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Status of reefs in selected Southeast Asia countries

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Abstract

In 2012 the status of Southeast Asia's coral reefs was determined using Reef Check survey methods on 295 sites from six different countries; 50 in Brunei, 22 in Philippines, 40 in Taiwan, 24 in Thailand, 18 in Indonesia and 141 in Malaysia. Data collected and assessed were the Indo Pacific Reef Check indicator fish, invertebrates and substrate. The assessment of the data showed that reefs in Southeast Asia were in fair condition with 43.20% of live coral (hard coral + soft coral) cover. However the abundance of highly prized food fish (Barramundi Cod, Humphead Wrasse and Bumphead Parrotfish) and several other fish targeted for food were low. In addition, invertebrates targeted for curio trade and food trade were also present in small number and only seen at 42 of the 319 sites surveyed. Overfishing seems to be the main impact to coral reefs in this region.

Key words: coral reefs, survey, status, Southeast Asia, Reef Check

Introduction

Coral reefs in Southeast Asia (SEA) have the highest degree of biodiversity of all the world's reefs. Total reef area is approximately 100,000 km^2 or 34% of the world's total reef area (Tun et al., 2004). SEA's reefs hold more than 75% of the world's coral species and more than 33% of the world's reef fish. They also contain nearly 75% of the world's mangrove

species and more than 45% of seagrass species (Burke et al., 2002; Tun et al., 2004). Most reefs in SEA are on the continental Sunda and Sahul Shelves with all reef types – fringing, platform, barrier reefs and atolls (Tun et al., 2008).

For thousands of years people have coexisted with reef ecosystems in SEA, enjoying the goods and services, protection and contribution to coastal culture and lifestyle provided by this diverse ecosystem (Burke et al., 2002). However, SEA's reefs are also the most threatened and damaged reefs, facing unprecedented threats from human activities (Tun et al., 2004). According to Burke et al., (2002), the reefs of Philippines, Vietnam, Singapore, Cambodia, and Taiwan are some of the most threatened in SEA, each with over 90% reefs threatened. In Malaysia and Indonesia, over 85% of its reefs are threatened. Indonesia and Philippines hold 77% of SEA's reefs and nearly 80% of SEA's threatened reefs. From a later paper by Burke et al. (2012), the percentage of threatened reefs in Indonesia has escalated to nearly 95%, while in Malaysia and Philippines almost all reefs are threatened. This study was carried out to further understand the threat levels stated by Burke et al.

Materials and Methods

Reef surveys were carried out in 2012 at 295 sites and spanned over 6 countries within the SEA region. A total of 50 sites were surveyed in Brunei, 22 in Philippines, 40 in Taiwan, 24 in Thailand, 18 in Indonesia and 141 in Malaysia. Surveys were done by different teams of EcoDivers based in each country. The survey sites were determined by team leaders and country coordinators for their respective country status reports and not selected specifically for this study.

All reef surveys were done using the Reef Check methodology (Hodgson et al., 2006) along fixed depths of two depth contours (3-6m and 6-10m depth). A 100m transect line was deployed and four 20m sections were surveyed, each section separated by a 5m gap where no data were collected, which provided four replicates per transect for statistical analysis. Three types of data were collected, 1) abundance of fish commonly targeted by fishermen and aquarium collectors, 2) abundance of invertebrates commonly targeted as food species or collected as curios, and 3) percentage cover of specific substrate categories.

Results

Using Chou et al. (1994) 'Coral Reef Health Index', the general condition of SEA's reefs was categorised as 'Fair', based on the average 'Live Coral Cover' (Hard Coral + Soft Coral) of 43.20% (Fig. 1). The level of 'Recently Killed Coral (RKC)', 'Nutrient Indicator Algae (NIA)' and 'Silt' were relatively low at 3.58±0.11%,

