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Initial Findings of the Nationwide Assessment of Philippine Coral Reefs

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The Philippine archipelago is well known for its species-rich coral reefs, yet updated information on the present status of its coral reefs at the national level is lacking. Hence, a nationwide assessment was initiated in 2014 to update the information on the status of coral reefs in the Philippines. Reefs sampled were randomly selected from around the country, with the number of assessment stations for each of six biogeographic regions stratified by the total area of reefs in each of these regions. Five 50 m transects were randomly deployed in each assessment station. The initial data gathered from 2015 up to 2017 included a total of 166 stations (108 in Luzon, 31 in Visayas, and 27 in Mindanao), sampled across 31 provinces. None of these stations were classified in the excellent category based on live coral cover, and more than 90% of the same stations were in the poor and fair categories. Their average hard coral cover, weighted by the reef area of each biogeographic zone, was 22% (95% confidence intervals: 19.4, 24.9). These values indicate a marked decline in the condition of local reefs over the last four decades, thereby revealing the urgent need for the revision and update of conservation and management policies.

Key words: coral reef assessment, hard coral cover

INTRODUCTION

The first ever nationwide assessment of coral reefs in the Philippines was conducted from 1976 to 1981. The initiative sampled stations located mainly in the Luzon and the Visayas regions and classified them using a four-category scale based on live coral cover (LCC), which is defined as the total of soft and hard coral cover. A reef is in "poor" condition if it has an LCC of 0-25%, "fair" if LCC is >25-50%, "good" if LCC is >50-75%, and "excellent" if LCC is >75% (Gomez et al. 1981). The results showed that 434 of the 619 stations (70.1%) that were surveyed were in "poor" and "fair" condition and only 34 (5.5%) of the stations were in "excellent" condition (Gomez et al. 1981).

More geographically focused coral reef assessments from 1987-1994 found that 64 of the 85 stations sampled (75.3%) had LCC that were classified as poor and fair, and only two of 85 stations (2.4%) were classified as excellent (Gomez et al. 1994). An overlapping assessment from 1990-1999 found that 29 of 673 sites (4.3%) were in excellent condition (Licuanan & Gomez 2000).

Starting in 2002, the Philippine Coral Reef Information Network (PhilReefs) issued a series of publications that became a venue for reporting the status of Philippine coral reefs to the Global Coral Reef Monitoring Network (Aliño et al. 2002; PhilReefs 2010). However, instead of looking at the reefs of the country as a whole, the PhilReefs publications provided detailed information on reefs at smaller scales (from barangay to province level). Furthermore, the reports were mostly focused on

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marine protected areas which were the subject of regular monitoring and evaluation.

The first publication of the PhilReefs series to include a national update used time series data on hard coral cover from the 1990s to the early 2000s. All six biogeographic regions were represented in the 61 municipalities/cities with time series data. These zones, as defined by Aliño & Gomez (1994), are the West Philippine Sea, North Philippine Sea, South Philippine Sea, Sulu Sea, Visayan Sea, and Celebes Sea. Although the authors found the overall trend for hard coral cover (HCC) to be increasing, they stressed that the trends were not statistically tested, and that the data were biased, as most of them were collected from marine protected areas (PhilReefs 2003).

Nañola et al. (2006) provided an update on the state of the country's reefs based on data collected from 2000 to 2004. All biogeographic zones were represented in the 424 transects analyzed, but nearly half the area covered was in the eastern Philippines facing the Pacific Ocean. The percentage of transects found to be in excellent condition (based on LCC) was only 0.2%. On the other hand, those found to be in poor condition increased to 40.8% (Nañola et al. 2006).

Much like the 2003 PhilReefs publication, the 2008 update used time series data. It covered 120 survey sites (in 52 municipalities/cities across 31 provinces) monitored from 1991 to 2008. The report revealed that generally, HCC had increased or remained stable (PhilReefs 2008).

In a status report embedded in the sixth of the PhilReefs publication series, Aliño et al. (2012) compared HCC data from 2008 to 2011 with the 2000 to 2004 dataset of Nañola et al. (2006). HCC seemed to improve. However, such could again be attributed to the bias of the sampling towards marine protected areas (Aliño et al. 2012).

