First Quantitative Assessment of Coral Bleaching on Indonesian Reefs

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ABSTRACT

Many reefs around the world have experienced repeated disturbances, particularly severe coral bleaching followed by coral mortality in the past decades, however, there have been few quantitative assessments of the impact of bleaching on Indonesian reefs and none published from Sulawesi. A four-year monitoring program (2007-2010) of coral reefs in the Spermonde and of Buton reefs in Sulawesi indicated that coral bleaching only occurred in the years 2009-2010. Here we provide the first report of bleaching prevalence among coral colonies and genera based on 142 quadrats (50 cm x 50 cm) and 87 digital photos in Spermonde, and 257 quadrats and 96 digital photos of bleached colonies in Buton reefs. The results show that the scleractinian families most susceptible to bleaching were the Acroporidae, Faviidae, Poritidae and Pocilloporoidae, and the Alcyonacea were also affected. The genera most susceptible to bleaching were the *Acropora, Diploastrea, Favia, Favites, Goniopora, Porites, Pocillopora* and *Sinularia*. The genera most resistant to bleaching were *Turbinaria, Pachyseris, Symphyllia,* and *Heliofungia actiniformis*. Sixty percent of species were susceptible to bleaching in Spermonde reef and 58% in Buton reefs. These bleaching events decreased live coral cover by 12.45% in Spermonde Reef between 2009-2010. Fishermen on these reefs first saw the bleaching in May; other respondents saw bleaching in June and July 2010. The bleaching occurence has reduced the abundance of reef fishes in the reef ecosystem and the number of fish caught.

Keyword： coral bleaching, Indonesian reefs

Introduction

Many reefs around the world have experienced frequent severe coral bleaching followed by coral mortality and/or recovery in the past three decades. Globally, mass bleaching events have been recorded in 1979-80, 1982-83, 1987, 1991, 1994, 1998, but bleaching events were not reported prior to 1979 (Hoegh-Guldberg and Loya 2009). It has been over 12 years since the last report of major bleaching on Indonesian reefs in 1997-1998. Since then, coral bleaching on Indonesian reefs occurred locally in April 2009 on Badi Island of Spermonde, Makassar Strait (Yusuf et al. 2010), and more widely throughout the region and globally in 2010 (Jompa and Yusuf 2010; Tun et al. 2010; Setiasih 2010).

High sea surface temperature (SST) anomalies have been linked with coral bleaching on almost all Indo-Pacific and Indian Ocean reefs, with more than 50% of corals bleaching on reefs in the Indian Ocean, Southeast Asia, and Caribbean Sea in 1998 (Wallace and AW, 2000). In 2010, coral bleaching on Southeast Asian reefs occurred in response to elevated sea surface temperatures (SST) caused by the intense La Niña event that started in early 2010 within the region and continued into late 2010 (Tun et al. 2010).

Mass bleaching on Indonesian reefs in 2010 occurred on reefs from western Aceh to Ambon, as well as on a few reefs in Raja Ampat. Otherwise, Tun et al. (2010) reported that bleaching of corals in Spermonde Archipelago in Makassar Strait is unpredictable.

During the 2009 and 2010 bleaching events in Sulawesi, our Center for Coral Reef Research and Marine Coastal and Small Island (MaCSI) Research and Development of Hasanuddin University was monitoring sea surface temperatures. In this study, we compare the timing of bleaching events with the timing of sea surface temperature (SST) anomalies in manual timeseries of SST on Spermonde reef for two years (2009 and 2010). The aims of this study are to quantify the extent of coral bleaching in 2009 and 2010, and to identify coral taxa that are susceptible or resistant to coral bleaching on Spermonde and Buton Reefs, Indonesia.