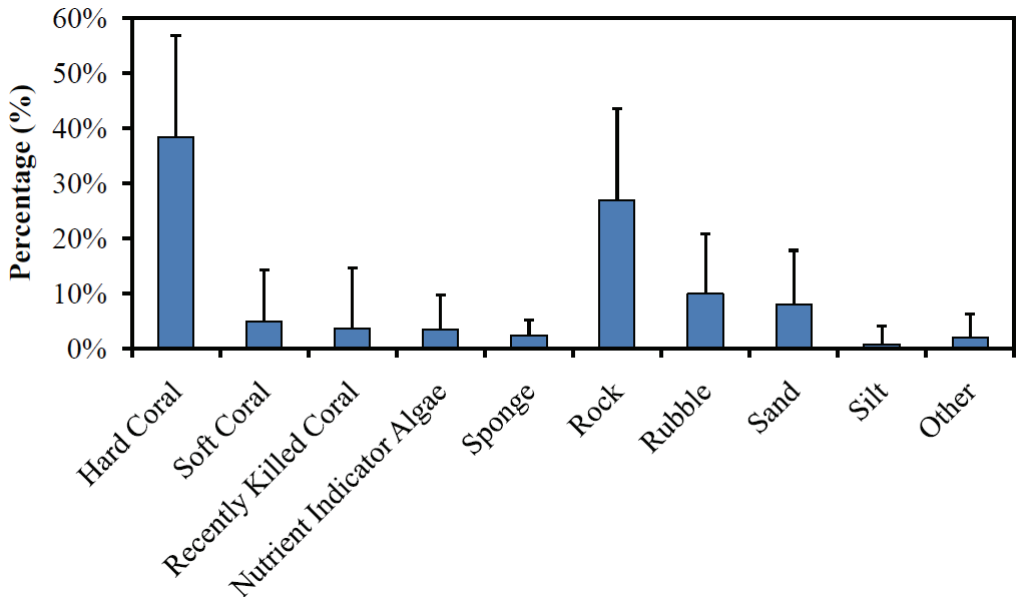

Fig. 1. Average Percentage of Substrate Cover with Standard Deviation Recorded within 20m Reef Check Surveys in Southeast Asia, 2012. Data used are from Brunei, Philippines, Taiwan, Thailand, Indonesia and Malaysia.

3.42±0.06% and 0.72±0.03% respectively, all of which are indicators of disturbance on reefs. 'Rubble' which is also an indicator of disturbance was within acceptable limits at 9.91±0.11%. The percentage of 'Rock' was considered normal (26.84±0.17%). Sponge recorded 2.33±0.03%, Sand 8.04±0.10% and Other 1.95±0.04%. Comparison between SEA's countries were also made and Indonesia recorded the highest Hard Coral coverage and living coral coverage for this region (Table 1 and 2). The highest RKC was recorded in Thailand and highest RC was recorded from Brunei.

Abundance were low for several fish that are usually targeted for food, with abundance of many being less than 1 ind./500m^3, including sweetlips, barramundi cod and moray eel (Fig. 2). The most abundant food fish was snapper at 7.90±32.12 ind./500m^3. The abundance of high value humphead wrasse and bumphead parrotfish were very low, less than 1 ind./500m^3. Butterflyfish recorded 4.44±5.18 ind./500m^3 and parrotfish recorded 2.44±4.46 ind./500m^3. This result also reflected between the SEA countries except for Thailand with a high abundance of Snapper with a value of 20.63 ± 50.67 ind./500m^3 (Table 3).

Abundance of those invertebrates

targeted for the curio trade was very low, with banded coral shrimp, pencil urchin, and triton recorded 0.10±0.54, 0.01±0.04, and 0.00±0.03 ind./100m^2 respectively (Fig. 3). Similarly, invertebrates targeted for food trade were low, with collector urchin, lobster, sea cucumbers and giant clams recorded 0.02±0.11, 0.05±0.18, 1.03±2.61 and 2.32±10.22 ind./100m^2 respectively. *Diadema* recorded 27.26±74.06 ind./100m^2 while crown-of-thorns recorded 0.17±0.62 ind./100m^2. Within the SEA countries, Thailand recorded the highest abundance of *Diadema* and giant clams with a value of 94.74 ± 159.29 and 14.96 ± 32.38 respectively (Table 4).

