marine sanctuary. All sites exhibited good condition indices despite the low coral cover in some. Reef development was good in Apo Chapel and the sites in Davao Oriental. The high cover of abiotic-related components compared to coral-related components indicated poor reef development in Masbate and Bantayan. Mortality indices were highest and species diversities lowest in Davao sites and Bantayan. Factors such as level of protection, exposure to natural and anthropogenic disturbances and species composition that influence these changes are discussed.

Keywords: Philippine coral reefs, temporal variation, coral cover, diversity, disturbance.

INTRODUCTION

The Philippines has about 26,000 km^2 of coral reef and is considered the center of highest marine biodiversity within the Coral Triangle (Wilkinson, 1992). Sixty per cent of the population reside in the coastal zone and are chiefly dependent on the sea for subsistence with >50% of the dietary requirements derived from municipal fisheries and the shallow coastal habitats (D' Agnes *et al.* 2005). Basically, coral reefs are one of the most important ecosystems in the world because of its ecological and economic functions (White, 1987). The value of coral reefs to fisheries and tourism has made great contributions to the nation's economy. Unfortunately, the escalating local and regional environmental pressures aggravating the effects of climate change have now extremely threatened this ecosystem leading to its accelerated deterioration (Hoegh-Guldberg *et al.* 2009). Burke *et al.* (2002) reported that more than 80% of Philippine reefs are threatened by overfishing, more than 70% by blast and poison fishing, more than 40% by coastal development pressures and approximately 35% are threatened by sedimentation and pollution associated with land-use changes. The Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD, 2001) further reported that the 1997-1998 El Niño brought a production loss of 7,142 t and economic loss of Php 319.21M in marine fisheries in the country. In the past, typhoons are rarely experienced in the southern Philippines, but now these have become more frequent. Wilkinson (1992) indicated that the alteration in cyclonic storm patterns and frequencies as an effect of climate change can potentially impact latitudes that have not currently experienced them. According to Nañola *et al.* (2004), the percentage of excellent reefs suggests that the reefs in the country may be experiencing a steady state of decline, i.e. from over 5% in 1981 (Gomez *et al.* 1981) to 4% in 1997 (Licuanan and Gomez, 2000) to >1 % in 2000 to 2004 (Nañola *et al.* 2005; 2006).

Thus, this study was conducted to document changes in coral reef condition over time and compare current conditions between sites in the region that were identified as poor and good based on baselines. This study is built on the premise that well-managed reefs will exhibit improved coral condition as opposed to reefs that are poorly or not protected at all. Results can guide reef managers in determining the need for interventions.

This study is part of a larger project, STEWARDS (Science Towards Environmental Well-being and Resource Development for Society in a changing climate) funded by the Commission on Higher Education (CHED)- Philippine Higher Education Research Network (PHERNet) Program. The primary objective of this project is to compare the services and goods (i.e. fish standing stocks) between poor and good reef and seagrass habitats.

STUDY SITES

Two reef sites in each three regions, Regions V (Masbate), VII Negros Oriental) and XI (Davao Oriental) were surveyed. These sites were previously assessed under several projects in different years: Region V in 2009 (Reboton and Candido, 2014), Bantayan in Region VII, in 1995 (Calumpong *et al.* 1997) and in 2009 (Reboton, unpublished) while Apo has been regularly surveyed since 1995 (Calumpong *et al.* 1997; UNEP-ICRAN, 2003-2007; DENR-ICRMP, 2010).

Two sites in Region V are located in Ticao I. which is one of the three major islands in the province of Masbate: Sitio Baladingan (12.62690° - 12.62758° N, 123.70632° - 123.70760° E) in Brgy. Famosa, Monreal and Brgy. Tacdogan (12.61577° - 12.61529° N, 123.71575° - 123.71714° E) in San Jacinto (Fig.1). Baladingan is characterized by a 3-km stretch of white sandy beach that is lined by a limestone cliff on its southern side. Here, the shoreline is fully covered with water during high tide except at the southern-most tip where beach formation is absent. Water visibility is up to $\geq$15 m deep. The Tacdogan site is located within a bay which consists of a 0.5-km stretch of sandy beach at the center of the bay and eastward, a limestone cliff that extends about 1 km seaward. Sediments are a combination of dark coarse and fine grains. Water visibility is poor at <6 m deep as the area receives outputs from the adjacent Ighod River of Baladingan that is fringed by mangrove vegetation. Strong currents are experienced during ebb tide which increases water turbidity and decreases visibility to 0 m. Ticao I. is affected by the northeast monsoon from November to January. The intertidal areas are generally composed of narrow (5 m wide) and sparse seagrass beds that is followed by a narrow (<20 m wide) and shallow (maximum 7 m deep) sandy-rocky reef flat with patchy coral communities. Toward the north of Baladingan and farther east of Tacdogan, the reef flat is highly covered by the algae *Padina* and *Sargassum*. There are still no existing ordinances for the protection of marine environment in the area even though the concept of marine conservation has been continually introduced to the community. Transects were established at the southern side of Baladingan and east of Tacdogan.

Upland farming, cattle-raising and fishing activities are the major livelihood activities in the area. Generally, Ticao Pass serves as a major fishing ground for sardines. Gleaning for sea urchins *Diadema* is also practiced in Baladingan. Illegal fishing from different barangays and municipalities have been a problem.

In Region VII, the sites surveyed were Bantayan (9°19'15"N and 123°18'07"E), located in the mainland of Dumaguete City, and Apo I., off Dauin mainland, Negros Oriental (Fig. 1). A dense seagrass meadow extends approximately 150 m offshore, at which a narrow and patchy coral and rubble zone, approximately <50 m, occurs. Farther offshore, a mixed seagrass bed grows to about 10 m depth, and beyond a monospecific bed of *Halodule uninervis* down to 15 m depth. Sediments are predominantly volcanic in origin with dark coarse grains in the surface layer overlying finer sediments underneath. The area is exposed to the northeast monsoon. Depending on the tidal state, currents can be strong. Water visibility exceeds 10 m but can be very turbid during natural events associated with strong winds and waves (Tomasko *et al.* 1993). Turbidity may last for weeks following major storms. Bantayan Beach is a populated area where gleaning and fishing are commonly practiced by the residents. Other activities such as swimming and docking of dive boats are often carried out by non-residents. The transect station is inside the 1.2-ha marine sanctuary which was recently established in 2012 (Fig. 1). The sanctuary is actively managed by the city government, the barangay and the city fish wardens fisher's organization. Transects were established inside the sanctuary area.

The other site is the 74-ha volcanic island of Apo (9°5'N, 123°15'E) located off the southeastern tip of Negros Island, 25 km south of Dumaguete City (Fig. 1). A 1.06 km^2 of fringing coral reef surrounds the island down to the 60 m isobath (Russ and Alcala, 1989). Water current is non-reversing and flows in a consistently southwest direction (Calumpong *et al.* 1997). Water visibility reaches to depths of greater than 30 m (Smith *et al.* 1982 in UNEP/IUCN, 1988). The island has been protected for almost 30 years since the establishment of the 22-ha "no-take" marine zone on the southeastern side in 1984. On August 9, 1994, the whole island was declared a Protected Landscape and Seascape (Apo Island Protected Landscape and Seascape or AIPLS) (total = 691.45 ha) under the NIPAS (National Integrated Protected Area System) and under the jurisdiction of the PAMB (Protected Area Management Board). Prior to Marine Protected Area establishment, dynamite fishing used to be rampant but now only traditional fishing methods are practiced outside the sanctuary. Since the late 80's, Apo is one of the favored diving destinations in the country where ten dive sites have been identified. Calumpong *et al.* (2005) estimated diving-associated damage levels not to have reached a threshold that can be interpreted as carrying capacity. A total of 15 guided divers and a maximum of 32 snorkelers per day (i.e. eight snorkelers per hour) inside the sanctuary were implemented by the PAMB in order to manage diving activities. Apo is considered as one of the world's best known community-organized marine sanctuaries. It has also been classified as among the four excellent reefs in the country together with Tubbataha Reef Marine Park in Palawan, Apo Reef in Puerto Galera in Mindoro and the Verde Island Passage in Batangas (Reef Check, 2007).

Apo I. has been exposed to a number of natural occurrences like the 1997-1998 and 2010 El Niño events, and recently, Severe Tropical Storm Washi ("Sendong) in 2011 and Super typhoon Bopha ("Pablo") in 2012. The transect station was established in the Chapel (9.07717° - 9.07622° N, 123.26641° - 123.26623° E), west of the island facing the community area (Fig. 1). This dive site has an extensive reef flat ($\geq$ 50 m) and a gradual to steep slope (40-70°). Like the other areas in the island, the shallower portion is dominated by soft corals while hard corals are concentrated near the reef slope. The Chapel site represents an area of good coral condition based on previous records. At present, the no-take sanctuary is temporarily closed for diving and snorkelling due to massive devastation brought by the typhoons.

The site in Region XI was in Pujada Bay (6°48'04"-6°54'25" N and 126°9'08"- 126°19'33" E), Mati, Province of Davao Oriental, located at the southern tip of Mindanao, 157 km east-southeast of Davao City (Jimenez *et al.* 2002). The bay was declared as the Pujada Bay Protected Seascape (PBPS) by Proclamation 431 on July 31, 1994, under the NIPAS, covering an area of 212 km^2 (http://www.pawb.gov.ph). The transect stations were in Sitio Guang-guang, Brgy. Dahican (6.91408° - 6.91279° N, 126.25706° - 126.25694° E), located along the mainland inside the bay, and Pujada I. (6.79690° - 6.79641° N, 126.25823° - 126.26016° E) which is situated at the mouth of the bay (Fig. 1). The marine environment is characterized by extensive seagrass beds that thrive even beyond the intertidal zone down to a depth of 12 m (i.e. Pujada I.). Coral reefs are of fringing type. In Guang-guang, the reef occurs from about 3 m to ~13 m deep with coral growths mostly concentrated at around 6 m depth. The slope is gradual with a 20-30° angle. The area is quite silty with vertical water visibility of approximately 10 m due to the presence of an extensive mangrove forest (Guang-guang Mangrove Park and Nursery) that spans the whole length of the shoreline. The coral reef in Pujada I. extends some 30 m from the shoreline down to a depth of ~20 m. It slopes at about

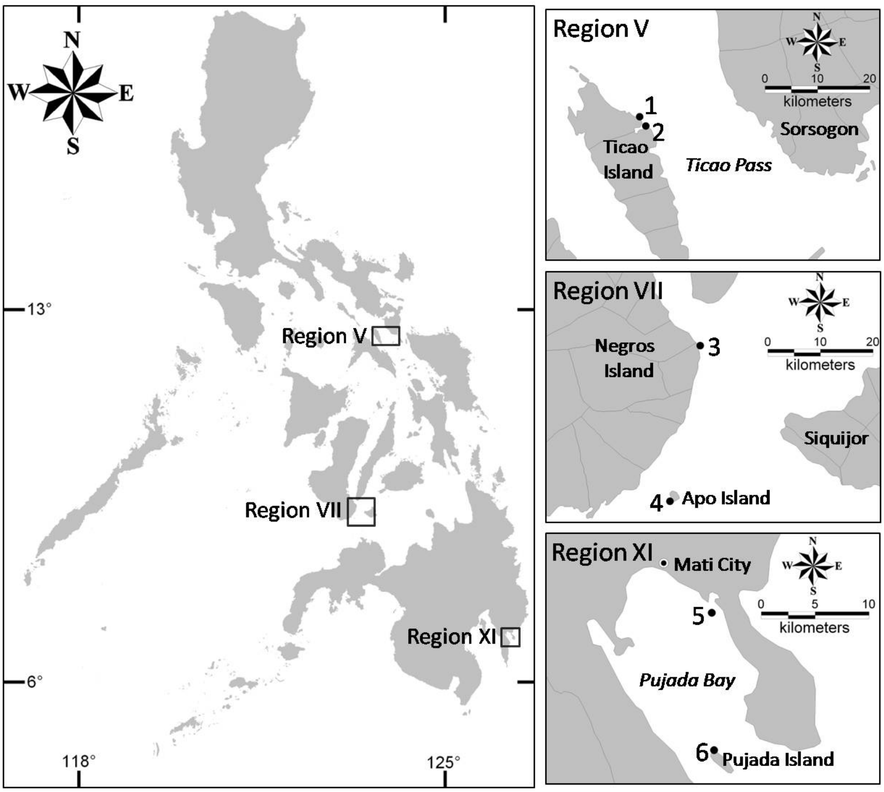

Fig. 1. Maps showing location of coral sampling stations. Region V (Ticao Island) – (1) Baladingan, (2) Tacdogan; Region VII – (3) Dumaguete, (4) Apo I.; Region XI (Pujada Bay) – (5) Guang-guang, and (6) Pujada I.