None of the previous assessments followed a statistically valid national framework, hence no accurate estimate of average coral cover in the country, and how this has changed over the last few decades, has emerged. The National Assessment of Coral Reef Environments (NACRE) program was thus launched in 2014 to fill the need for an updated, comprehensive assessment of the coral reefs of the Philippines, following the framework described in Licuanan & Aliño (2014). The NACRE program has five component projects focusing on reef benthos (mainly hard corals), fish, mangroves and associated habitats, watersheds, and remote sensing. The present report provides the initial results of the Synoptic Investigations of Human Impacts on Nearshore Environments (SHINE): Coral Reefs project, which is the component of the NACRE program that focuses on reef benthos. The report also presents a new scale by which HCC estimates that result from these assessments may be evaluated.

METHODS

The coral reefs that were surveyed in this study were identified through a stratified random sampling procedure. The randomly generated sampling points were used to select the contiguous reef to be visited, and an assessment station on that reef's slope was chosen. Assessment stations within the same reef were more than 1 km apart.

Assessment stations that qualified were surveyed using the photo-transect method of van Woesik et al. (2009). In each station, five transects were randomly deployed within a 75 m by 25 m area along the reef slope at 2 m to 6 m depth. Fifty images, each covering a 1 m^2 area, were captured along the shallow side of each transect.

Transect images were analyzed using Coral Point Count with Excel extensions (CPCe) (Kohler & Gill 2006). The percentage cover of benthic categories in CPCe is the relative frequency from ten randomly located scoring points per image, averaged across each transects. Benthic categories scored included over 60 taxonomic amalgamation units, including soft corals and various hard coral taxa.

RESULTS

A total of 166 assessment stations across 31 provinces were sampled between Jan 2015 and Jan 2017 by the SHINE: Coral Reefs project. A majority (108 of 166) of these stations was in Luzon, especially around the Verde Island Passage (VIP). The VIP served as the pilot study area for the NACRE program because of complementary interests of two other research programs studying the area's reefs.

Two scales were used for classifying the status of the assessment stations (Table 1). The first is the widely used quartile scale of Gomez et al. (1981) from the first

Table 1. Existing and proposed scales and thresholds for evaluating status of reefs in the Philippines. The first set of thresholds are for live coral cover (i.e., hard plus soft coral cover) as proposed by Gomez et al. (1981). The second is based only on hard coral cover and is used in most of the present analysis.

	Categories			
	Poor	Fair	Good	Excellent
Live (hard + soft) coral cover scale	0%-25%	>25%-50%	>50%-75%	>75%
Hard coral cover scale	0-22%	>22-33%	>33-44%	>44%

nationwide assessment of Philippine reefs. In this scale, reef condition is categorized as "poor", "fair", "good", or "excellent" based on live coral cover (LCC), the sum of covers of hard and soft corals) within the ranges listed in Table 1. The second scale (proposed in this study) uses only hard coral cover (HCC; see the last row of Table 1). HCC alone is used in the second scale because soft corals are not generally considered as important reef builders (Licuanan & Gomez 2000; but see Schuhmacher 1997).

The first threshold (22%) in the second scale is based on the average HCC in the Indo-Pacific in 2003 (22.1%) (Bruno & Selig 2007). Thus, reefs in the "poor" category have below-average HCC. The second threshold (33%) of the proposed scale is based on HCC measured from 2012 to 2014 in eight monitoring stations in the Tubbataha Reefs (Licuanan et al. 2017). Ergo, reefs in the "good" and "excellent" categories of the second scale have higher HCC than the average condition in Tubbataha reef slopes. Note that the Tubbataha Reefs Natural Park is the largest, and the best managed marine protected area in the Philippines (Dygico et al. 2013). The third threshold (44%) is arbitrarily set to double the first threshold, leading to an easy-to-remember "22-33-44" set of thresholds to redefine poor, fair, good, and excellent coral communities.