Table 1. Substrate categories coverage (%) between countries

Substrate	Country					
	Brunei	Philippines	Taiwan	Thailand	Indonesia	Malaysia
Hard Coral	35.86 ± 0.13	36.22 ± 0.18	31.42 ± 0.13	23.93 ± 0.13	51.01 ± 0.13	41.68 ± 0.20
Soft Coral	2.81 ± 0.02	11.17 ± 0.13	5.86 ± 0.08	1.21 ± 0.03	7.74 ± 0.07	4.70 ± 0.11
Recently Killed Coral	0.36 ± 0.004	0.60 ± 0.02	0.38 ± 0.01	32.56 ± 0.24	3.61 ± 0.08	1.52 ± 0.04
Nutrient Indicator Algae	3.91 ± 0.01	3.30 ± 0.05	8.14 ± 0.11	0.15 ± 0.001	2.60 ± 0.04	2.71 ± 0.05
Sponge	2.66 ± 0.02	4.15 ± 0.05	1.50 ± 0.02	1.54 ± 0.02	3.89 ± 0.03	2.13 ± 0.03
Rock	35.56 ± 0.09	21.62 ± 0.07	42.16 ± 0.17	12.79 ± 0.11	3.85 ± 0.09	25.74 ± 0.15
Rubble	10.21 ± 0.04	7.44 ± 0.06	4.05 ± 0.05	7.13 ± 0.09	11.08 ± 0.09	11.86 ± 0.12
Sand	7.52 ± 0.03	11.22 ± 0.12	4.58 ± 0.07	13.72 ± 0.13	13.02 ± 0.10	7.25 ± 0.10
Silt	0.25 ± 0.01	2.13 ± 0.06	0.42 ± 0.02	0.03 ± 0.001	0.66 ± 0.01	0.85 ± 0.04
Other	0.78 ± 0.02	2.16 ± 0.02	1.50 ± 0.03	6.94 ± 0.11	2.53 ± 0.03	1.59 ± 0.04

Table 2. Live Coral Coverage (HC+SC) between countries in SEA region

	Brunei	Philippines	Taiwan	Thailand	Indonesia	Malaysia
Live Coral Cover (%)	38.67*	47.38*	37.28*	25.14*	58.75**	46.37*

** Fair ; **Good*

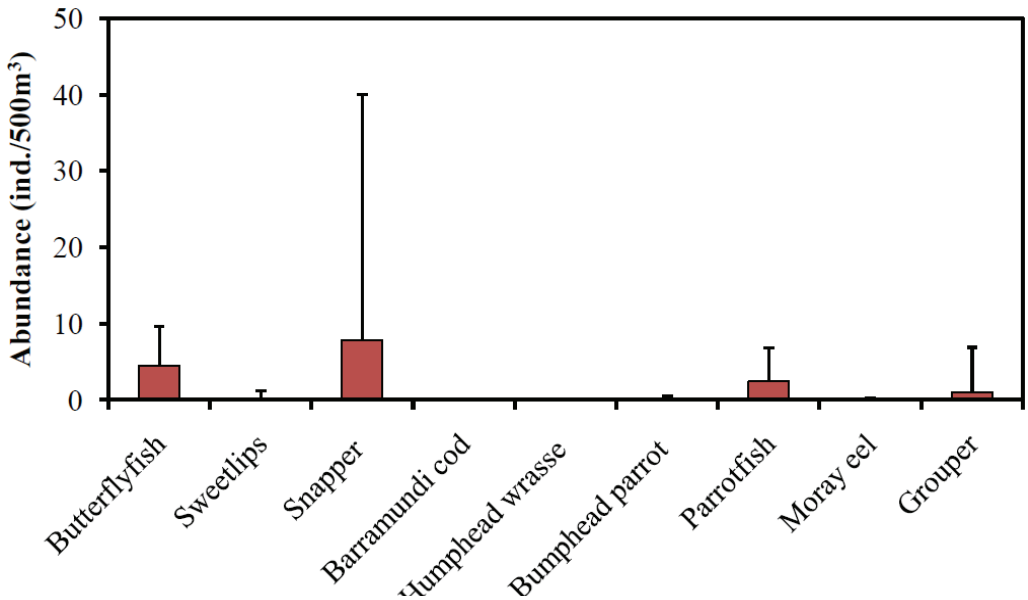

Fig. 2. Abundance of Indicator Fish with Standard Deviation Recorded within 500m^3 Reef Check Surveys in Southeast Asia, 2012. Data used are from Brunei, Philippines, Taiwan, Thailand, Indonesia and Malaysia.