30° at 6-10 m deep. Coral growths are most abundant at shallower depths around 3-7 m. During low tide, the tidal flat is completely exposed (Jimenez *et al.* 2002). Water visibility is good exceeding 15 m. Pujada Bay is one of the major fishing grounds in the region (Jimenez *et al.* 2002). Gleaning for molluscs and sea urchins is also a common practice in the intertidal area in Guang-guang. Illegal fishing and unsound upland practices have been reported to threaten the marine ecosystems within the bay (Jimenez *et al.* 2002). In Gguang-guang, transects were established in the reef between DENR and the cove in Maitum. The transects in Pujada I. were established in the northern side facing Lawigan.

METHODS

The manta tow technique was conducted to obtain a general description and condition of the site. Line-intercept transect (LIT) method (English *et al.* 1997) was used to determine the benthic cover composition. Five 20-m transects were established in each sampling site within the same locations used in previous surveys. Previous surveys, however, used fewer transects in most sites. Transects were laid at 5-6 m depth in Ticao sites and Bantayan marine sanctuary and at 7-10 m depth in Apo Chapel and Davao Oriental where hard coral growths are concentrated. Species of corals encountered were identified following the descriptions of Veron and Pichon (1976; 1979; 1982), Veron *et al.* (1977), Veron and Wallace (1984), Wallace (1999), Veron (2000), and Fabricius and Alderslade (2001). Reef condition was determined using the four categories of hard coral cover: poor = 0-24.9%, fair = 25-49.9%, good = 50-74.9%, excellent =75-100% (Gomez, 1991). Reef quality assessment indices (i.e. condition, development, and succession of algae and other fauna) developed by Manthachitra (1994) and mortality index developed by Gomez *et al.* (1994) were further applied to provide a broader perspective of the actual reef condition. These indices allow for a more appropriate analysis as coral cover data alone may be misleading. Undisturbed coral communities may yield a low coral cover because certain large areas of the reef are unavailable or unsuitable for coral growth (Gomez *et al.* 1994).

The assessment indices used the formulae:

Condition index indicates the condition of coral reef assemblage,
$CI = log\ (LC/DRC)$

Development index indicates the degree of coral reef assemblage development, $DI = log\ (CRC/ARC)$

Succession index for algae indicates the level of succession by algae, *SI I = log [ALGAE/(DC + OT)]*

Succession index for others indicates the level of succession by other fauna, *SI II = log [OT/(DC + ALGAE)]*

where *LC* = live hard coral, *ALGAE* = algal assemblage + turf algae + macroalgae + coralline algae, *DC* = dead coral + dead coral with algae, *DRC* (dead coral related components) = DC + ALGAE + others including soft corals (OT) that only colonize dead corals, *ARC* (abiotic related components) = rubble + rock + sand + ALGAE + other fauna that do not colonize on coral component, and *CRC* (coral related components) = LC + DC + OT + ALGAE that only colonize live and/or dead corals.

The qualities for these indices are based on the following scale: very poor = < -0.602, poor = -0.602 to -0.176, fair = -0.175 to 0.176, good = 0.177 to 0.602 and very good = > 0.602.

Mortality index, *MI* = dead coral cover / (live + dead coral cover)

Mortality index is gauged on its nearness to the value 1 such that the closer the value index to 1, the higher would be the theoretical mortality.

The Shannon-Weiner Index for diversity and Simpson's Index for dominance (Odum, 1971) were calculated to further describe the coral community. Measurements and counts limited only to colonies found under the transects. Rogers *et al.* (1983) and Arif Zainul Fuad (2010) used the same method in calculating species diversity in U.S. Virgin Islands and Bunaken National Park, Indonesia, respectively. Transect methods to assess coral diversity were also discussed by Beenaerts and Vanden Berghe (2005). Although this underestimates the actual value of the community compared to belt-transects (Nakajima *et al.* 2010), the LIT data was used due to time and effort constraints. Since we are using permanent transects, this will allow comparisons over time for the same areas. These indices were not calculated in the previous surveys due to insufficient information.

Simpson's Index of Dominance, $c = \Sigma(ni/N)^2$,
where ni = importance value for each species (number of individual), and N = total importance of values

Shannon-Weiner Diversity Index, $H' = - \Sigma Pi \log Pi$,
where Pi = importance probability for each species = ni/N

Relative composition of coral growth forms from cover data was also generated for all years at each site to determine changes apart from overall hard coral cover.

Rugosity was measured using a modified version of the Chain method of Hill and Wilkinson (2004) wherein a second tape was laid on the upper contour of the reef within the 20 m transect used for LIT. Rugosity was calculated as the length of tape used per 20-m transect. A rugosity index of 1 would mean a perfectly flat surface, with larger numbers signifying a greater degree of architectural complexity (Alvarez-Filip *et al.* 2009).

Analysis of data was conducted using appropriate statistical tools. Prior to analysis, percentage data were log-transformed (https://www.ndsu.edu/ndsu/horsley/Transfrm.pdf; http://www.graphpad.com) and tested for normality using Kolmogrov-Smirnov Test, and variance homogeneity using Bartlett's Test. One-way ANOVA F test was employed to determine significant differences between substrate categories or between more than two time periods. For data sets that show normal distribution but violate the assumption for homogeneity of variance, Welch's ANOVA (Welch's F) was used. Post-hoc analysis was carried out to further investigate differences between groups. Depending on the variance and sample size, Tukey's HSD was analyzed for data sets with equal variances and sample size, Games Howell for unequal variances and Gabriel's Test for unequal sample size with equal variances. Trend analysis for one way-ANOVA (F) was also applied to detect significance in patterns (Field, 2012). Only the p-values of linear contrast were included in this paper since all quadratic contrasts did not show any significance. Where the assumptions for normality and homogeneity are not met, the non-parametric equivalent Kruskal-Wallis H test was applied using untransformed data. Kruskal-Wallis multiple comparisons test was conducted as a post hoc test while Jonckheere-Terpstra (T_{JT}) test was used to analyze for trends.

To compare differences between the sites or between two time periods, the two-sample t-test was used with the two-tailed Mann-Whitney U test as the non-parametric equivalent. One-tailed Mann-Whitney U Test was used for trend analysis.

Because of the small sample sizes, correlation analysis was applied using Spearman's Rank Correlation Test to determine significant relationships between the number of years of protection and substrate cover. This test was only applied on Apo since data sets were sufficient enough.

Significance level was established at $p<0.05$ for all tests. Minitab 14 and IBM SPSS Statistictics 21 softwares were utilized for the analysis.

Connell's (1997) formula to estimate ecological significance of decline was also used to analyze coral cover. He estimated at least 33% decrease from the initial cover as a threshold to define an ecologically significant decline in coral cover (i.e. ratio of loss in cover to the amount of its original cover). Significance for recovery was not used as it cannot be applied on the available data sets.

Collection of data was carried out in October 2009 and June 2013 in Ticao, Masbate. In Negros, Bantayan data were obtained in December 1995, January 2009 and October 2013 while Apo data were taken in April 1999, April 2000, April 2003, July 2004, April 2005, May 2006, June 2007 and October 2013. In Davao Oriental, data collection was conducted in December 2010 and May 2013.

RESULTS

Region V.

Benchmark vs. Current Data. The LIT survey conducted in southern side of Baladingan indicated an increasing trend in hard coral cover over a 5-year period (U, $p=0.004$, 1-tailed). Hard coral cover significantly differed between 2009, with poor cover (13.8$\pm$4.4%), and 2013, with fair cover (33.3$\pm$3.3%) (U, $p=0.009$, 2-tailed). No significant difference between the study periods was detected in other categories. Similarly, cover of sand showed no significant difference between 2009 at 51.5$\pm$8.4% and 2013 at 30$\pm$ 3.9% (t, $p=0.157$), but pattern of decrease proved to be significant with time. Rock, the second dominant abiotic component, remained almost constant at 19.7$\pm$3.4% and 18.9$\pm$2.6%, respectively (Fig. 2). Within each study period, sand dominated the substrate in 2009 (H, p=0.000) but was equally dominant with hard corals in 2013 (F, p=0.000). Cover of dead corals, soft corals, other fauna, algae and rubble fell to $\leq$ 8%.

Among hard corals, massive forms dominated the cover composition in both periods accounting for $\geq$69%. *Acropora* was reduced from 9 to 2% (Fig. 3).

Comparison of Current Data. In terms of species composition, Baladingan recorded a higher number of 120 hard coral species (118 scleractinia, two non-scleractinia) than Tacdogan with 111 (107 scleractinia, four non-scleractinia) (Table 1). However, from transects, Baladingan showed a lower diversity index in terms of percent cover (H'=2.74) and colony counts (H'=3.20). Consequently, index of dominance was higher (c=0.18) with *Porites lobata* as the most dominant species (13.65±2.42% cover at c=0.17; 51 colonies at c=0.08). Generally, massive corals account for almost 75% (or 24.4±3.28% cover) of the total live hard coral cover. In Tacdogan, massive (15.05±2.92%) (e.g. *P. lobata* - 4.6±1.49% at c=0.02, *P. lutea* - 4.65±2.37% at c=0.02) and branching (10.6±5.54%) (e.g. *Montipora cactus* - 4.4±4.39% at c=0.02 and *P. nigrescens* - 3.7±1.40% at c=0.01) forms were most dominant in cover (Table 2). Except for *M. cactus* (2 colonies at c=0.00), these species

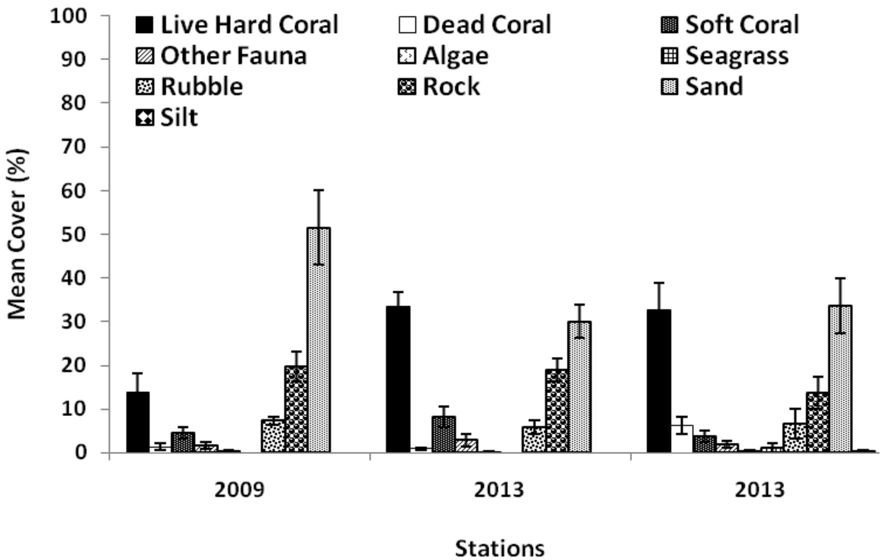

Fig. 2. Mean percent cover of substrate categories in Ticao I. Data for 2009 from Reboton and Candido (2014; n=6); 2013 (n=5).

Table 1. Number of species and indices of dominance (c) and diversity (H') based on colony cover and counts in the surveyed sites in 2013.

		General	Based on Transects					
Sites	Stations	Total No. Species	No. Species	No. Colonies	%Cover		%Counts	
					c	H'	c	H'
REGION V MASBATE	Baladingan	120	56	182	0.18	2.74	0.10	3.20
	Tacdogan	111	51	157	0.08	3.08	0.07	3.24
REGION VII NEGROS ORIENTAL	Bantayan	53	18	56	0.38	1.59	0.15	2.29
	Apo Chapel	121	51	198	0.16	2.54	0.12	2.91
REGION XI DAVAO ORIENTAL	Guang-guang	42	12	109	0.78	0.57	0.58	1.03
	Pujada I.	27	11	118	0.69	0.76	0.56	1.08

were also numerically and almost equally abundant (*P. lobata* - 21 colonies at c=0.02, *P. lutea* - 25 colonies at c=0.03, *P. nigrescens* - 22 colonies at c=0.02). Four genera of soft corals were also noted. Table 3 shows the list of species identified.