The scale of Gomez et al. (1981) defined an excellent reef as having more than 75% LCC. Application of this LCC scale on the data from the 166 reef stations of the present study reveals that none of the reefs at present qualify in the excellent category (Figure 1). Gomez et al. (1981) reported that 70% of the reefs were in the poor and fair categories of their scale. A newer study (Gomez et al. 1994) found that 75% of the reefs studied were in the same categories. More than 90% of the stations of the present study are in the poor (74 of 166 stations) and fair (80 of 166 stations) categories. The loss of excellent category reefs and the increase in the numbers of reefs in the poor and fair categories indicate that live coral cover on Philippine reefs has undergone marked decline since the late 1970s and early 1980s and confirm the trends shown in Gomez et al. (1994), Licuanan & Gomez (2000), and subsequent studies reviewed earlier. This suggests that the establishment of marine protected areas, and other interventions in the past 40 years have not caused an appreciable impact on overall reef condition in general, except in particular localities. This conclusion is further substantiated by changes in average HCC.

In 2003, surveys of 390 reefs in the Indo-Pacific yielded an average cover of 22.1% (95% CI: 20.7, 23.4) (Bruno & Selig 2007). The average HCC found in the Philippines so far, weighted by the reef area of each biogeographic zone, is 22% (95% CI: 19.4, 24.9). The non-significant difference (two sample t-test, p=0.1164) between the Indo-Pacific average and the current general Philippine average (24%, 95% CI: 22.0, 26.3) suggests that HCC in Philippine reefs is comparable to those in the surrounding regions. However, Licuanan & Gomez (2000) reported higher HCC in Philippine reefs from 1990 to 1999, with an overall average of 32%. In contrast, Osborne et al. (2011) reported that HCC changed little on 47 reefs of the Great Barrier Reef (GBR) from 1995 to 2009. The GBR average HCC (29%, ranging from 23% to 33%) (Osborne et al. 2011) is higher than current average HCC in the Philippines. These comparisons assume the all numbers were derived from statistically valid sampling schemes.

Gomez et al. (1994) introduced the coral mortality index (CMI) to complement assessments based on HCC because parts of a reef are naturally unsuitable for coral recruitment and growth. The CMI is the ratio of dead coral cover to the sum of hard and dead coral cover. They reported that 84%

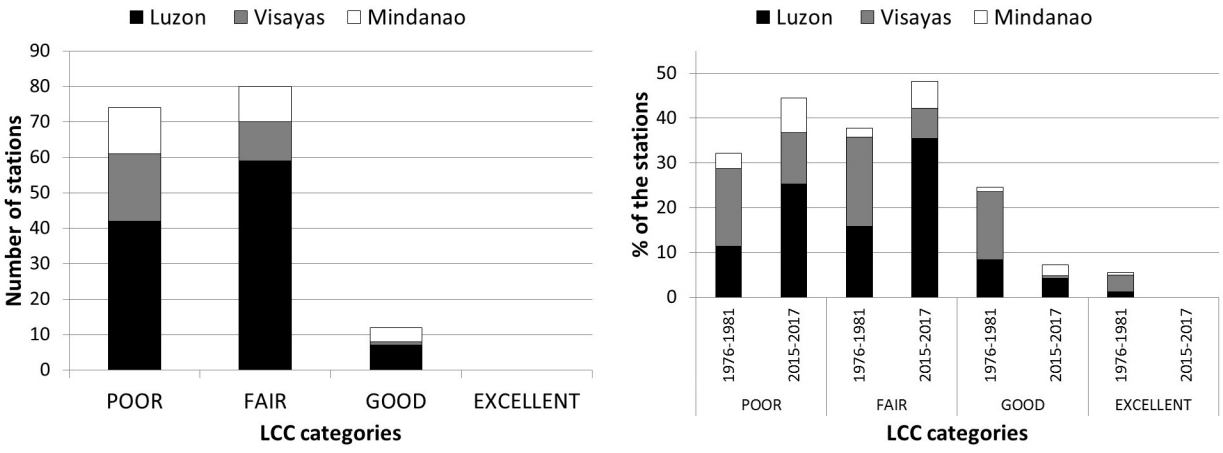

Figure 1. The current state of Philippine coral reefs based on live coral cover (left) and the comparison of the results of the first national assessment (1976-1981) and the current national assessment (2015-2017) (right).