Table 3. RC fish indicator groups between countries in the SEA region

RC Indicator Species	Country					
	Brunei	Philippines	Taiwan	Thailand	Indonesia	Malaysia
Butterflyfish	1.73 ± 1.18	12.57 ± 7.90	1.93 ± 2.57	6.20 ± 8.82	4.91 ± 2.98	4.47 ± 4.14
Sweetlips	0.26 ± 0.27	0.06 ± 0.16	0.13 ± 0.29	0.02 ± 0.07	1.00 ± 1.00	0.25 ± 1.21
Snapper	1.45 ± 3.04	2.14 ± 4.74	0.16 ± 0.60	20.63 ± 50.67	3.46 ± 4.37	11.13 ± 39.55
Barramundi cod	0	0	0.01 ± 0.08	0	0.03 ± 0.08	0.003 ± 0.03
Humphead wrasse	0.005 ± 0.04	0	0	0	0	0.01 ± 0.05
Bumphead parrot	0.12 ± 0.31	0	0	0	0	0.12 ± 0.57
Parrotfish	1.63 ± 1.73	2.19 ± 2.11	0.28 ± 1.00	6.34 ± 12.27	3.71 ± 4.13	2.54 ± 3.19
Moray eel	0.01 ± 0.04	0.22 ± 0.38	0.08 ± 0.15	0.05 ± 0.12	0.14 ± 0.21	0.05 ± 0.12
Grouper	0.19 ± 0.24	0.18 ± 0.44	0.04 ± 0.18	7.68 ± 20.52	0.60 ± 0.82	0.71 ± 0.85

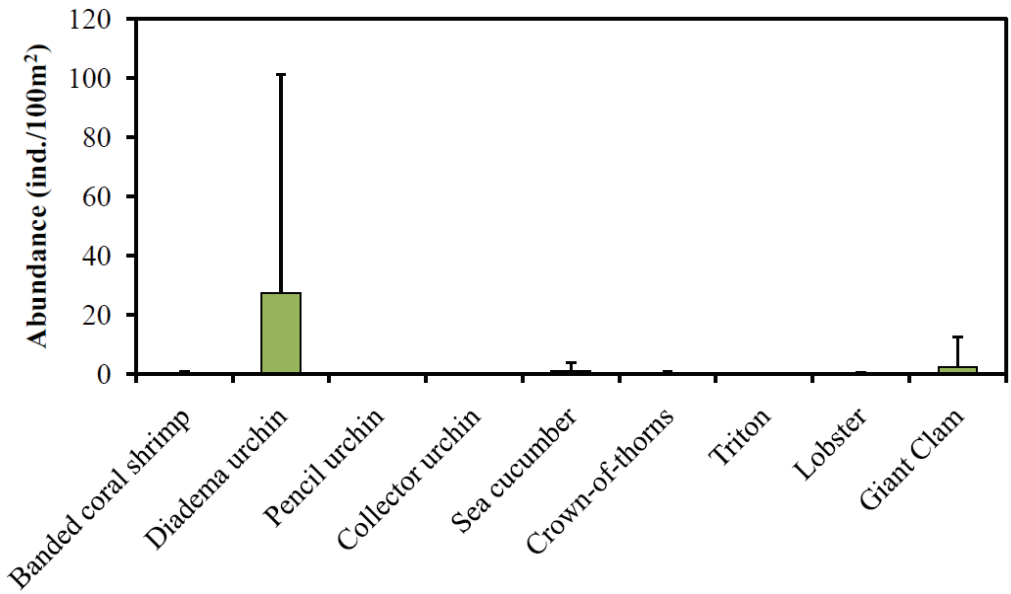

Fig. 3. Abundance of Indicator Invertebrates with Standard Deviation Recorded within 100m^2 Reef Check Surveys in Southeast Asia, 2012. Data used are from Brunei, Philippines, Taiwan, Thailand, Indonesia and Malaysia.