Current survey revealed that there is no reef around Ticao that can be categorized under good. Broad observation using manta tow revealed similar condition of hard coral cover (23±5.1%) with Tacdogan (28.6±1.9%). Sand dominated in Tacdogan (40±4.5%) while sand, rubble and rock occupied the same percentages with hard corals in Baladingan (≥20%).

Detailed survey (using LIT) of the selected locations also showed similar hard coral cover at 33.3±3.3% in the south of Baladingan and 32.7±6.2% in the east of Tacdogan (t, p=0.763) (Fig. 2). The latter station was found to be more rugose with an index of 1.25±0.06 while the former only had an index of 1.18±0.02 (Table 4).

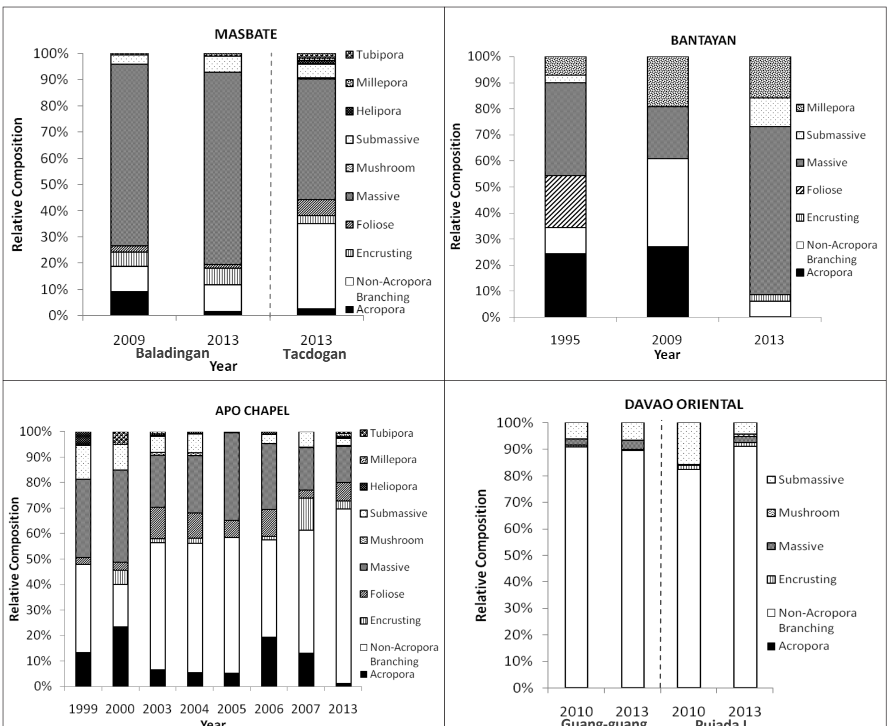

Fig. 3. Relative composition of hard coral growth forms based on cover.

Both areas also showed similar covers of rock (18.9±2.6% and

13.6±3.6%) (t, p=0.157) and sand (30±3.9% and 33.6±6.4%) (t, p=0.780). Cover of other components also did not vary between the stations but were significantly lower than hard corals, rock and sand (Baladingan: F, p=0.000; Tacdogan: H, p=0.000) (Fig. 2). Post-hoc analysis showed that the covers between the latter three categories were statistically similar in these sites. The only significant difference between stations was the higher cover of dead corals in Tacdogan (6.2±2% vs. 0.9±0.3%) (t, p=0.006) resulting in a higher mortality index. Generally, the areas had good condition indices but poor reef development indices (Table 5).

Table 2. Mean percent cover of hard coral growth forms in the surveyed sites in 2013.

BENTHIC CATEGORIES	REGION V MASBATE				REGION VII NEGROS ORIENTAL				REGION XI DAVAO ORIENTAL			
	Baladingan		Tacdogan		Bantayan		Apo Is.		Guang-Guang		Pujada Is.	
	Mean	±S.E.	Mean	±S.E.	Mean	±S.E.	Mean	±S.E.	Mean	±S.E.	Mean	±S.E.
LIVE HARD CORALS Screlactinia *Acropora* Branching	0.10	0.10					0.35	0.35				
Corymbose	0.25	0.11	0.40	0.29			0.30	0.30	0.10	0.10		
Encrusting							0.04	0.04				
Submassive			0.40	0.40								
Table	0.15	0.15										
Total Acropora	0.50	0.18	0.80	0.41			0.69	0.64	0.10	0.10		
Non-*Acropora* Branching	3.35	0.87	10.60	5.54	1.20	0.96	40.43	5.11	37.50	5.60	36.62	5.89
Encrusting	2.15	0.87	1.05	0.61	0.50	0.39	2.44	0.73	0.20	0.20	0.50	0.22
Foliose	0.50	0.21	2.00	1.17			3.55	3.13				
Massive	24.40	3.28	15.05	2.92	12.90	6.67	8.41	1.55	1.40	0.70	1.00	0.49
Mushroom			0.15	0.15			0.20	0.20			0.30	0.30
Submassive	2.05	0.95	1.65	0.53	2.20	1.16	1.60	0.86	2.85	2.85	1.80	0.60
Total Non-*Acropora*	32.45	3.11	30.50	5.57	16.80	8.66	56.63	6.35	41.95	3.47	40.22	6.23
Total Scleractinia	32.95	3.06	31.30	6.30	16.80	8.66	57.32	6.76	42.05	3.40	40.22	6.23
Non-Scleractinia *Heliopora*			0.50	0.50			0.46	0.35				
Millepora			0.30	0.30	3.20	1.62	0.70	0.70				

Tubipora	0.40	0.40	0.60	0.40			0.45	0.28				
Total Non-Scleractinia	0.40	0.40	1.40	0.43	3.20	1.62	1.61	0.92				
Total Live Hard Corals	33.35	3.31	32.70	6.17	20.00	9.86	58.93	7.21	42.05	3.40	40.22	6.23

Region VII.

Benchmark vs. Current Data. Hard coral cover in Bantayan marine sanctuary has been consistently poor without any significant difference between the years at 17.5±15% in 1995, 26.9±4.69% in 2009 and 20±9.9% in 2013 (H, p=0.668). A loss of 7% between 2009-2013 indicates the decline to be ecologically non-significant (25.7%). Dead corals, algae, rubble and rock apparently increased from 2.8±2.8% to 7±3.9%, 0.2±0.2% to 11.7±3.1%, 7.2±1.2% to 12.7±3.5% and 1.5±1.5% to 17±4% , respectively (Fig. 4). Except for algae, (Welch's F, p=0.004), statistical analysis revealed these differences to be non-significant (H, p=0.447; F, p=0.396; F, p=0.133, respectively). Cover of bare sand significantly decreased from 46.2± 5.8% to 13.9±1.6% (F, p=0.002). Seagrass cover also lowered from 23.8± 12.2% to 16.8±10.6%, with much lower cover in 2009 at 4.7± 3.7%, but values did not significantly differ (H, p=0.331). Trend analysis further indicates that algal and sand cover significantly increased (*F*, p=0.002) and decreased (*F*, p=0.001), respectively, with time. Within each study period, cover of substrate categories differed significantly in 1995 (F, p=0.026) and in 2009 (H, p=0.000) but not in 2013 (H, p=0.174). In 1995, sand dominated the substrate but towards 2013, all substrate components have not significantly varied.

Initially, hard coral composition was dominated by massive corals at 36% followed by *Acropora* and foliose forms at ≥20%. In 2009, *Acropora* and non-*Acropora* branching types dominated among the hard corals at 27-34% while massive forms only accounted for 20%. An increase in the relative cover of *Millepora* from 7 to 19% while the disappearance of foliose corals were noted. In 2013, massive corals predominated over the other growth forms at 64%. Composition of *Millepora* only slightly decreased to 16% while submassive types increased to 11% from 0-3% in the previous years. *Acropora* corals disappeared while non-*Acropora* branching forms were greatly reduced to 6% (Fig. 3).

Table 3. List of coral species in the surveyed sites. BAL = Baladingan, TAC = Tacdogan, BAN = Bantayan, APO = Apo Chapel, GUA = Guang-guang, PUJ = Pujada I. X indicates presence.

SPECIES	BAL	TAC	BAN	APO	GUA	PUJ	SPECIES	BAL	TAC	BAN	APO	GUA	PUJ
HARD CORALS: ORDER SCLERACTINIA **I. FAMILY ACROPORIDAE**													
Acropora aspera	X						*Acropora yongei*		X				
Acropora batunai	X						*Acropora sp.1*	X					
Acropora brueggemanni		X	X				*Acropora sp.2*		X				
Acropora cerealis					X		*Astreopora expansa*		X				
Acropora convexa		X					*Astreopora myriophthalma*	X	X		X		X
Acropora divaricata					X		*Montipora cactus*		X		X		
Acropora exquisita	X						*Montipora efflorescens*				X		
Acropora florida		X					*Montipora cf. floweri*				X		
Acropora gemmifera				X			*Montipora grisea*		X	X	X		
Acropora grandis		X					*Montipora hoffmeisteri*				X		
Acropora hoeksemai	X						*Montipora incrassata*				X		
Acropora humilis	X		X				*Montipora informis*	X	X		X		
Acropora hyacinthus	X						*Montipora malampaya*	X	X				
Acropora indonesia	X			X			*Montipora monasteriata*						X
Acropora inermis				X			*Montipora peltiformis*				X	X	

Acropora insignis	X	X			X
Acropora intermedia		X			
Acropora kimbeensis				X	
Acropora latistella					X
Acropora loripes	X	X		X	
Acropora microphthalma	X				
Acropora nasuta					X
Acropora palifera	X	X	X		
Acropora parilis		X			
Acropora proximalis				X	
Acropora pulchra		X			
Acropora recruit				X	
Acropora rosaria	X				
Acropora samoensis	X				
Acropora sarmentosa				X	
Acropora secale	X	X			
Acropora selago	X	X			
Acropora subglabra					X
Acropora tenuis	X	X		X	
Acropora valenciennesi		X			
Acropora valida	X	X			X

Montipora spongodes	X	X				
Montipora stellata	X	X				
Montipora tuberculosa	X			X		
Montipora turgescens	X			X		
II. FAMILY AGARICIIDAE						
Coeloseris mayeri	X	X	X	X		
Gardineroseris planulata	X	X	X	X		
Leptoseris incrustans				X		
Leptoseris mycetoseroides	X		X			
Leptoseris scabra				X		
Leptoseris yabei					X	
Pachyseris rugosa	X	X		X	X	X
Pachyseris speciosa					X	
Pavona cactus	X	X			X	
Pavona decussata	X	X				
Pavona explanulata	X		X	X		
Pavona frondifera	X	X				
Pavona varians	X		X	X	X	
Pavona venosa	X		X	X	X	X
III. FAMILY ASTROCOENIIDAE						
Stylocoeniella armata				X		

SPECIES	BAL	TAC	BAN	APO	GUA	PUJ	SPECIES	BAL	TAC	BAN	APO	GUA	PUJ
IV. FAMILY CARYOPHYLLIDAE													
Euphyllia ancora	X	X		X			*Favites sp.*	X					
Euphyllia cristata		X		X			*Goniastrea aspera*	X	X		X		
Euphyllia glabrescens	X	X		X			*Goniastrea australensis*		X				
Physogyra lichtensteini		X			X		*Goniastrea edwardsi*			X	X	X	X
Plerogyra sinuosa	X	X		X			*Goniastrea minuta*		X				
V. FAMILY DENDROPHYLLIDAE							*Goniastrea pectinata*	X	X		X		X
Turbinaria frondens	X	X		X			*Goniastrea retiformis*	X		X	X	X	
Turbinaria mesenterina	X	X		X			*Leptastrea purpurea*	X	X	X	X	X	
Turbinaria peltata	X	X		X			*Leptoria phrygia*				X		
Turbinaria reniformis				X	X		*Montastrea colemani*	X	X		X		X
Turbinaria stellulata	X	X		X			*Montastrea curta*			X	X		
VI. FAMILY FAVIIDAE							*Montastrea magnistellata*		X				
Caulastrea tumida	X						*Montastrea salebrosa*	X					
Cyphastrea chalcidicum				X			*Montastrea valenciennesi*	X	X	X	X		
Cyphastrea microphthalma	X	X		X		X	*Oulastrea crispata*		X				
Cyphastrea serailia	X	X	X	X			*Oulophyllia crispa*			X	X		
Diploastrea heliopora	X	X	X	X			*Oulophyllia bennettae*			X			
Echinopora gemmacea	X						*Platygyra acuta*	X	X	X	X		