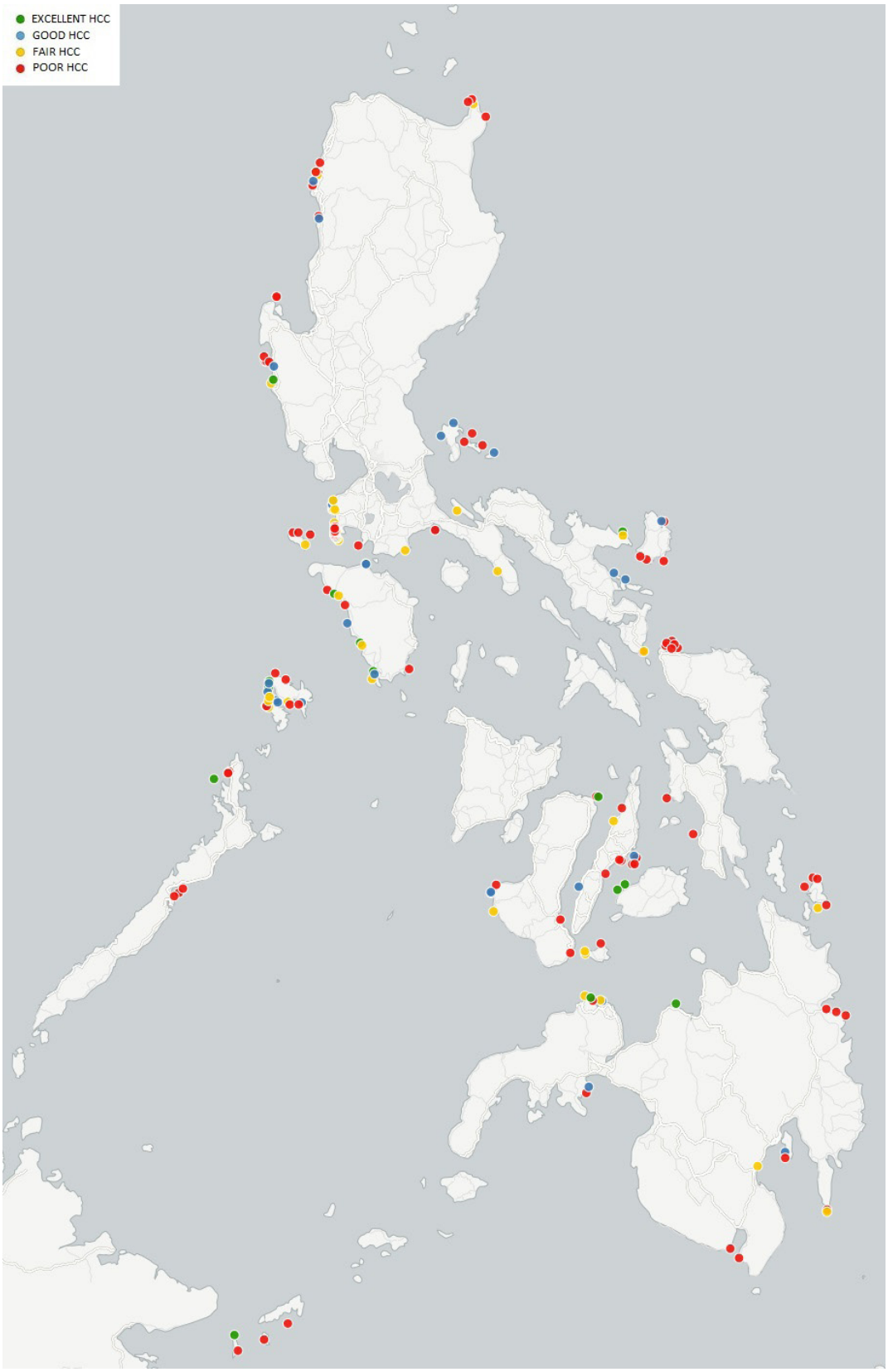

Figure 2. Map of the stations surveyed. The colors of the points indicate whether the hard coral cover (HCC) in a station is excellent, good, fair, or poor based on the HCC scale proposed in this paper.

of the reefs surveyed have a CMI of at most 0.5. The overall average CMI for Philippine reefs from 1987-1994 was 0.2 (standard deviation = 0.1) (Gomez et al. 1994). In the current assessment, only 23% of the reefs have a CMI of at most 0.5, provided cover of turf algae are included in the numerator and denominator to account for differences in scoring categories in use then and now. Moreover, the average CMI, weighted by the reef area of each biogeographic region, was 0.7 (standard deviation = 0.02). These changes in CMI indicate a marked decline in reef condition. The applicability and utility of CMI and other indices of reef condition require further study.

