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## First Quantitative Assessment of Coral Bleaching in Indonesian Reefs

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### ABSTRACT

Many reefs around the world have experienced repeated besiege, severe coral bleachings followed by coral mortality and recovery in the past decades. There have been few publications on quantitative assessments of the impact of bleaching on Indonesian reefs and none from Sulawesi. A four-year monitoring (2007-2010) of coral reef in the Spermonde and Buton reefs in Sulawesi indicated that coral bleaching only occurred in the years of 2009-2010. Here we provide the first overview of bleaching prevalence among coral colonies and genera based on 142 quadrats transect (50 cm x 50 cm) and 87 digital photos in Spermonde, and on 257 quadrat transects and 96 digital photos of bleaching colonies in Buton reefs. The results shows that the bleached scleractinian famili corals were dominated by Acroporidae, Faviidae, Poritidae and Pocilloporoidae while the Alcyonacea also are affected. The bleached genera were *Acropora*, *Diploastrea*, *Favia*, *Favites*, *Goniopora*, *Porites*, *Pocillopora* and *Simularia*. On the other hand, the resistant genera were *Turbinaria*, *Pachyseris*, *Symphyllia*, and *Heliofungia actiniformis*. Sixty percent of the species were susceptible to bleaching in Spermonde reef and 58% in Buton reefs. These bleaching events had decreased the live coral cover by 12.45% in Spermonde Reef between 2009-2010. Fishermen of these reefs observed the first bleaching on May of 2010, though some observed it later on the month of June and July in the same year. The bleaching occurrence had reduced the reef fishes in the reef ecosystem as well as the fish catch.

**Keyword** : coral bleaching, Indonesian reefs

### Introduction

Many reefs around the world has experienced frequent severe coral bleaching followed by coral mortality and/or its recovery in the three past decades. Mass bleaching were recorded during 1979-1980, 1982-1983, 1987, 1991, 1994, 1998. There were no reports of bleaching events prior to 1979 (Gulberg and Loya 2009). The last record on Indonesian reefs was more than 12 years since the extensive coral bleaching phenomenon in 1997-1998. Nevertheless, the bleaching phenomenon in Indonesian reefs was never reported simultaneously. Lately, local coral reef bleaching occurred and been observed on April 2009 in Indonesia. Previous research done by Yusuf et al (2010) on Badi Island of Spermonde Makassar Strait, found that mass coral bleaching struck the area again in 2010 (Jompa and Yusuf 2010; Tun et al 2010; Setiasih 2010).

Water temperature rise in the area were reported related to the El-Nino events. This high temperature anomaly causes coral bleaching in almost all the Indo

Pacific and Indian Ocean. Wallace and AW (2000) reported that coral reefs around the Indian Ocean, Southeast Asia, and Caribbean Sea bleached more than 30% in 1998. The recent phenomenon were widespread, affecting many reefs within the region, with countries reporting severe bleaching comparable to, and in some cases, more severe than the 1998 bleaching event. In 2010, Southeast Asia coral bleaching occurred in response to elevated sea surface temperatures (SST) caused by the intense La Niña event that started in early 2009 (Tun et al 2010).

Mass coral bleaching in Indonesia in 2010 were recorded happened to the reefs from western Aceh to Ambon and few in Raja Ampat. According to Tun et al (2010), coral bleaching in Makassar Straits is unpredictable. Some susceptible species were reported bleached, while in some areas, severe bleaching also affected more resistant genus.

The coral bleaching of 2009 and 2010 in Sulawesi according to us from Center for Coral Reef Research and Marine Coastal and Small Island (MaCSI) Research

were impacted by the Sea Surface Temperature (SST) rise due to climate change. It was necessary to compare the difference SST in the year of 2004 and 2010. Therefore, this study aims to quantify the extent of coral bleaching prevalence in taxa and the colonies of Spermonde and Buton Reefs, Indonesia.

## Material and Methods

### Study Site

Study sites were located on Spermonde Archipelago Reef in South West of Sulawesi and Buton Island fringing reefs in Southeast Sulawesi, Indonesia (Fig. 1)

*Spermonde Archipelago* extends approximately 60 km offshore, about 150 coral cays and islands, as well as a large number of barrier and submerged patch reefs, fringing reefs and extensive soft substrate habitats (Wardmann 1995 in Knitweis et al 2009, Pet-Soede, 2000, Moll 1983, Tomascik et al 1997).