Table 4. Invertebrate RC indicator organism between countries in SEA region

RC Indicator Species	Country					
	Brunei	Philippines	Taiwan	Thailand	Indonesia	Malaysia
Banded coral shrimp	0.01 ± 0.06	0.12 ± 0.27	0.10 ± 0.30	0.31 ± 1.04	0.26 ± 0.59	0.08 ± 0.57
Diadema urchin	0.02 ± 0.06	19.45 ± 18.86	3.11 ± 6.57	94.74 ± 159.29	1.88 ± 2.81	35.36 ± 76.42
Pencil urchin	0	0.01 ± 0.05	0	0	0.06 ± 0.14	0.01 ± 0.03
Collector urchin	0	0.03 ± 0.07	0.09 ± 0.28	0.01 ± 0.05	0	0.001 ± 0.02
Sea cucumber	0.50 ± 1.77	0.02 ± 0.11	0	1.61 ± 1.77	0.35 ± 0.39	1.56 ± 3.31
Crown-of-thorns	0.03 ± 0.09	0.39 ± 1.24	0.06 ± 0.30	0.15 ± 0.36	0.24 ± 0.46	0.21 ± 0.69
Triton	0.01 ± 0.04	0	0	0	0.04 ± 0.10	0
Lobster	0.04 ± 0.10	0.03 ± 0.11	0.03 ± 0.09	0.21 ± 0.54	0.18 ± 0.25	0.01 ± 0.06
Giant Clam	0.17 ± 0.18	2.50 ± 8.38	0.53 ± 0.79	14.96 ± 32.38	0.60 ± 0.44	1.72 ± 4.48

Discussion and Conclusion

This paper provides an overview of the status of coral reefs for SEA based on the results from standardised Reef Check surveys conducted in six countries in 2012. Some limitations apply to the results presented in this study, firstly, the number of survey sites for each country presented in this paper varied based on the availability of Reef Check survey data. Secondly, Taiwan is a state in East Asia. However it is included in this study as the Reef Check "Indicator Species" used for surveys in Taiwan are the same as those used in other countries in SEA, which is the Indo-Pacific Indicator Species.

Substrate

RKC (coral killed within the past one year) results from a variety of impacts; including bleaching, predation and other local stressors (Hodgson, 1999). The relatively low level of RKC indicates few recent impacts to reefs as a whole for SEA countries. However, Thailand recorded the highest RKC percentage among the SEA countries which possibly a results from the 2010 mass bleaching event which impacted the coral reef in Thailand severely (Karenne et al. 2010). Both NIA and sponge is indicator of The nutrient enrichment, at which both will bloom and can cover large areas of reefs (Hodgson, 1999). The low level of NIA (3.42%) and sponge (2.33%) shows that nutrient levels on the reefs are not an issue of concern at present.

Silt arises from a variety of natural sources (e.g. mangroves and mud flats) as well as from land use changes, including agriculture, forestry and development. Silt can smother corals, depriving them of sunlight and causing coral death (Paul et al., 2012). The low level of silt (0.72%) on the reefs is therefore not a cause for concern.

Rubble comprises small pieces of rock, coral fragments, dead shells and other small pieces of substrate. These are created by a number of factors, some natural such as storms (Harborne et al., 2000) and others from human activities, including fish bombing (Koh et al., 2002) and physical impacts from boats, anchors and reef users (Tratalosa et al., 2001). The average level of rubble (9.91%) indicates that the reefs did not suffer from those disturbances. It may also indicate that coral regeneration on the reefs will not be a problem. According to Fox (2004), on damaged reefs with high levels of rubble, coral regeneration is slow due to the difficulty of coral recruiting onto a mobile substrate: new coral recruits are easily damaged or displaced on a mobile substrate moving around in local currents and this state of current-induced abrasion of coral recruits is thus detrimental to the post settlement survivorship of corals.

Rock comprises both natural rock and dead coral (coral dead over a year) and is critical for reef recovery,

regeneration and extension as it forms the base for new corals to recruit onto (Davies et al., 2013). Therefore, some amount of rock is important and the level of rock (26.84%) in this study was considered normal.