The HCC scale proposed in the present study is used for succeeding discussions. Table 2 lists the mean HCC, mean CMI, and the number of stations per HCC category per province. Figure 2 shows a map of the individual stations that have been surveyed so far. Most of the stations sampled (108 of 166 stations) were in Luzon. Based on the HCC scale, reefs in Luzon were mostly in the poor category. The province of

Table 2. Provinces sampled from Jan 2015 to Jan 2017. Categories are based on the HCC scale proposed in this study.

Island Group	Province	Number of Municipalities/Cities	Number of Stations	Mean CMI	Mean HCC (%)	Number of Stations Categorized by HCC			
						Poor	Fair	Good	Excellent
Luzon	Albay	2	2	0.44	39	0	0	2	0
	Batangas	5	24	0.68	25	9	12	3	0
	Cagayan	1	4	0.68	23	3	1	0	0
	Camarines Sur	1	2	0.58	38	0	1	0	1
	Catanduanes	3	5	0.62	17	4	0	1	0
	Ilocos Sur	6	9	0.67	18	5	2	2	0
	Mindoro Occidental	7	13	0.64	30	5	3	2	3
	Mindoro Oriental	2	3	0.53	29	1	0	2	0
	Palawan	5	25	0.62	29	11	4	7	3
	Pangasinan	1	2	0.80	14	2	0	0	0
	Quezon	7	10	0.63	25	4	2	4	0
	Sorsogon	1	2	0.46	19	1	1	0	0
	Zambales	4	7	0.69	25	4	1	1	1
Visayas	Bohol	2	2	0.44	46	0	0	0	2
	Cebu	8	10	0.70	20	7	1	2	0
	Leyte	2	2	0.89	8	2	0	0	0
	Negros Occidental	3	6	0.56	33	2	1	2	1
	Negros Oriental	2	2	0.74	6	2	0	0	0
	Northern Samar	4	6	0.73	13	6	0	0	0
	Siquijor	3	3	0.70	18	1	2	0	0
Mindanao	Davao del Norte	1	2	0.68	22	1	0	1	0
	Davao del Sur	1	1	0.59	30	0	1	0	0
	Davao Oriental	1	2	0.78	18	1	1	0	0
	Misamis Occidental	1	2	0.43	34	0	1	1	0
	Misamis Oriental	1	1	0.28	56	0	0	0	1
	Sarangani	2	2	0.83	10	2	0	0	0
	Surigao del Norte	5	5	0.78	16	4	1	0	0
	Surigao del Sur	2	3	0.98	1	3	0	0	0
	Tawi-Tawi	3	4	0.55	26	3	0	0	1
	Zamboanga del Norte	2	3	0.66	28	1	1	0	1
	Zamboanga del Sur	1	2	0.59	29	1	0	1	0

Pangasinan had the lowest mean HCC (14%, based on two stations), while the province of Albay had the highest mean HCC (39%, based on two stations). Mindoro Occidental and Palawan had the greatest number of reefs in the excellent category in Luzon and in the Philippines (three each).

So far, the SHINE project has surveyed 31 stations in the Visayas region, which is the biogeographic zone with the largest reef area. Although reefs in the Visayas surveyed were mostly in the poor category, reefs in the excellent category were also found (in Bohol and Negros Occidental). The province with the lowest mean HCC was Negros Oriental (6%, based on two stations), while Bohol had the highest mean HCC (46%, based on two stations).

The 27 reefs sampled in Mindanao were mostly in the poor and fair categories. Mean HCC per province ranged from 1% (Surigao del Sur, three stations) to 56% (Misamis Oriental, one station). These province HCC averages were also the lowest and the highest, respectively, in the Philippines as a whole.

Note that the sampling scheme used in the present study was not designed to produce robust estimates of HCC per province and thus Table 2 is just meant to provide indications of possible local patterns.