*Buton Fringing Reefs* is located around Buton Island is also the name of the district. It is geographically located at latitude 4.96 ° - 6.25 °S and 120° - 123.34° E. Buton coral reefs extended to 221.82 km<sup>2</sup> having 231 species of reef fish species.

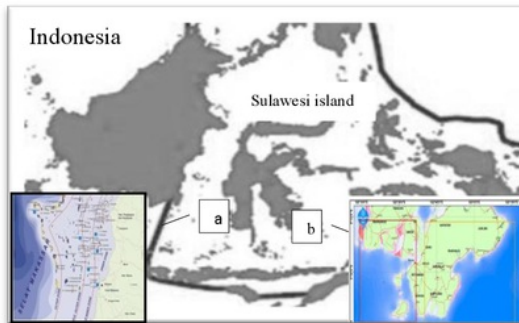


Figure 1. Site of study in south west and south east Sulawesi region, Indonesia (a) Spermonde Archipelago and (b) Buton Island (map from Critic Coremap LIPI)

### Sea Surface Temperature (SST) measurement

Sea surface temperature was measured manually using digital thermometer, during morning (06:00-07:00am), midday (12:00-13:00) and afternoon (17:00-18:00pm). The sampling were done in the period of May 2009 to August 2011 in Badi Island, Spermonde. Anomaly data analysis for SST was based on the normal average temperature of 29.08 °C in 2004-2006.

### Bleaching prevalences observation

Coral reef bleaching observed using quadrant transects (English et al 1997; Krebs 1999; Brokovich et

al 2009) 50 cm x 50 cm, with total transects 142 in Spermonde and 257 transects in Buton. Quadrant transects were placed on the left and right along the line transects of 25 m. The line transects was placed on the reef slope of 3-5 m depth. The digital camera was also used to record the bleaching (Brokovic, et al 2009). All in all, there are 87 photos of coral colonies in Spermonde and 96 photos in Buton.

The coral colonies were estimated in proportion to the affected area of the bleached colony and the healthy living coral. The prevalence of bleaching coral is divided into four conditions, namely: 1) fresh life polyps, 2) partially bleach colony, 3) whole bleach and 4) algal covered. Afterward, all the species in the sampling quadrant transects are classified as either bleaching species or resistant species.

### Live coral coverage

Live coral cover were measured using the Point Intercept Transect of 25 m in length and were repeated three times in each location. Datas of live coral coverage in Buton were taken Critic-Coremap LIPI and local Coremap monitoring (2006-2010) reports while for Spermonde were taken from Hasanuddin University's researchs reports (2007-2010). Coral species in transect square and free sampling were identify into species or genera (Veron 2000, Wallace 1998, Suharsono 2009).

### Local knowledge

This study describes the local community's view of the climate change, associated with the phenomenon of coral mortality which impacted local fishing. Around 26 local active fishermen were taken as respondents from six different villages, mostly in between 20 to 46 years old, but there were two respondents aging 60 and 70 years old and still active as fisherman. Among those, one of the respondents is female and doing fishing with her husband.

## Results

### Sea Surface Temperature Rise

Sea Surface Temperature (SST) rise in Spermonde Reef were based on 540 days observations from May 2009 to December 2010 (Fig.2). While normal SST in Spermonde was approximately 29.08 °C (Rani *et al*, 2006), the result shows that the highest temperature anomaly reached up to 3.8 °C and the lowest was 1.49 °C. The high SST anomaly were found grouped into four periods: 1) before May 2009, 2) September – December 2009, 3) February – May 2010, and 4) September – November 2010.

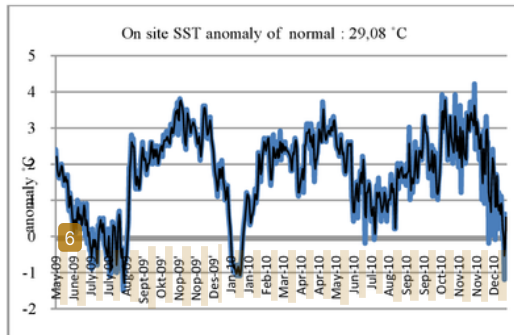


Figure 2. Elevated sea surface temperature (°C) on site of Spermonde Archipelago.