Echinopora horrida						X	*Platygyra daedalia*	X	X	X	X		
Echinopora lamellosa	X	X	X	X			*Platygyra lamellina*	X	X				
Echinopora pacificus	X			X			*Platygyra pini*	X	X	X	X		
Favia danae		X					*Platygyra ryukyuensis*	X					
Favia favus	X	X	X	X			*Platygyra sinensis*	X	X	X	X		
Favia lizardensis				X			*Platygyra verweyi*	X			X		
Favia matthaii	X		X	X			*Platygyra yaeyamaensis*				X		
Favia pallida	X	X	X	X			*Plesiastrea versipora*	X					
Favia rotundata	X	X					**VII. FAMILY FUNGIIDAE**						
Favia speciosa		X		X			*Cycloseris costulata*	X					
Favia truncatus	X	X		X	X		*Cycloseris cyclolites*	X					
Favites flexuosa				X			*Cycloseris patelliformis*		X		X		
Favia vietnamensis	X	X					*Cycloseris vaughani*				X		
Favites abdita	X	X	X	X			*Ctenactic crassa*		X		X		X
Favites acuticollis	X						*Ctenactic echinata*	X	X			X	X
Favites chinensis				X			*Fungia danai*					X	
Favites halicora	X	X	X				*Fungia fungites*	X	X	X	X		
Favites micropentagona				X			*Fungia paumotensis*	X	X		X	X	
Favites pentagona	X		X		X		*Fungia repanda*		X		X		X
Favites stylifere				X			*Fungia cf. scabra*				X		

SPECIES	BAL	TAC	BAN	APO	GUA	PUJ	SPECIES	BAL	TAC	BAN	APO	GUA	PUJ
Fungia scutaria				X			*Pocillopora eydouxi*			X			
Halomitra pileus				X			*Pocillopora meandrina*				X		
Heliofungia actiniformis						X	*Pocillopora verrucosa*	X	X	X	X	X	X
Herpolitha limax	X	X				X	*Seriatopora caliendrum*	X	X			X	
Herpolitha weberi		X				X	*Seriatopora hystrix*	X	X	X		X	
Lithophyllon lobata					X		*Stylophora pistillata*	X	X	X		X	
Lithophyllon mokai				X			**XIII. FAMILY PORITIDAE**						
Litophyllon undulatum	X	X		X			*Alveopora catalai*				X		
Podabacia crustacea	X						*Alveopora cf. spongiosa*			X			
Polyphyllia talpina	X	X					*Alveopora tizardi*				X		
Sandalolitha dentata				X			*Goniopora cf. burgosi*		X		X		
Sandalolitha robusta	X	X				X	*Goniopora columna*				X		
VIII. FAMILY MERULINIDAE							*Goniopora djiboutienis*	X	X		X		
Hydnophora exesa	X	X	X				*Goniopora fruticosa*				X		
Hydnophora microconos	X		X				*Goniopora minor*	X	X				
Hydnophora pilosa		X					*Goniopora norfolkensis*			X			
Hydnophora rigida	X		X	X			*Goniopora sp.1*				X		
Merulina ampliata	X	X		X			*Goniopora sp.2*			X			
Merulina scrabicula	X	X	X	X			*Goniopora tenuidens*	X	X	X			

IX. FAMILY MUSSIDAE						
Acanthastrea subechinata	X					
Lobophyllia corymbosa		X		X		
Lobophyllia flabelliformis	X					
Lobophyllia hemprichii	X	X	X	X		
Lobophyllia serratus			X			
Symphyllia radians	X			X		
Symphyllia recta		X				
X. FAMILY OCULINIDAE						
Galaxea fascicularis	X	X	X	X	X	X
Galaxea horrescens				X		
XI. FAMILY PECTINIIDAE						
Echinophyllia orpheensis				X	X	
Mycedium elephantotus	X	X				
Oxypora lacera				X		
Pectinia lactuca	X			X		
Pectinia paeonia	X	X		X		
XII. FAMILY POCILLOPORIDAE						
Pocillopora damicornis	X	X	X	X		

Porites annae	X			X		
Porites cf. annae				X		
Porites attenuata	X			X		X
Porites australensis	X	X			X	
Porites cylindrica	X	X	X	X	X	X
Porites latistella						X
Porites lobata	X	X	X	X	X	X
Porites lutea	X	X		X	X	
Porites monticulosa					X	X
Porites napopora					X	
Porites negrosensis					X	X
Porites nigrescens	X	X		X	X	X
Porites cf. rugosa				X		
Porites rus	X	X		X	X	X
Porites solida	X	X		X	X	
Porites sp.		X				
Porites tuberculosa				X	X	
Porites vaughani	X					

SPECIES	BAL	TAC	BAN	APO	GUA	PUJ
XIV. FAMILY SIDERASTREIDAE						
Coscinaraea exesa	X					
Psammocora contigua			X			
Psammocora obtusangula				X		
Psammocora profundacella	X	X		X	X	X
Psammocora superficialis				X		
XV. FAMILY TRACHYPHYLLIDAE						
Trachyphyllia geoffroyi		X				
Total	118	107	50	118	42	27
ORDER COENOTHECALIA I. FAMILY HELIOPORIDAE						
Heliopora coerulea		X		X		
ORDER MILLEPORINA: II. FAMILY MILLEPORIDAE						
Millepora exaesa			X			
Millepora platyphyllia	X	X	X			
Millepora sp. (CB)		X	X	X		

SPECIES	BAL	TAC	BAN	APO	GUA	PUJ
ORDER STOLONIFERA III. FAMILY TUBIPORIDAE						
Tubipora musica	X	X		X		
Total	2	4	3	3		
TOTAL HARD CORAL SPECIES	120	111	53	121	42	27
SOFT CORALS: ORDER ALCYONACEA						
Briareum				X		
Lemnalia				X		
Lobophytum	X		X	X		
Nephthea	X	X	X	X		
Sarcophyton			X	X		X
Sinularia	X	X	X	X	X	X
Xenia	X	X			X	
TOTAL SOFT CORAL GENERA	4	3	4	6	2	2

Table 4. Rugosity index in the surveyed sites in 2013.

Sites	Stations	Rugosity Range	Average Rugosity ±S.E.
REGION V MASBATE	Baladingan	1.14-1.24	1.18 ± 0.02
	Tacdogan	1.15-1.39	1.25 ± 0.06
REGION VII NEROS ORIENTAL	Bantayan	1.04-1.50	1.27 ± 0.09
	Apo I.	1.30-1.71	1.45 ± 0.07
REGION XI DAVAO ORIENTAL	Guang-Guang	1.18-1.57	1.40 ± 0.07
	Pujada I.	1.29-1.43	1.37 ± 0.02

Table 5. Theoretical Mortality Index (MI) and index quality for Condition (CI), Development (DI), Succession by Algae (SI I) and Other Fauna (SI II) in three surveyed reef sites using the Manthachitra Index (1994). Quality of index: VP = very poor, P = poor, F = fair, G = good, VG = very good.

Sites	Stations	MI	CI	DI	SI I	SI II
MASBATE	Baladingan	0.025	1.594 (VG)	-0.284 (P)	0.000 (F)	
	Tacdogan	0.175	0.682 (VG)	-0.185 (P)	0.000 (F)	-1.336 (VP)
NEGROS ORIENTAL	Bantayan	0.259	0.432 (G)	-0.423 (P)	0.024 (F)	
	Apo I.	0.026	1.158 (VG)	0.244 (G)	-0.032 (F)	-0.150 (F)
DAVAO ORIENTAL	Guang-Guang	0.330	0.302 (G)	0.232 (G)	-0.006 (F)	-1.839 (VP)
	Pujada I.	0.283	0.281 (G)	0.345 (G)	0.018 (F)	-0.933 (VP)

In contrast, an increasing hard coral cover was documented at Apo Chapel. Hard coral cover started to rise from 18.8±7.8% in 1999 to 37±15% in 2003 and remarkably increased in 2005 at 60.4±19.5%. Since then, it has remained stable (Fig. 5). Although the p-value in Welch's ANOVA indicates no significant overall difference between mean coral cover at each year (p=1.50), trend analysis implies a significant linear pattern suggesting that coral cover increased with time (*F*, p=0.010). Dead coral cover was consistently low at less than 2% except in 2003 and 2004 where it increased to 6.2±0.7% and 7.8±2.6%, respectively (H, p=0.016). There was no significant trend observed with time (T_{jt}, p=0.466). The increase in hard coral cover is accompanied by the decline in other categories. Cover of soft corals declined particularly from 1995 to 2007 at 28±22.5% to 9.4±2.4%, respectively, after which it increased to 22.1±2.6% after 6 years. During this time hard coral cover slightly decreased from 69.2±16% to 58.9±7.2% but was not ecologically significant (14.8% or 10.2% loss). Rubble cover significantly dropped from 16.6±10.4% to 2±1.4% (Welch's F, p=0.025) showing a significant negative declining trend with time (*F*, p=0.004). Sand also exhibited a noticeable decrease from 28.4±24.1% to 6.2±4.6% although values did not statistically differ. Between 1999-2000, the substrate consisted mostly of soft corals and sand. Hard corals started to dominate the substrate in 2003, significantly dominating over the other categories by 2007 (H, p=0.028) and 2013 (H, p=0.001).

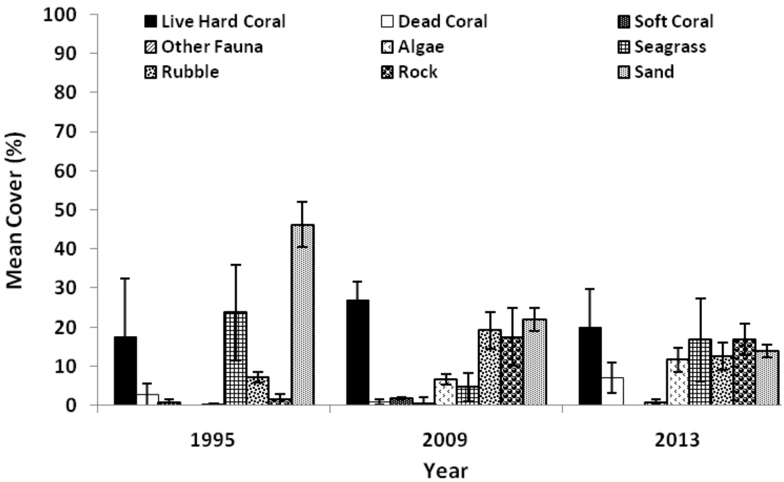

Figure 4. Mean percent cover of substrate categories in Bantayan Data for 1995 from Calumpong et al. (1997; n=2); 2009 from Reboton (2009 n=5); 2013 (n=5).

Spearman's rank correlation analysis further indicates that coral cover and the length of years of protection is significantly and positively correlated (r_s=0.547, p=0.007) (Fig. 6).

Hard coral composition is consistently dominated by non-*Acropora* branching corals from 35 to 69% except in 2000 wherein relative cover decreased to 17% while *Acropora* increased from 13% in 1999 to 23%. *Acropora* decreased in 2003 to 2005 at ≤7%, increasing again in 2006 at 19% but was greatly reduced by 2013 with only 1%. Massive corals ranked second in relative cover throughout the study period although percentages exhibited a decrease from >30% to 14%% (Fig.3).