Fish

The low abundance of most fish targeted for food and live-food fish trade indicates fishing pressure for these fish is high. The presence of butterfly fish in most survey sites was a good indication that there was low collection pressure for these fish, a popular item in the aquarium trade and usually missing on reefs fished for aquarium trade (Hodgson et al., 2006). Furthermore, the high numbers of butterfly fish at some survey sites reflects the fairly healthy status of reefs around SEA, as they thrive on healthy reefs with many species, if not all, feeding mainly on live tissue of hard corals as food (Hourigan et al., 1988).

Equally important are healthy parrotfish populations. Parrotfish are herbivores and an important control on the amount of algae growing on reefs, helping to protect corals from proliferation of algae. This is achieved by grazing behaviour of parrotfish that limit corals' algal competitors (Mumby, 2009). Subsequently, it promotes settlement of new coral recruits (Davies et al., 2013).

Invertebrate

While the low abundance of invertebrates targeted for curio and food trade may be partly explained by low natural abundance, it may also indicate significant fishing pressure for these invertebrates. However, without baseline data from each area, it is difficult to determine whether this low abundance was due to high levels of fishing or naturally low numbers. Lobsters usually hide during the day and hunt nocturnally; however they are easily observed during the day due to their long antennae which usually extend outside their hiding space. Thus it is very unlikely that many lobsters were missed during surveys as the survey protocol requires searching the crevices (Hodgson, 1999).

The abundance of *Diadema* urchins varies widely between areas, and in some sites they were present in sufficient numbers to cause a concern. In a balanced reef ecosystem, the numbers of *Diadema*, in combination with herbivorous fish, keep algal growth in check and increase the amount of substrate available for settlement by colonial invertebrates (Bradley and Kenneth, 2009).

In high numbers, *Diadema* can have two negative impacts. First, if algae are scarce, their feeding preference can change to coral tissue, and large numbers actively grazing can cause a weakening of the hard coral structure (Carreiro-Silva and McClanahan, 2001). Secondly, urchins scour the reef as they move over

the surface during feeding, removing a large proportion of calcium carbonate in addition to the algae growing on the reef and potentially damaging the reef structure and ecology due to the considerable rates of bio-erosion (Carreiro-Silva and McClanahan, 2001; Griffin et al., 2003). The scouring caused by urchin feeding might also contribute to coral death, particularly for juvenile corals (Sammarco, 1980).

Crown-of-thorns starfish feed on corals and can cause significant damage to coral reefs, destroying large areas in a short period of time. According to CRC Reef Research Centre (Australia), a healthy reef can support a population of 0.2-0.3 ind./100m^2 (Harriott et al., 2003). The abundance of crown-of-thorns found during surveys (0.17 ind./100m^2) was below this range; suggesting that crown-of-thorns numbers are within acceptable limits.

It is acknowledged that the number of survey sites conducted in some of the six countries were not sufficient to fully represent the condition of reefs for that particular country. This can be seen for countries like Philippines and Indonesia where surveys were conducted in less than 25 sites, which is small in comparison to the amount of reefs in those countries. More sites would make both local and regional interpretations of reef health more reliable. As a result, the 2012 survey data may not represent the real situation of the country. We strongly suggest that the number of sites surveyed be increased and to ensure that all the sites are surveyed annually. The resulting Reef Check survey data would provide crucial insight in detecting changes on the reefs on a local and regional scale, as well as providing information for evaluating the success or failure of reef conservation efforts in the SEA region.

However, some broad conclusions can be drawn. There is clearly a wide variation in the condition of reefs around the region and in individual countries. This is perhaps indicative of varying levels of local threats and managers would be advised to focus on reducing their own local threats as far as possible (e.g. from tourism and destructive fishing methods).

The low abundances or absence of most indicator fish and invertebrate indicators suggest that reefs have been overfished. Overfishing of key species has been shown to cause a physical breakdown of the reef system (McClanahan et al., 1995). Therefore, increasing the amount of coral reef in protected areas and strict enforcement of regulations is critical to allow the populations of these indicator species to recover. Introducing aquaculture of these individuals to meet the growing demand for seafood and to build up the natural populations to the size where they can begin to reproduce naturally may also be an option.

Experience in several countries suggests that community involvement in managing reefs may effectively help reef recovery, in addition to instilling sense of ownership and willingness to be the guardian of the reefs among the communities. Involving local communities in monitoring their own reefs can be an important step in building this commitment.

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