### Coral Community

Spermonde Archipelago has a great variety of corals: 78 genera and subgenera, 262 total species (Moll 1983). A study of LIPI (1996) reported that 239 species of hard corals in the vicinity of Kaposang Island or approximately 40% of overall 590 coral species in Indonesia. The dominant genera were *Acropora*, *Porites*, *Fungia*, *Montipora*, *Pocillopora*, *Seriatopora*, *Favia* and *Favites*, whereas, rarely found genera were *Catalaphyllia*, *Cynarina*, *Blastomussa*, *Plerogyra*, *Tubastrea*, *Trachyphyllia*, *Nemenezophyllia*, etc (Yusuf 2005). Critic-Coremap LIPI (2008) observed coral communities in Buton Reefs at 14 sites and found 111 species of 15 families of hard corals (Scleractinia). At several research sites e.g. Kance Bungi Reef, the community was dominated by non *Acropora* such as massive corals of *Porites*, *Favia*, *Favites*, *Montipora*, *Goniopora*, and *Fungia*. However, dominance of *Acropora*, *Fungia*, *Pocillopora* and *Seriatopora* were observed in other location.

### Live Coral Cover Change

Table 1 shows live coral cover from 2006 to 2010, both in Spermonde and Buton. The table indicates an increase in coral coverage from 2007 to 2009 and a decreased in 2010 for Spermonde. Further discussion, will elaborate the coral bleaching in 2009 – 2010 of Spermonde..

Year	Y.2006	Y.2007	Y.2008	Y.2009	Y.2010
Spermonde Reef	No data	36,25%	46,77%	47,26%	23,10%
Buton Reefs	29,79%	30,16%	32,05%	30,61%	28,17%

Table 1. Live coral cover in 2006-2010 from permanent transects both in Spermonde and Buton Reefs (Critic Coremap LIPI 2006-2010)

As for Buton Reefs, live coral cover tends to increased from 2006 to 2008, but decreased in 2009 and

2010. The decreased were assumed as an impact of the bleaching event in 2009 and 2010.

### Bleaching Prevalence of Coral Colonies

Coral bleaching of 2010 in Sulawesi Indonesia is presented in Fig.3. The figure shows that healthy coral colonies category was recorded 42% in Buton and 24% in Spermonde. In contrast, intensity of coral bleaching (partly and whole) was higher in Spermonde compared to Buton reefs. However, coral colonies covered by algae was more in Buton than in Spermonde.

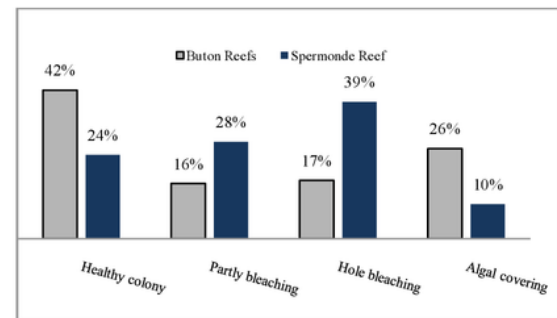


Fig 3. Prevalencies of bleaching of coral colonies in Buton and Spermonde Reefs in 2010.

Therefore, it may be assumed that: 1) in general, more coral colonies in Buton were more resistant than Spermonde; 2) species diversity and density of coral colonies in Spermonde Reef are higher, hence the proportion of bleached corals is higher as well; 3) during periods of several months corals in Spermonde were quickly recovered and not dying unlike in Buton, prior to bleaching coral colonies were wrapped by algae.

In addition, Spermonde reef are located in the route of Indonesian throughflow and are more vulnerable to coral bleaching. Warmer water mass from the Pacific Ocean passing Makassar Strait and encompass the Spermonde Reef. Whereas, Buton Reef has geographical variation of its coasts and bays so that the water mass is well mixed causing lower temperature anomaly compared to Spermonde Waters.

Figure 4 shows the changes proportion of four stages of coral bleaching as observed in June 2010 and November 2010. There was an increased in proportion of healthy coral polyps and algal-covered colonies. In contrast, there was decreasing in proportion of bleached polyps and clean skeleton. These prevalence changes indicated a decrease in the bleaching intensity during five months. For the bleached corals, there is possibility to become healthy polyps again whenever the temperature is back to the normal condition. Similarly, proportion of clean skeleton until November 2010 has decreased and changed to dead coral colonies wrapped by algae.