Comparison of Current Data. The station in Apo Chapel supported a much higher number of 121 hard coral species (118 scleractinia, three non-scleractinia) compared to Bantayan marine sanctuary (Table 1). Bantayan had less than half the number in Apo Chapel with only 53 species (50 scleractinia, three non-scleractinia). Expectedly, diversity index (cover, H'=2.54 and counts, H'=2.91) in Apo Chapel was also higher. Massive

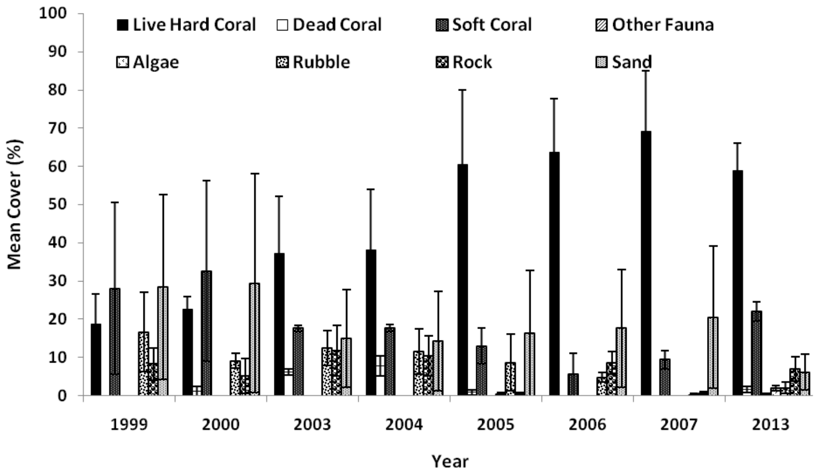

Fig. 5. Mean percent cover of substrate categories in Apo Chapel. Data for 1999-2000 from USAID-SU COE-CRM Project 1999-2000 (n=2); 2003-2007 from UNEP-ICRAN 2003-2007 (n=3); 2013 (n=5).

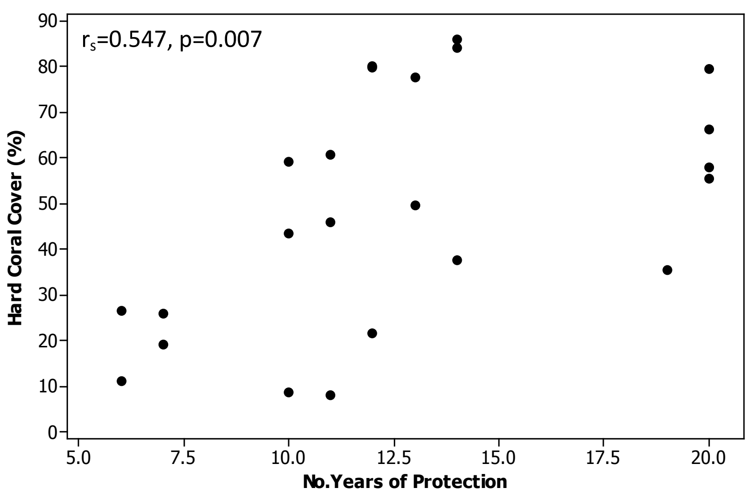

Fig. 6. Scatterplot showing relationship between hard coral cover and the number of years of protection in Apo Chapel.

forms (12.9±6.67% cover or 60% of the total hard coral cover) dominate the coral composition in Bantayan resulting in a higher dominance index (cover, c=0.38 and counts, c=0.15) contributed mostly by *P. lobata* in terms of cover (11.90±6.36% cover at c=0.35) and number of colonies (11 colonies at c=0.04). Smaller submassive *Pocillopora verrucosa* (16 colonies at c=0.08) and fire coral *Millepora platyphyllia* (7 colonies at c=0.02) colonies were also numerically abundant. In Apo Chapel, branching corals (40.43±5.11% cover or 69% of the total hard coral cover) were the most dominant growth form, particularly *Porites nigrescens* (16.89±3.84% cover at c=0.08 and 56 colonies at c=0.08) and *P. cylindrica* (14.65±4.26% cover at c=0.06 and 30 colonies at c=0.02) (Table 2). Massive *P. lobata*, submassive/encrusting *Pavona varians* and branching *Montipora cactus* were also common in terms of colony number, though less abundant. Four soft coral genera were listed in Bantayan and six in Apo Chapel.

Manta tow survey revealed a poor hard coral cover of only 8±2.1% in Bantayan while a greater portion of the area is occupied by rubble (23.5±7.2%), seagrasses (23.8±9.4%) and algae (36.1±8.6%). Apo Chapel, on the contrary, showed better hard coral growths at 33.3±15.9% with 47.5±12.5% recorded from deeper area. Soft corals and sand also contributed a relatively high percentage with 26.2±8.7% and 20±15.2%, respectively.

Results of the LIT further confirmed that Apo Chapel had a significantly higher hard coral cover at 58.9±7.2% compared to Bantayan marine sanctuary which only had 20±9.9% (U, p=0.016, 2-tailed) (Figs. 4-5). Moreover, it is more structurally complex (1.4±0.1) than the latter (1.3±0.1) (Table 4). Algae and rubble only covered 2% in Apo Chapel while contributing more than 11% in Bantayan (t, p=0.009 and t, p=0.020, respectively). Seagrasses were absent in Apo Chapel. Cover of dead corals was also higher in Bantayan (7±3.9% vs. 1.6±0.8%) while soft corals, dominated by *Briareum* spp. (12.6±2%), comprised a relatively high percentage in Apo Chapel (22.1±2.6%). Soft coral cover appeared to be naturally low in Bantayan with only <2% in 1995-2009 and none was recorded in 2013. Bantayan showed a higher mortality index compared to Apo Chapel (Table 5). Reef condition in both sites was generally good. However, development index was poor in Bantayan while good in Apo Chapel.

Region XI.

Benchmark vs. Current Data. In Guang-guang, hard coral and dead coral cover appeared to increase from 2010 to 2013 (27.2±10.2% to 42±3.4% and 7.5±4% to 20.7±4.4%, respectively) (Fig. 7). In reverse, covers of abiotic components were found to have lowered especially sand (21. ±1.2% to 10.4±2.4%) and rock (18.5±7.9% to 4.9±3%). Statistically, these differences were not significant (U, p=0.143, 2-tailed; t, p=0.178; t, p=0.054, respectively) except for rock (t, p=0.046). Trend analysis, however, showed significance in pattern with time for sand (U, p=0.018, 1-tailed) but not for rock (U, p=0.071, 1-tailed), hard corals (U, p=0.071, 1-tailed) and dead corals (U, p=0.071, 1-tailed). Within time periods, hard coral cover dominated significantly from soft corals (0.2±0.2%) and silt (1.6±1.6%) (F, p=0.000) in 2010 and over all the other components in 2013 (H, p=0.000).

In comparison, the northern side of Pujada I. showed a significant decrease in hard coral cover over the 4-year period (U, p=0.018, 1-tailed) with higher hard coral cover recorded in 2010 (74.8±2.5%) compared to 2013 (40.2±6.2%) (t, p=0.012). On the other hand, other fauna (0.7±0.4% vs. 4.9±1.6%) (t, p=0.028), algae (1.2±0.9% vs. 10.7±1.3%) (t, p=0.050) and rubble (1.7±0.6% vs. 25.2±3%) (U, p=0.036, 2-tailed) exhibited an opposite pattern with significant trend p-values (U, p=0.036, p=0.018, p=0.018, 1-tailed, respectively) (Fig. 7). Hard corals significantly dominated the substrate in 2010 (H, p=0.032) while in 2013, values did not differ statistically from dead corals and rubble except from the rest of the categories (Welch's F, p=0.000). Ecologically, the decline in hard coral cover was also significant (46.3% or 34.6% loss).

Hard coral composition in both sites was dominated by branching corals (82-91%) during the study periods (Fig. 3).

Comparison of Current Data. Forty-two hard coral species were recorded from Guang-guang whereas the northern side of Pujada I. only had 27 species (Table 1). However, higher diversity index for both cover (H'=0.76) and counts (H'=1.08) were obtained in Pujada I. Consequently, index of dominance (c=0.78 and c=0.58, respectively) was higher in Guang-guang with branching *P. cylindrica* as the dominant species (36.90±5.75% cover at c=0.77; 82 colonies at c=0.57) constituting 88% of the total hard coral cover. *Porites cylindrica* was also abundant in Pujada

I. (33.12±6.23% at c=0.68; 87 colonies at c=0.54) accounting for 82% of the hard coral cover. Other numerically common but less abundant species were *P. rus* in both stations and *P. nigrescens* in Pujada I. Total percentages of branching corals in these stations were 37.5±5.6% and 36.6±5.9%, respectively. Two soft coral genera were noted from each station.

Manta tow survey revealed that almost half of the area in Guang-guang is occupied by sand at 47.2±3.3% while hard corals covered only 27.2±5.4%. Pujada, on the other hand, showed better coral growths at 47.4±9.9% with smaller sandy patches occupying 16.4±2.4%. The tow which was conducted in a west to east direction showed a change in coral composition, from an area that is primarily reef and dominated by branching *Porites* to an extensive seagrass bed, 30.4±11.6%, frequently interspersed by large coral patches dominated by massive *Porites*. At the transition zone, these forms are almost equally abundant.

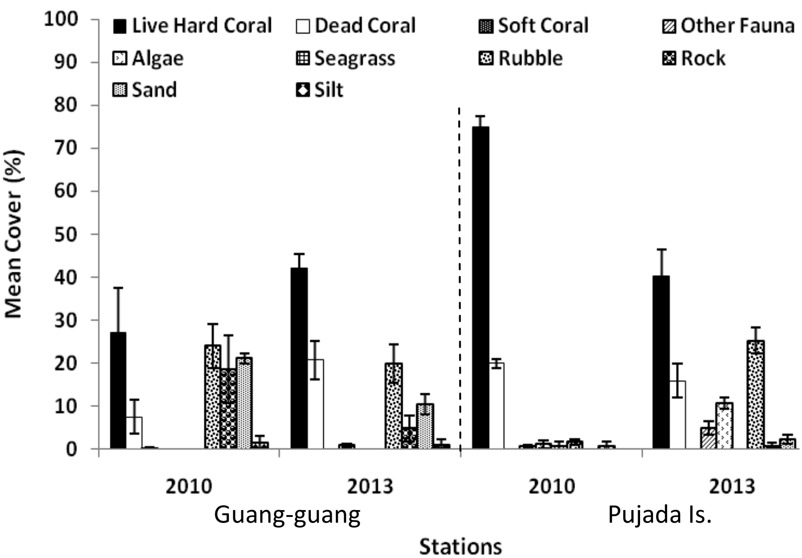

Fig. 7. Mean percent cover of substrate categories in Davao Oriental. Data for 2010 from DENR-ICRMP (2010; n=3); 2013 (n=5).

Survey by LIT revealed that the current hard coral cover did not significantly differ between Guang-guang (42±3.4%) and the north of Pujada I. (40.2±6.2%) (t, p=0.667) (Fig. 7). Reef complexity was slightly higher in Guang-guang at 1.4±0.1 than Pujada, 1.4±0 (Table 4). In Pujada, calcareous algae, *Halimeda* (7%), as well as, algal assemblage, turf- and macroalgae have been found growing between branches of some live and dead colonies of *P. cylindrica*. Dead corals (20.7±4.4%) and rubble (19.9±4.5%) in Guang-guang were not significantly different from Pujada (15.9±4% and 25.2±3%, respectively) (t, p=0.516 and t, p=0.245, respectively), both of which accounted for almost half the cover of live corals. Stations significantly differed in cover of other fauna which was higher in Pujada (4.2±1.6% vs. 0.9±0.4%) (t, p=0.015) and cover of sand found to be higher in Guang-guang (10.4±2.4% vs. 2.4±0.9%) (t, p=0.017). Mortality index was slightly higher in Guang-guang compared to Pujada (Table 5). Reef condition and development indices were good. Total coral-related components were twice the cover of abiotic-related components.

DISCUSSION

Studies investigating changes in coral communities have mostly cited a declining coral cover trend. These findings have been associated with increasing human activity and recently as a synergistic effect with climate change. Time-series data from the Great Barrier Reef indicated a major decline in hard coral cover over 27 years (28% in 1985 to 13.8% in 2012 or 50.7% loss of the initial cover) with an increasing rate of decline at approximately 1.45% yr^{-1} since 2006 (De'ath *et al.* 2012), similar to Carribean reefs (50% in 1977 to 10% in 2002 or 80% loss, ~1.4 yr^{-1} rate of decline) (Gardner *et al.* 2003). Contrasting processes led to the decline in these reef systems. The Great Barrier reef experienced periodic COT infestation and cyclones but only few losses to bleaching (De'ath *et al.* 2012), while the Carribean reefs suffer from a combination of coral diseases and storms, mass die-off of *Diadema antillarum* resulting in phase shifts from coral to algal-dominance, and more likely from overfishing, sedimentation, temperature stress, habitat destruction and eutrophication (Gardner *et al.* 2003). Although water quality does not directly affect coral cover in the Great Barrier Reef, elevated nutrient run-off and sediment loads from urbanized catchments are already significantly increasing macroalgal cover while diminishing coral species richness and recruitment (De'ath *et al.* 2012). Cleary *et al.* (2014) likewise reported an overall decline in hard coral cover in the Jakarta Bay-Thousand Islands reef system from ~50 to ~60% in 1985 to ~40% in 2011 with significant shifts in coral generic composition. Here, pollution, coral extraction, blastfishing and the bleaching event in 2010 are the major causes of degradation.