DISCUSSION

Findings and Comparisons Between Surveys

Findings of the current assessment are best viewed as a snapshot of the current state of Philippine reefs. Reef assessments of previous years are not directly comparable with the current assessment because of differences in survey methods used and their geographic coverage.

Data from the stations of the current assessment were obtained from randomly selected reefs in country, using 50 m long photo-transects at a depth of 2-7 meters. The 619 stations of the assessments from 1976-1981 were distributed mainly in the Luzon and the Visayas regions, and only marginally in Mindanao, and involved either the transect-quadrat method or haphazard deployment of quadrats. The transect-quadrat method was performed by recording data on-site, from 1 m^2 quadrats that were placed at 10 m intervals along a 300 m transect line laid perpendicular to the shore. In places where a line was not deployed, 1 m^2 quadrats were thrown haphazardly from the boat. In both cases, the sampling covered reef flats, where coral cover is usually lower, along with the reef slopes and reef crests (Gomez et al. 1994).

The geographic distribution of the 85 stations surveyed from 1987-1994 was limited to the Luzon and Visayas regions, and the method that was used in the surveys was the line-intercept transect method (Dartnall & Jones 1986; Gomez et al. 1994). The transect lines were laid along depth contours of the reef slope, at 3 m and 10 m below the reef crest.

Licuanan & Gomez (2000) summarized data from 1990-1999 that were collected using various sampling methods that included the line-intercept transect method and the video-transect method. Like the surveys from 1987-1994, these data were collected at fixed depths only at the reef slope - where most corals are found.

The data from 2000-2004 that were reported by Nañola et al. (2006) were also collected with similar methods and sampling depths. However, about half of the 424 transects reported by Nañola et al. (2006) came from the erstwhile un-surveyed reefs facing the Pacific Ocean in eastern Philippines. Moreover, these surveys were conducted after the 1998 mass coral bleaching affected the reefs of the country. This may explain their conclusion that the condition of Philippine reefs continues to decline.

One may be led to believe that general reef condition has been improving in recent years if the earlier assessments are compared with the newer findings summarized in PhilReefs reports. However, most monitoring reported in PhilReefs is biased towards sampling protected areas and this would yield higher coral cover values. For example, Magdaong et al. (2014) found coral cover is 5.8% higher in protected areas in the Philippines. Whether this is indeed the case will be confirmed by another project in the NACRE program.

It is for these reasons that in general, previous assessment datasets are not directly comparable to the results of the current assessment. Differences preclude detailed analysis beyond coarse comparisons of cover data between the first assessment (1976-1981) and the newer surveys (Licuanan & Gomez 2000). Comparisons are valid only if the methods used yield comparable data, if the same zones of the reefs surveyed, and if the same regions (i.e. Luzon, Visayas, or Mindanao) are sampled with the same intensity over time. However, given the spatial extent and large number of stations covered in the present study, the absence of excellent category (based on LCC) reefs and the decline in average HCC should trigger reconsideration of government priorities, and urgent revision and update of conservation and management policies, including one described in the following section.

Scales for Assessing Coral Cover

The quartile scale of Gomez et al. (1981) is an arbitrary LCC scale that was introduced with the first nationwide assessment of coral reefs. It has been widely used in the country since its publication. Its use with the data of those reef assessments in the 1970s and 1980s showed that only

5.5% of country's reefs are in "excellent" condition (Gomez et al. 1981; Licuanan & Gomez 2000). This finding has galvanized regulatory and conservation action from the national to the local community level for over 30 years. However, this arbitrary scale sets unrealistically high expectations for cover levels for reefs in the "excellent" category (>75% LCC) considering, for one, that Bruno & Selig's (2007) study of 390 reefs in the Indo-Pacific found only seven with coral cover >60%. These expectations become crucial when used in laws and regulations. For example, the Philippine Environmental Impact Assessment (EIA) system requires that a coral community should have at least 50% LCC to be considered an "environmentally critical area" (Presidential Proclamation 2146 Series 1981; DENR EMB-EIAMD 2007). This high threshold effectively reduces the legal protection afforded to about 63% of Philippine reef stations (using data from three Philippine coral reef surveys reviewed in Gomez et al. 1994). If this high threshold is applied to the present dataset, 93% of Philippine reef stations will be classified as not environmentally critical. This is untenable given the enormous economic and environmental values of coral reefs to the Philippines (White & Cruz-Trinidad 1998; White et al. 2000). In addition, being labelled as a "poor" category reef could be misconstrued as meaning the reef is effectively dead and "written off" in local government settings. Note that by law, the management of the first 15 km of coastal waters (and the reefs within them) is at the local (town and city) level. This is where scientific expertise and reef benchmarks to guide reef management are most needed.