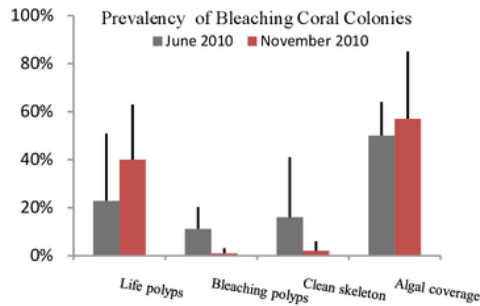


Figure 4. Four categories of coral bleaching prevalence changes on June and November 2010.

#### Bleaching and Resistance colonies of Coral genera

Some quite predominant coral genera in each coral reef community are *Acropora*, *Porites*, *Favites*, *Montipora* and *Fungia*. Almost all coral genera, expected values of resistant corals were higher than those bleaching corals in Spermonde Reef ( $n_{bleaching} 47 < n_{resist} 60$ ). In other hand, more bleached corals than resistant corals ( $n_{bleaching} 28 > n_{resist} 26$ ). In overall, numbers of recorded coral genera and colonies in Spermonde reef were higher than those in Buton. This indicated that condition of coral reef community in Spermonde reef is better than Buton reef. It is a fascinating fact in which coral bleaching in Spermonde reef in 2009 had slightly higher expectation values than in 2010.

#### Bleaching Prevalencies of Coral Families

Figure 5a and 5b below displayed prevalence of coral bleaching summarized within taxa family group. Intensity of coral bleaching at family Pocilloporidae and Euphyllidae was recorded as the highest 100%, while bigger coral polyps of Family Mussidae had 95% of bleaching prevalence.

More than 50% Agariciidae and Poritidae had prevalence of healthy polyps during the study in June 2010, in which both of these are more resisted to the SST gradients than others. The prevalence of Faviidae, Acroporidae, Oculinidae, Mussidae, Pocilloporidae, Pectinidae and Euphyllidae were exceeded 50% of bleaching category.

Bleaching polyps during the study at Acroporidae was 31%, that Acroporidae experienced bleaching earlier before this study was commenced. Family of Pectinidae is the weakest SST anomalies, and the worst was soft corals (Alcyonidae) were crushed.

Observed in Buton reefs, Euphyllidae, Mussidae and Pocilloporidae had prevalence of healthy polyps as much as 50%. Whereas, Acroporidae, Agariciidae,

Faviidae, Fungiidae and Poritidae had healthy polyps less than 50% that may survive more than 50%. Acroporidae, in which more than 50% had covered by algae in June 2010. It meant that this coral is suffered from bleaching faster than any other corals. On the other hand, for Euphyllidae, healthy polyps was accounted to more than 60% showing ability to adapt to the increasing temperature changes.

#### Local Knowledge of Climate Change and Bleaching

Marine and coastal is an area that is also vulnerable to climate change, and the impacts were felt by the local communities. According to the local communities in Sulawesi, climate change is a phenomenon of extreme weather. Perceived and directly impact their lives. Some 77% of the respondents ( $n=26$ ) knew the climate change. They consider that a bit extreme of natural events are mediocre as well have held in last times.

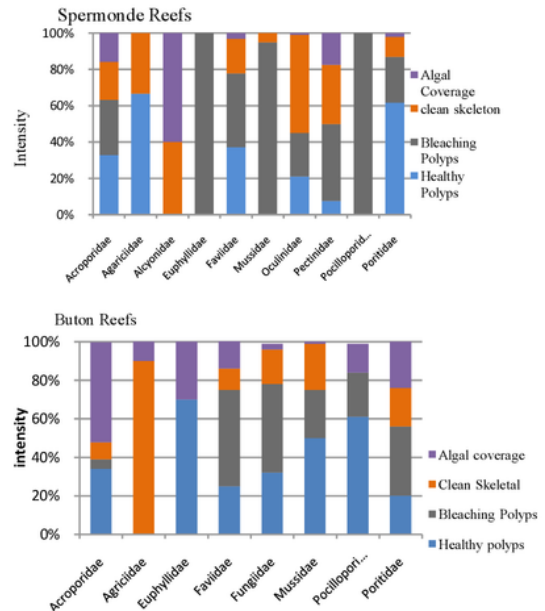


Figure 6. Four categories of bleaching prevalence of coral families on Spermonde Reef and Buton Reefs. The categories: healthy polyps, bleached polyps, clean skeleton, algal coverage.