Results of this study show contrasting patterns in coral cover changes with significantly increasing trends over time at the south of Baladingan (14 to 33%) and Apo Chapel (19 to 59%), while decreasing in the north side of Pujada I. (75 to 40%). Guang-guang and Bantayan marine sanctuary did not show any change over the study period.

Of these sites, only Apo I. and Pujada Bay have been legally protected as a Protected Landscape and Seascape and Protected Seascape, respectively, for over 20 years. The only contrast was that Apo I. has been strictly protected, with an MPA rating of level 4 as of 2005 (http://www.coast.ph/), which in effect has positively increased the coral cover over years of protection. In contrast, Pujada Bay only reached level 1 (MPA established) up to this day (Dizon *et al.* 2011). Although Mati municipality is part of the PBPS, no sites, including Guang-guang, have reached the requirement for MPA establishment (http://www.mpa.msi. upd.edu.ph/mpa). The Protected Area Management Board has been reported to be non-functional (Dizon *et al.* 2013). Coastal pollution from unmanaged aquaculture and agricultural run-off and mining operations, weak law enforcement, lack of public awareness and destructive fishing are major environmental issues (Jimenez *et al.* 2002; ADB, 2006).

Previous studies have shown that Apo I. suffered from the 1998 and 2010 bleaching events and recently, from the sequential Severe Tropical Storm Washi in 2011 and Super Typhoon Bopha in 2012. Divinagracia (2000) reported that the 1997-1998 El Niño event resulted in coral bleaching that affected 35% (0.37 km^2) of the total reef area (1.06 km^2 to the 60 m isobath). The eastern side where the sanctuary is located is the most impacted with 90% of the dominant massive *Galaxea fascicularis* bleached (Raymundo and Maypa, 2002). Cover dropped from 75.1% in 1995 to 40.2% in 1999 (Calumpong *et al.* 1997; USAID-SU COE-CRM Project 1999-2000). Raymundo (Reef Check 6-year Report) also recorded a drop from 62% during the bleaching period to 40% the following year. Cover rapidly recovered in 2003 at 63% and after the 2010 bleaching event, has declined to 21.1% early in 2011 (Reboton and Rosell, unpublished). Although there was no data specific for Apo Chapel prior to 1999, coral cover in the western side of the island ranged from 15.4% in 1983 (White, 1984 in MCDP, 1985 and Pialago *et al.* 1991) to 35.2%

in 1992 (White and Calumpong, 1992) showing only a difference of 16% from 1999 Chapel data. Unlike the sanctuary, Apo Chapel is dominated by branching *Porites* species. From our study at the sanctuary in 2010 (Reboton and Rosell, unpublished), these species were found to be less susceptible to bleaching although some colonies temporarily developed white spot disease. Between 2007 and 2013, the relative composition of branching *Porites* in Apo Chapel suggests no negative impacts from bleaching. *Porites* species are tolerant to bleaching due to its symbiont *Symbiodinium* C15 and a high concentration of host proteins (Fitt *et al.* 1993; Faxneld, 2011; Tonk *et al.* 2013). In the succeeding years, Apo was struck by typhoons that decimated the eastern side, leaving less than 1% of hard coral cover (Reboton, in DENR, SU-IEMS and CCEFI on-going-project). On the contrary, the western side was sheltered from the typhoons. As shown by the slight decrease in hard coral cover between 2007 and 2013, it may suggest that both El Niño and typhoons generally had very minimal impact on Apo Chapel, except for *Acropora* which are more fragile and highly susceptible to bleaching (Loya *et al.* 2001; Maynard *et al.* 2008; Obura, 2008; Li *et al.* 2011; Putnam *et al.* 2012). These accounts are further reflected by the high structural complexity, low mortality as well as good condition and development qualities of the area. Live coral cover and rugosity are important influential factors to coral reef fish abundance and species diversity (Bell and Galzin, 1984; Nguyen and Phan, 2008; Komyakova *et al.* 2013).

There are no available earlier data that are specific to the sites in Pujada Bay but Jimenez *et al.* (2002) mentioned that about 22% of the reefs exhibit excellent condition, 30% are good, over 20% are fair while 28% are in poor condition. Similar to Apo Chapel, Guang-guang and the north of Pujada I., which are also dominated by branching *Porites,* did not show noticeable signs of bleaching in 2010. Covers were found to be in fair to almost excellent condition. Although, typhoon Bopha has also affected the municipality of Mati in 2012 (PDNA, 2013), the contrasting pattern in coral cover is more likely attributable to the location of the sites. Guang-guang is more protected inside the bay while Pujada I. is likely to suffer the consequences of the typhoons being located at the mouth of the bay that faces the Pacific Ocean. Previous report by Jimenez *et al.* (2002) indicates that Pujada Bay used to be rarely visited by typhoons. Of note, there are also anecdotal reports of dynamite fishing that is more rampant in areas far from the mainland. Altogether, these factors cause a remarkable decline in coral cover (46%). It is expected that with the decrease in hard coral cover, particularly due to physical damage, cover of rubble and algae also increase. Cleary *et al.* (2014) documented similar patterns in Jakarta wherein coral cover decrease was accompanied by the increase in rubble cover. Hughes and Connell (1999) and Kuo *et al.* (2012) also demonstrated that the impact of recurrent typhoons combined with overfishing and the influence of growing human population resulted in macroalgal blooms. Of all the sites surveyed, the sites in Pujada Bay exhibited the highest mortality index. While coral mortalities in Pujada I. could be mostly attributed to mechanical damage due to typhoons and destructive fishing, majority of mortalities in Guang-guang are likely due to elevated siltation associated to high energy disturbances especially that this site fronts the Guang-guang Mangrove Park and Nursery. In Pujada I., rubble cover has significantly increased while the cover of dead standing corals remained stable. In contrast, dead coral cover increased in Guang-guang while no change was observed in the cover of rubble. Despite the robust appearance of *Porites cylindrica* in the latter site, the colonies were actually very fragile. According to Rogers (1990), heavy sedimentation causes coral mortality due to smothering and is further linked with low coral diversity, greater abundance of branching forms and decreased calcification. Nevertheless, dead corals will eventually collapse to rubble. It should also be noted that both areas have the lowest diversity among the sites.

Comparatively, there was no notable change in coral cover in Bantayan for over 19 years, even after experiencing the brunt of the two typhoons. Growing human population in the coastal area and increasing human activity have been a persistent threat in this site. The sanctuary was just recently implemented in 2011, a few months after typhoon Washi, and any signs of improvement are not yet visible. Unlike Apo Chapel, diversity and rugosity indices were low. Coral cover has remained poor as abiotic components comprised the bulk of the substrate, thus the poor development index. The effect of human disturbance and previous storms (e.g. typhoon Frank in 2008) were likely the cause in the decrease in seagrass cover and the increase in algae, rubble and rock covers in 2009. Moreover, foliose corals which are fragile had disappeared. Increase in dead coral cover and significantly in algal cover occurred after the recent bleaching event and the two major typhoons resulting in a high mortality index. These typhoons also caused elevated sedimentation that lasted for weeks. Although coral cover did not change significantly, these disruptions caused a shift in coral composition from finer *Acropora* and branching coral-dominated to more hardy massive coral-dominated habitat. In fact, live *Acropora* colonies were no longer seen in the transects. Massive corals are less susceptible to bleaching because of their high concentration of fluorescent pigment granules, low colony integration and thicker tissues (McClanahan *et al*. 2004). Submassive corals also increased in cover while robust forms of *Millepora* persisted since 2009. Shifts in the coral composition due to warming events in the Arabian Gulf, such as spatial replacement of *Acropora* to *Porites,* was reported by Sheppard *et al*. (2010). The long-term study of Edmunds (2013) in the U.S. Virgin islands and Cleary *et al*. (2014) in Indonesia similarly demonstrated changes in community structure and coral composition associated to environmental stresses.

Meanwhile, Ticao I. is one of the five geographic units in the pacific coast that have been identified as high priority site for conservation (Licuanan *et al.* 2011). Participatory coastal resource assessments rated most coastal habitats around Ticao as fair to good. Unfortunately, weak management of the marine resources, localized population pressure, domestic pollution, coral quarrying, illegal fishing (e.g. dynamite, superlights, cyanide, compressor, Danish seine) pose threats to the coral reefs (GEF Project Executive Summary). The sites in this study are not directly along the path of typhoons, however, they are at greater risk of inundation from probable sea level rise (The World bank in the Philippines, 2012). Moreover, blastfishing is not practiced here but poaching by fishers from different municipalities/barangays is a major concern in Baladingan. Despite the fact that no sanctuary has yet been established, the southern side of Baladingan exhibited an increase in coral cover over the 5-year period. The introduction of the concept of conservation by Silliman University has raised the level of awareness of the community that, at some point, perhaps produced positive impacts to the marine habitats. Massive corals which are more hardy and resilient to mechanical stresses consistently dominated the hard coral composition with >69% relative cover. *Acropora* species which are more delicate and sensitive to increased water temperature may have been reduced by both fishing disturbances and bleaching. Current data shows Tacdogan to exhibit similar conditions except for the higher cover of dead corals and mortality index, and the almost equal dominance of massive and branching forms. While Baladingan is far from the effect of sedimentation, Tacdogan experiences regular bouts of siltation from the nearby river and mangrove forest during ebb tide. The dominant *Porites* and

Montipora species, both of which have small calices, are reportedly tolerant to high sedimentation levels (Rogers, 1990).

Even though sites varied in their hard coral cover, overall, they exhibited good condition, however, poor reef development indices are noted for some where cover of abiotics is relatively high (i.e. Baladingan, Tacdogan, Bantayan). Highest mortalities are observed in sites that experience high anthropogenic and natural pressures (i.e. Guang-guang, Pujada I., Bantayan). Likewise, these areas have the lowest coral diversity. Hutchings *et al.* (2008) suggested that coral diversity is low in low and high disturbance regimes which result in monospecific stands of competitively dominant fast growing species or encrusting algal and coral forms that provide little to structural heterogeneity. The "intermediate disturbance" hypothesis of Connell (1978) states that at the intermediate scales and frequency of disturbance, diversity is higher. Regular wave action and storms are not necessarily detrimental to the overall health of a reef as they clear up space for recolonization by other species (Huston, 1994; Hutchings *et al.* 2008). Connell (1978) clearly explained that at low disturbance levels, the processes of succession will eventually lead to a climax community predominated by fewer species of substantial biomass. Disruption of this state will provide potential space for colonization by opportunistic species. As a result, the assemblage is modified and now consists a combination of climax and opportunistic species, thus increasing the diversity. Such could be the case in Apo Chapel. But at higher disturbance severities and frequencies, the time for recolonization is brief and will allow only a few species that quickly reach maturity to thrive. The resulting community is an assemblage of low diversity (Connell, 1978).

The chance of coral recovery from acute disturbances is higher than chronic disturbances, but is prolonged when the physical environment becomes altered (Connell *et al.* 1997). Changes in the habitat, hence new conditions, may also favor a different larval pool of recruits causing change in species composition and abundances (Hughes and Connell, 1999). According to Johnson and Preece (1992), recovery from disturbance events depend on both large-scale and smaller scale level properties so that even in systems with identical reef state (=coral cover) but with different state variances, the abilities to recover may be dissimilar. For instance, a change in the community structure occurred at the Glovers Atoll due to massive bleaching and hurricane ("Mitch") in 1988 (Mumby, 1999) while lack of recovery from recurrent typhoons (i.e. Allen in 1980 and Gilbert in

1989) was experienced in Jamaica due to the scarcity of herbivores from overfishing, and hence, a prolonged macroalgal bloom. This exemplifies that coral assemblage recovery from natural catastrophes can be hindered by anthropogenic impacts (Hughes and Connell, 1999; Berumen and Pratchett, 2006), or rendered impossible (Stobart *et al.* 2002) leading to phase shifts, i.e. usually a transition from hard coral- to algal- dominance (Berumen and Pratchett, 2006), that are already irreversible (Knowlton, 1992). In the Philippines, dynamited reefs take 38 years to recover to 50% areal cover, but reports on certain reefs with no significant recovery in 9-10 years after blasting imply that this figure may be underestimated (Alcala and Gomez, 1979).