The "22-33-44" HCC scale proposed is more realistic because it describes attainable values of cover in Philippine settings and is thus better able to resolve differences between sets of reefs. The thresholds are based on averages for the Indo-Pacific and the Tubbataha reefs. Given the arbitrary nature of the LCC scale, it is recommended that local policies be revised and use only the "22-33-44" HCC scale.

Some may consider the use of newer benchmarks in the HCC scale as shifted baselines leading to lower expectations and standards (Knowlton & Jackson 2008). For example, Bruno & Selig (2007) estimate that coral cover in the Indo-Pacific is at least 20% lower than the best historical baselines. Note, however, that the poor category of both the LCC and HCC scales are basically the same, especially since the average soft coral cover in the current data set is only 3.7%. Yet most reefs in the first national assessment rated reefs as fair (based on LCC) while most of the reefs in the present assessment were classified as mostly poor (based on HCC).

As shown earlier, the methodologies used in the first national assessment preclude detailed comparisons with the findings of assessments using newer methods (see Gomez et al. 1994; Licuanan & Aliño 2014). It was also shown that the quartile LCC scale sets unrealistic expectations on coral cover in reefs. However, the results of the current assessments do indicate that reefs have deteriorated since the pioneering surveys led by Professors E.D. Gomez and A.C. Alcala. The present work provides the foundation for new baselines. Researchers are now focused on the setting of benchmarks for coral cover and generic diversity for fringing reefs, the classification of coral community structure data to identify representative reef types for different bioregions, and the establishment of a network of "sentinel" reefs for a national reef monitoring system. The classification of reef community types is the first step in identifying "reference" reefs, i.e., reefs with minimal human impacts that will serve as region-specific benchmarks for various reef condition indices (see Jameson et al. 2003). Reference reefs and the sentinel reefs may be the same, and Tubbataha Reefs, described in Licuanan et al. (2017) should be one of them.

CONCLUSIONS AND RECOMMENDATIONS

To fill the need for updated information on the status of coral reefs in the Philippines, a nationwide assessment was launched in 2014. One hundred sixty-six reefs have been sampled over a two-year period. Based on LCC, more than 90% of the sampled reefs are in the poor and fair categories. So far, the mean HCC of the country, 22%, is comparable with that of the Indo-Pacific region, but much lower than previous estimates for the Philippines.

In addition to providing an update on the status of Philippine coral reefs, a new scale for classifying the status was introduced. The authors propose the revision of administrative orders dealing with the definition of "environmentally critical" reefs based on this HCC scale since the LCC scale by Gomez et al. (1981) is arbitrary and sets unrealistically high expectations for the country's reefs. The use of the new scale with HCC data will not only emphasize the need for better management of Philippine coral reefs, but will also present attainable targets for improvement of local reef condition.

Ideally, future assessments would be conducted using the site selection criteria and methodologies used in the SHINE: Coral Reefs project. This would allow comparisons between the present and future datasets, and retain a permanent record of images for more detailed studies; for example, to distinguish the algal taxa found living between the coral colonies. Aside from HCC and coral diversity, many other parameters in evaluating reef condition should also be used (see Flower et al. 2017). For instance, reef rugosity provides a measure of structural complexity, which is a factor determining the number of ecological niches available in a reef (Dustan et al. 2013). There are also indices, like the deterioration index (the

mortality of branching corals divided by their recruitment rates) which may better measure the disturbance levels experienced by a reef (Ben-Tzvi et al. 2004).

A coordinated, national reef monitoring system using standardized methods can better serve the needs of reef management and conservation instead of repeated independent assessments throughout the country. This monitoring system should be established as soon as possible given the Filipinos' dependence on goods and services provided by coral reefs and the impacts of humans and climate change on these reefs.

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