Fishermen were often understood as a symptom of climate change as extreme weather is directly occurring to human race. For example, bad weather at sea, during rainy season with high wind and waves. What is felt by the people due to the weather is actually a part of the phenomenon of climate change.

Local fishermen call the phenomenon of climate change include: long term rainy season, storm, higher waves and high sea water temperature. Among these

phenomena, prolonged rain is a phenomenon of climate change the most important perceived namely by 47%. Prolonged rains with winds are assessed as both a phenomenon that is by 29%. Otherwise, 16% of the high wave phenomenon as a result of tight wind. These are the dominance mind of local fishermen about the climate change.

They were less familiar with the SST, it was only 8% of respondents understand that the SST may impact to climate change or coral bleaching. According to the local fishermen, coral bleaching has been found since May 2010 (35%) of respondents. Respondents characterize the phenomenon of bleaching in a small category as much as 54%.

The fishermen argued that bleaching events caused less fish populations. Reduced populations of coral reef fish as residents have an impact on the reduction of fishing. It is also found in this study where 81% of respondents said that when the little fish catches during the bleaching.

#### Discussion

This study showed significant degradation in both coral reefs quantity and quality in 2010 in Spermonde Reef and Buton reefs. This phenomenon was strong evidence of bleaching effects to the coral communities.

Severe coral bleaching in the Spermonde Archipelago, which has around 70.000 ha of patch and fringing reefs. Our recent observation for the coral reef condition indicated that coral bleaching were only happened in the last few years, significantly in 2010. Otherwise, mass bleaching in Indonesia for the year (2010) were recorded in many reefs from western Aceh to Ambon and few in raja Ampat Sabang, Aceh, Padang, Thousand Island of Jakarta, Karimun Jawa, Situbondo, Banyuwangi, Bali (Ngurah Rai Reef, North-East Bali), the Gilis Lombok, Bangko-Bangko, Kupang, Wakatobi, Spermonde, Tomini Bay, and Ambon.

Our direct measurement on water temperature in the last 2 year 2009-2010 indicated that the temperature anomaly rate was around 2,27°C warmer (during April-May 2010) which higher 3,8°C compared to the average yearly water temperature were stimulation factor to initiate a bleaching event. The maximum SST anomaly in this research is closely similar to that in Palau which heating to 3.9 degree than normal. It was causing some corals dead in 1998 (Gulberg, 2002) to 70-90 %. Study in Wakatobi Reef on December had prevalence 23.55% -50.94% of bleaching. Whereas, in Buton Reefs was as much as 33 %. J.Wilson observation in Wakatobi on July 2010 revealed that about 60-65% of corals surveyed showed some signs of bleaching with 10-17% of colonies recorded as fully bleached (white) (Setiasih, 2010).

Otherwise, due to individual and species responses to SST anomaly were different in time and space. Some react to bleaching directly, and others was resistant. Monitoring of natural bleaching events has revealed marked interspecific and intraspecific variation in the degree of bleaching at one site. Among corals, branching forms, e.g. *Acropora* and *Pocillopora* species, generally bleach more strongly than massive corals (McClanahan et al 2001).

On this study, the most bleaching suffered were *Acropora*, *Porites*, *Favia*, *Favites*, *Montipora*, *Fungia* and *Goniopora*. A comparison in 1998 in Kenya, coral species that suffered more bleaching were *Pocillopora verrucosa* and *Porites lutea*. Other species of *Acropora*, *Echinopora*, *Galaxea*, *Montipora*, *Pavona*, *Platygyra*, *Favia* and *Fungia* were also responding to the temperature increase by releasing zooxanthellae as primary indicator of bleaching (McClanahan 2003). Baird and Marshall (2002) find that *Acropora* colonies bleached quickly and most had either recovered or died, in contrast the *Platygyra* and *Porites* took longer to bleach, longer to recover and to die. On this study, soft coral taxa were dramatically dead and completely crushed in June 2010 in Spermonde. The Soft corals species that had white colonies, were like *Simularia spp*, *Sarcophyton spp*, and *Lobophytum spp*.

All fishermen had known while this phenomenon caused less reef fishes in around of coral reef, and should be adapted for several months. Since significant number of local fishermen depends on coral reef related resources, the severity of this bleaching might potentially have serious threat for them. Therefore, adaptive strategic management need to be developed both locally and nationally to cope with the potential effects of climate changes.

#### Acknowledgement

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