Marine protected areas do not actually provide a refuge from bleaching or typhoons. The differences in species composition determine the susceptibility of the area to the disturbance (Hughes *et al.* 2003; Cote and Darling, 2010) but potential for recovery of colonies that are already under pressure from anthropogenic factors is reduced (Wilkinson *et al.* 1999). Moreover, they protect food webs and key functional groups (e.g. reef constructors, herbivores, and bioeroders) and act as larval sources to facilitate recovery of nearby affected areas (Johnson and Preece, 1992; Hughes *et al.* 2003). At Pescador, Philippines where the reef is within a MPA, recovery from <5% to 45% was observed four years after typhoon "Nitang" (Alcala and Gomez, 1990). Rapid recovery of *Acropora* and massive corals in Florida was also observed within 5 years after decimation by hurricane (Shinn, 1976 in Alcala and Gomez, 1979). A study in Banilad Sanctuary, Dumaguete projected about 4 years of recovery to pre-disturbance cover from a grounding incident (Reboton, 2009). It should be noted that various mechanisms may cause coral mortality over a brief period, and the rate of this routine mortality (due to smothering/abrasion, predation, shading by competitors) are usually high even in the absence of a major disturbance. As such, periodic censuses only provide a snapshot of the actual sequences of events (Hughes and Connell, 1999).

SUMMARY, CONCLUSION AND RECOMMENDATION

Several factors can influence the state of a reef. Results of the study indicate that the level of protection, exposure to natural and anthropogenic factors and species composition influence the reef's condition. Improvement in coral cover can be attributed to strict protection of reef areas such as in the case of Apo I. On the contrary, Bantayan which has not been protected for years showed no improvement at all. The sites in Davao Oriental, though within the Pujada Bay Protected Seascape, do not receive ample protection and combined with the effects of typhoons and sedimentation resulted in coral cover decline and mortalities. The sites in Masbate may be protected from typhoons such that they show improved coral cover yet fishing practices caused some changes in coral composition. In spite of the good condition exhibited by all the sites, the natural makeup of the substrate can also influence the degree of reef development (i.e. high cover of abiotic-related components causes poor degree of development). In addition, coral cover may also be influenced by the composition of species depending on their tolerance to these disturbances.

As the severity and frequency of the impacts of climate change continues to increase, it is therefore important that reefs be protected from human-related destructions in order to improve the well-being of our environment.

The lack of previous and sufficient information in most of the sites surveyed is the limitation of this study such that extensive comparisons cannot be fully achieved. Long-term studies are recommended to fully understand the actual trends in the condition of these reefs.

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REFERENCES

Alcala, A.C. and E.D. Gomez. 1979. Recolonization and growth of hermatypic corals in dynamite-blasted coral reefs in the Central Visayas, Philippines. In: Proceedings of the International Symposium on Marine Biogeography and Evolution in the Southern Hemisphere. Auckland, New Zealand, 17-20 July 1978, 2: 645-661.

Alcala, A.C. and E.D. Gomez. 1990. Recovery of a reef from typhoon damage at Pescador Island, Cebu, Central Visayas, Philippines. In: Proceedings of the First ASEAN Symposium on Southeast Asia Marine Science and Environment

Protection. UNEP Regional Seas Report and Studies, 116: 105-109.

Alvarez-Filip, L., N.K. Dulvy, J.A. Gill, I.M. Cote and A.R. Watkinson. 2009. Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. Proceedings of the Royal Society B, 276: 3019-3025.

Arif Zainul Fuad, M. 2010. Coral reef rugosity and coral biodiversity. Bunaken National Park – North Sulawesi, Indonesia. Master's thesis submitted to the International Institute for Geo-information Science and Earth Observation, Enschede, The Netherlands, 60 p.

Asian Development Bank. 2006. Proposed Loan and Administration of Grant from the Global Environment Facility. Republic of the Philippines: Integrated Coastal Resources Management Project. Report and Recommendation of the President to the Board of Directors, 64p.

Beenaerts, N. and E. Vanden Berghe. 2005. Comparative Study of three transect methods to assess coral cover, richness and diversity. Western Indian Ocean Journal of Marine Science, 4 (1): 29–37.

Bell, J.D. and R. Galzin. 1983. Influence of live coral cover on coral-reef fish communities. Marine Ecology - Progress Series, 15: 265-274.

Berumen, M.L. and M.S. Pratchett. 2006. Recovery without resilience: persistent disturbance and long-term shifts in the structure of fish and coral communities at Tiahura Reef, Moorea. Coral Reefs, 25: 647-653.

Burke, L., E. Selig and M. Spalding, 2002. Reefs At Risk in Southeast Asia. World Resources Institute, 72p.

Calumpong, H.P., J.S. Estacion, M.V. Lepiten, C.E. Acedo (Eds.). 1997. Status of the Coastal Resources of the Negros Oriental Learning Site (Manjuyod to Dauin). Vol.1. Dumaguete City, Philippines: Silliman University Marine Laboratory and the Center of Excellence in Coastal Resources Management, 195 p.

Calumpong, H.P., C. Reboton and P.L. Cadiz. 2005. Tourism Impacts on Apo Island Protected Landscape and Seascape. UPV Journal of Natural Sciences, 10 Supl.: 33-40.

Cleary, D.F.R., A.R.M. Polónia, W. Renema, B.W. Hoeksema, J. Wolstenholme, Y. Tuti and N.J. de Voogd. 2014. Coral reefs next to a major conurbation: a study of temporal change (1985-2011) in coral cover and composition in the reefs of Jakarta, Indonesia. Marine Ecology Progress Series, 501: 89–98.

Connell, J.H. 1997. Disturbance and recovery of coral assemblages. Coral Reefs, 16: S101-S113.

Connell, J.H. 1978. Diversity in tropical rainforests and coral reefs. Science, New Series, 199 (4335): 1302-1310.

Connell, J.H., T.P. Hughes and C.C. Wallace. 1997. A 30-Year Study of Coral Abundance, Recruitment, and Disturbance at Several Scales in Space and Time. Ecological Monographs, 67(4): 461–488.

Conservation International Philippines for the Philippine's National Coral Triangle Initiative (CTI) Coordinating Committee. 2013. Benchmarking MPA performance towards promoting effective management, 12 p.

Coral Reef Monitoring for the Continuing Support for Apo and Bais (USAID-SU COE-CRM Project), 1999-2000.

Cote, I. and E.S. Darling. 2010. Rethinking Ecosystem Resilience in the Face of Climate Change. PLoS Biology, 8 (7): 1-5.

D'Agnes, H., J. Castro, L. D'Agnes and R. Montebon. 2005. Gender Issues within the Population-Environment Nexus in Philippine Coastal Areas. Coastal Management, 33 (4), October-December 2005, 12: 447-458.

De'ath, G., K.E. Fabricius, H. Sweatman and M. Puotinen. 2012. The 27–year decline of coral cover on the Great Barrier Reef and its causes. PNAS, 109 (44): 17995-17999.

Department of Environment and Natural Resources-Integrated Coastal resource Management. 2010. Training of survey methods for the Regional ICRM Centers.

Divinagracia, M.F. 2000. Extent and degree of coral bleaching in selected reefs in Central Visayas. Masters Thesis, Biology Department, Silliman University, Dumaguete City.

Dizon, E., R. Geronimo, and E. Miclat. 2011. Benchmarking of Marine Protected Areas in the Philippines: Understanding the Level of Management Effectiveness of MPAs. Presented during the National Conference on Marine Sciences, Tagaytay City, 19–22 October 2011.

Dizon, E.C., R.C. Geronimo, and R. Quicho Jr. 2013. Benchmarking the management effectiveness of nationally-managed marine protected areas in the Philippines and policy recommendations.Final Report for USAID Coral Triangle Support Partnership (CTSP) and Conservation International – Philippines.

Edmunds, P.J. 2013. Decadal-scale changes in the community structure of coral reefs of St. John, US Virgin Islands. Marine Ecology Progress Series, 489: 107–123.

English, S.A., C.R. Wilkinson and V.J. Baker. 1997. eds. Survey Manual for Tropical Marine Resources 2nd ed. Townsville, Australia: Australian Institute of Marine Science.

Fabricius, K. and P. Alderslade. 2001. Soft Corals and Sea Fans. A comprehensive guide to the tropical shallow water genera of the central-west Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Australia, 264 p.

Faxneld, S. 2011. Coral reefs in the Anthropocene: The effects of stress on coral metabolism and symbiont composition. Ph.D. Dissertation. Department of Systems Ecology, Stockholm University, Sweden.

Field, A. 2012. www.discoveringstatistics.com

Fitt, W.K., O. Pantos, R. Iglesias-Prieto, D.J. Franklin, L.I. Rodrigues, J.M. Torregiani, R. van Woesik, M.P. Lesser, R.D. Gates, O. Hoegh-Guldberg, J.C. Bythell, A. Jatkar, A.G. Grottoli, M. Gomez, P. Fisher and T.C. Lajuenesse. 2009. Response of two species of Indo-Pacific corals, *Porites cylindrica* and *Stylophora pistillata*, to short-term thermal stress: The host does matter in determining the tolerance of corals to bleaching. Journal of Experimental Marine Biology and Ecology, 373(2): 102-110.

Gardner, T.A., I.M. Cote, J.A. Gill, A. Grant, A.R. Watkinson. 2003. Long-Term Region-Wide Declines in Caribbean Corals. Science, New Series, 301 (5635): 958-960.

GEF Project Executive Summary. Integrated Coastal Resources Management Project. http://www.thegef.org/.

Gomez, E.D. 1991. Coral reef ecosystems and resources of the Philippines. Canopy Int., 16 (5): 1-12.

Gomez, E.D., A. Alcala and A.C. San Diego. Status of Philippine Coral Reefs – 1981. Proceedings of the 4th International Coral Reef Symposium, 1: 275-282.

Gomez, E.D., Aliño, P.M., Yap, H.T. and Licuanan, W.Y. 1994. A review of the status of Philippine Reefs. Marine Pollution Bulletin, 29 (1-3): 62-68.

GraphPad Statistics Guide. Analysis checklist: Oneway ANOVA. http://www.graphpad.com.

Hill, J. and C. Wilkinson. 2004. Methods for Ecological Monitoring of Coral Reefs. Version 1. A Resource for Managers. Australian Institute of Marine Science, 117 p.

Hoegh-Guldberg, O., H. Hoegh-Guldberg, J.E. Veron, A. Green, E.D. Gomez, J.

Lough, M. King, Ambariyanto, L. Hansen, J. Cinner, G. Dews, G. Russ, H.Z. Schuttenberg, E.L. Peñaflor, C.M. Eakin, T.R.L. Christensen, M. Abbey, F. Areki, R.A. Kosaka, A. Tewfik and J. Oliver. 2009. The Coral Triangle and Climate Change: Ecosystems, People and Societies at Risk. WWF Australia, Brisbane, 276 p.

Hughes, T.P. and J.H. Connell. 1999. Multiple stressors on coral reefs: a long-term perspective. Part 2: The Effects of Multiple Stressors on Freshwater and Marine Ecosystems. Limnology and Oceanography, 44 (3): 932-940.

Hughes, T.P., A.H. Baird, D.R. Bellwood, M. Card, S.R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J.B.C. Jackson, J. Kleypas, J.M. Lough, P. Marshall, M. Nyström, S.R. Palumbi, J.M. Pandolfi, B. Rosen and J. Roughgarden. 2003. Climate Change, Human Impacts, and the Resilience of Coral Reefs. Science, 301: 929-933.

Huston, M.A. 1994. Biological Diveristy: The coexistence of species on changing landscapes. Cambridge University Press, Cambridge.

Hutchings, P., M. Kingsford and O. Hoegh-Guldberg. 2008. The Great Barrier Reef: Biology, Environment and Management. CSIRO Publishing, Australia.

Jimenez, L., A.C. Eballe and C.L. Nañola . 2002. Pujada Bay. In: Aliño, P.M., E.F.B. Miclat, C.L. Nañola, Jr., H.A. Roa-Quiaoit and R.T. Campos (eds.). Atlas of Philippine Coral Reefs. Philippine Coral Reef Information (Philreefs). Goodwill Trading Co., Inc. (Goodwill Bookstore), Quezon City, Philippines: 100-102.

Johnson, C.R. and A.L. Preece. 1992. Damage, scale and recovery in model coral communities: the importance of system state. Proceedings of the 7th International Coral Reef Symposium, Guam, 1: 606-615.

Knowlton, N. 1992. Thresholds and multiple stable states in coral reef community dynamics. American Zoologist, 32 (6): 674-682.

Komyakova, V., P.L. Munday and G.P. Jones. 2013. Relative importance of coral cover, habitat complexity and diversity in determining the structure of reef fish communities. PLos ONE, 8 (12): e83178.

Kuo, C-Y., Y.S. Yuen, P-J. Meng, P-H. Ho, J-T. Wang, Y-C. Chang, C-F. Dai, T-Y. Fan, H-J. Lin, P-J. Liu, A.H. Baird, and C.A. Chen. 2012. Recurrent disturbances and the degradation of hard coral communities in Taiwan. PLoS ONE, 7 (8): e44364.

Li, S., K. Yu, T. Chen, Q. Shi and H. Zhang. 2011. Assessment of coral bleaching using symbiotic zooxanthellae density and satellite remote sensing data in the

Nansha Islands, South China Sea. Chinese Science Bulletin, 56 (10): 1031-1037.

Licuanan, W.Y. and E.G. Gomez. 2000. Philippine coral reefs, reef fishes and associated fisheries: status and recommendations to improve their management. Global Coral Reef Monitoring Network (GCRMN) Report.

Licuanan, W.Y., M.L.S. Medina, K.S. Luzon, M.S. Samson, C.L. Nañola, Jr., R.N. Rollon and M.Y. Roleda. 2011. Priority Reef Areas in the Pacific Coast of the Philippines for Marine Protected Area Deployment. The Philippine Agricultural Scientist, 94 (4): 384-400.

Loya, Y., K. Sakai, K. Yamazato, Y. Nakano, H. Sambali and R. van Woesik. 2001. Coral bleaching: the winners and the losers. Ecology Letters, 4: 122–131.

Manthachitra, V. 1994. Indices assessing the status of coral-reef assemblage: formulated from benthic lifeform transect data. In: S. Sudara, C.R. Wilkinson and L.M. Chou (Eds.). Proceedings, 3rd ASEAN-Australia Symposium on Living Coastal Resources: Research papers. Chulalongkorn University, Bangkok, Thailand, 2: 40-50.

Maynard, J.A. K.R.N. Anthony, P.A. Marshall and I. Masiri. 2008. Major bleaching events can lead to increased thermal tolerance in corals. Marine Biology, 155:173–182.

McClanahan, T.R., A.H. Baird, P.A. Marshall and M.A. Toscano. 2004. Comparing bleaching and mortality responses of hard corals between southern Kenya and the Great Barrier Reef, Australia. Marine Pollution Bulletin, 48: 327–335.

MCDP. 1985. Report of socio-environmental baseline data for Pamilacan Island, Bohol and Apo Island, Negros. Marine Conservation and Development Program, Silliman University, Dumaguete, Negros Oriental, Philippines.

MPA Database. http://www.coast.ph/

Mumby, P.J. 1999. Bleaching and hurricane disturbances to populations of coral recruits in Belize. Marine Ecology Progress Series, 190: 27-35.

Nakajima, R., A. Nakayama, T. Yoshida, M.R.M. Kushairi, B.H.R. Othman and T. Toda. 2010. An evaluation of photo line-intercept transect (PLIT) method for coral reef monitoring. Galaxea, Journal of Coral Reef Studies, 12: 37-44.

Nanola, C. L., H. Arceo, A. Uychiaoco, and P. M. Alino. 2004. Monitoring the effects of marine protected areas in CRMP learning areas (1997–2003). Coastal Resource Management Project of the Department of Environment and Natural Resources and the University of the Philippines Marine Science

Institute, Cebu City, Philippines, 62 p.

Nañola, C.L., Jr., A.C. Alcala, P.M. Alino, H.Z. Arceo, W.L Campos, E.D. Gomez, W.Y. Licuanan, MC. Quibilan, A.J. Uychiaoco, A.T. White. 2005. Philippines. In: Status of coral reefs in East Asian Seas Region: 2004. Global Coral Reef Monitoring Network Report.

Nañola, C.L., Jr., P.M. Alino, H.Z. Arceo, W.Y. Licuanan, A.J. Uychiaoco, M.C. Quibilan, W.L Campos, A.C. Alcala, A.T. White and E.D. Gomez. 2006. Status report on coral reefs of the Philippines – 2004. In: Y. Suzuki, T. Nakamori, M. Hidaka, H. Kayanne, B. Casareto, K. Nadaoka, H. Yamano, M. Tsuchiya (eds). Proceedings of the 10th International Coral Reef Symposium, Okinawa, Japan, June 28-July 2, 2004. Japanese Coral Reef Society, Tokyo Japan.

Nguyen, L.V. And H.K. Phan. 2008. Distribution and factors influencing on structure of reef fish communities in Nha Trang Bay Marine Protected Area, South-Central Vietnam. Environmental Biology of Fishes, 82 (3): 309-324.

Obura, D.O. 2008. Bleaching as a life history trait in coral-zooxanthellae holobionts – relevance to acclimatization and adaptation. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008: 1304-1308.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd Edition. W.B. Saunders Company, Philadelphia and London, 574 p.

Philippine Council for Agriculture, Forestry and Natural Resources Research and Development. 2001. El Niño southern oscillation: mitigating measures. Los Baños, Laguna: PCARRD, 296 p.

Philippine MPA Database. http://www.mpa.msi.upd.edu.ph/mpa

Pialago, W.R., E. Silva and H. Calumpong. 1991. Petition to make Apo Island, Dauin, Negros Oriental a National Marine Reserve.

Post Disaster Need Assessment (PDNA) for Typhoon "Pablo"- Davao Oriental. 21 January-06 February 2013, 84 p.

Profile: Pujada Bay Protected Seascape. http://www.pawb.gov.ph

Putnam, H., M. Stat, X. Pochon and R.D. Gates. 2012. Endosymbiotic flexibility associates with environmental sensitivity in scleractinian corals. Proceedings of the Royal Society B: 1-10.

Raymundo, L.J.H. and A.P. Maypa. 2002. Recovery of the Apo Island Marine Reserve, Philippines, two years after the El Niño Bleaching Event. Coral Reefs, 21: 260-261.

Reboton, C. 2009. Recruitment and Recruit Survival of Scleractinian Corals on a Shallow Ship Grounded Site in Banilad, Dumaguete City, Philippines. Masters Thesis submitted to Department of Biology-Silliman University, Dumaguete City.

Reboton, C. and A. Candido. 2014. Assessment on the coral and reef fish communities in Ticao Island, Masbate. Ecol.ogy, Environment and Conservation 19 (Special Issue on Coastal Resource Management): 29-39.

Reboton, C. and K. Rosell. Coral Bleaching in Central Visayas. Unpublished Data.

Reboton, C. AIPLS Coral Rehabilitation and Fish Recovery Project. DENR, SU-IEMS and CCEFI on going-project.

Reef Check 2007 Report. www.reefcheck.org

Rogers, C.S. 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, 62: 185-202.

Rogers, C.S., M. Gilnack and H.C. Fitz, III. 1983. Monitoring of coral reefs with linear transects: a study of storm damage. Contribution No. 87 from West Indies Laboratory: 285-300.

Russ, G.R. and A.C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. Marine Ecology-Progress Series, 56: 13-27.

Sheppard, C., M. Al-Husiani, F. Al-Jamali, F. Al-Yamani, R. Baldwin, J. Bishop, F. Benzoni, E. Dutrieux, N.K. Dulvy, S.R.V. Durvasula, D.A. Jones, R. Loughland, D. Medio, M. Nithyanandan, G.M. Pilling, I. Polikarpov, A.R.G. Price, S. Purkis, B. Riegl, M. Saburova, K.S. Namin, O. Taylor, S. Wilson and K. Zainal. 2010. The Gulf: A young sea in decline. Marine Pollution Bulletin, 60: 13–38.

Smith, D., M. Westlake and P. Castañeda. 1982. The Diver's Guide to the Philippines. In: UNEP/IUCN. 1988. Apo Island Municipal Reserve. Coral Reefs of the World. Vol. 2: Indian Ocean, Red Sea and Gulf. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland and Cambridge, U.K: 239-240.

Stobart, B., R. Buckley, L. Leclair, K. Teleki, N. Downing, D. Souter and M. Callow. 2002. Aldabra: Monitoring the Path to Recovery. In: O. Lindėn, D. Souter, D. Wilhelmsson, and D. Obura, Eds. Coral Reef Degradation in the Indian Ocean Status Report 2002. CORDIO: 232–247.

The World Bank in the Philippines. 2012. Climate change adaptation in coastal communities. A documentation of project experience. http://www-wds.worldbank.org/

Tomasko, D.A., C.J. Dawes, M.D. Fortes, D.B. Largo and M.N.R. Alava. 1993. Observations on a multi-species seagrass meadow offshore of Negros Oriental, Republic of the Philippines. Botanica Marina, 36: 303-311.

Tonk, L., P. Bongaerts, E.M. Sampayo and O. Hoegh-Guldberg. 2013. *SymbioGBR*: a web-based database of *Symbiodinium* associated with cnidarian hosts on the Great Barrier Reef. BMC Ecology, 13: 7.

Transformations. https://www.ndsu.edu/ndsu/horsley/Transfrm.pdf

UNEP-ICRAN Tourism monitoring – coral damage. 2003-2007.

Veron, J.E.N. and M. Pichon. 1976. Scleractinia of Eastern Australia. Part I. Families Thanmasteriidae, Astrocoeniidae, Pocilloporidae. Australian Institute of Marine Science Monograph Series. Vol. 1. Australian Government Publishing Service, Canberra. 86 p.

Veron, J.E.N., M. Pichon and M. Wijsman-Best. 1977. Scleractinia of Eastern Australia. Part II. Families Faviidae, Trachyphyllidae. Australian Institute of Marine Science Monograph Series. Vol. 3. Australian Government Publishing Service, Canberra. 233 p.

Veron, J.E.N. and M. Pichon. 1979. Scleractinia of Eastern Australia. Part III. Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae, Dendrophylliidae. Australian Institute of Marine Science Monograph Series. Vol. 4. Australian National University Press, Canberra. 422 p.

Veron, J.E.N. and M. Pichon. 1982. Scleractinia of Eastern Australia. Part IV. Family Poritidae. Australian Institute of Marine Science Monograph Series. Vol. 5. Australian National University Press, Canberra. 159 p.

Veron, J.E.N. and C.C. Wallace. 1984. Scleractinia of Eastern Australia. Part V. Family Acroporidae. Australian Institute of Marine Science Monograph Series. Vol. 6. Australian National University Press, Canberra. 482 p.

Veron, J.E.N. 2000a. Corals of the World. Vols. 1-3. Australian Institute of Marine Science and CRR Qld Pty Ltd.

Veron, J.E.N. 2000b. New species described in Corals of the World. Australian Institute of Marine Science Monograph Series. Vol. 11. Australian Institute of Marine Science.

Wallace, C.C. 1999. Staghorn Corals of the World. A revision of the coral genus Acropora. (Scleractinia; Astrocoenina; Acroporidae) worldwide, with emphasis on morphology, phylogeny and biogeography. CSIRO Publishing, Australia. 421p.

White, A.T., 1987. Coral reef: valuable resources of Southeast Asia. ICLARM Education Series 1. ICLARM, Manila, Philippines, 36 p.

White, A.T. and H.P. Calumpong. 1992. Summary Field Report: Saving Tubbataha Reef and Monitoring Marine Reserves in the Central Visayas. Earthwatch Expedition to the Philippines. 13 p.

Wilkinson, C.R. 1992. Coral reefs of the world are facing widespread devastation: can we prevent this through sustainable management practices? Proceedings of the 7th International Coral Reef Symposium, Guam, 1: 11-21.

Wilkinson, C., O. Linden, H. Cesar, G. Hodgson, J. Rubens and A.F. Strong. 1999. Ecological and socioeconomic impacts of 1998 coral mortality in the Indian Ocean: An ENSO impact and a warning of future change? Ambio, 28 (2): 188-196.