Material and Methods

Study Sites

Study sites were located on reefs in the Spermonde Archipelago in Southwest Sulawesi and on Buton Island fringing reefs in Southeast Sulawesi, Indonesia (Fig. 1). *Spermonde Archipelago* extends approximately 60 km offshore and is comprised of about 150 coral cays and islands, as well as a large number of barrier and submerged patch reefs, fringing reefs and extensive soft substratum habitats (Erdmann 1995, in Knitweis et al. 2009, Pet-Soede 2000, Moll 1983, Tomascik et al. 1997). The Archipelago can be divided into different zones parallel to the coastline, reflecting the strength of land or open ocean influences (Yanuarita 2012). *Buton Fringing Reefs* are located around Buton Island (latitude: 4.96 ° - 6.25 °S; longitude: 120° - 123.34° E). Reefs in Buton are extensive, covering 221.82 km^2. Overall, these reefs had 29.79% coral cover, with 231 species of reef fish species.

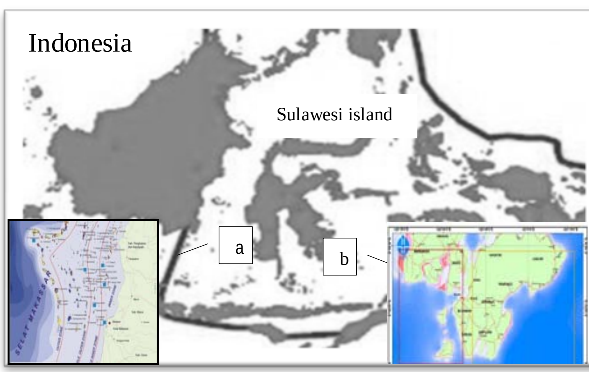

Figure 1: Study sites in Southwest and Southeast Sulawesi: (a) Spermonde Archipelago, (b) Buton Island (from Critc Coremap LIPI)

Sea Surface temperature (SST) measurement

Sea surface temperature was measured manually by a digital thermometer three times a day, i.e. morning (06:00-7:00am), midday (12:00-13:00) and afternoon (17:00-18.00pm), between May 2009 and August 2011 on reefs at Badi Island, Spermonde Archipelago. SST anomalies were identified based on the normal average temperature of 29.08°C in 2004-2006 (Yusuf and Rani 2006).

Bleaching prevalences observation

Coral bleaching was quantified using 25m belt transects comprised of 50cm x 50cm quadrats (English et al 1997; Krebs 1999; Brokovich et al 2009). In total, 142 quadrats were photographed in Spermonde and 257 in Buton. Quadrats were placed on either side of the line transects, which were laid on the reef slope at 3-5 m depth. Assessments of bleaching were made from 87 digital photos of corals in Spermonde, and 96 digital photos in Buton (Brokovich et al. 2009).

Bleaching impact was determined by estimating the proportions of each colony that were bleached or healthy. The prevalence of corals in each of four conditions was recorded, namely: 1) healthy live polyps, 2) partially bleached colony, 3) whole colony bleached, and 4) algal covered. Based on subsequent analysis, all species observed on the transects were classified as 1) bleaching susceptible, or 2) bleaching resistant species.

Live coral coverage

Live coral cover was measured by the Point Intercept Transect method, using 25 m transects, which were replicated 3 times at each location. Live coral cover data in Buton were from Critc-Coremap LIPI and local Coremap monitoring (2006-2010). In Spermonde, data were from Hasanuddin University (2007-2010). Coral species were identified to species or genera (Veron 2000, Wallace and Wolstenholme 1998, Suharsono 2009).

Local knowledge

Local views of climate change and the impacts of bleaching-induced coral mortality on local fishing were recorded. Around 26 active local fishermen from six villages were respondents. Fishermen ranged from 20-46 years old, except for two who were 0 and 70 years old but still active as fisherman. Among those one of the respondents was a female who actively fishing with her husband.

Results

Elevated Sea Surface Temperature

A trend for increasing SST's from May 2009 to December 2010 was detected at Spermonde Reef (Fig.2). Compared to normal average SSTs in Spermonde 29.08 ˚C (Yusuf and Rani 2006), the highest temperature anomaly was 3.8 ˚C, while the lowest was -1.49 ˚C. High SST anomalies were divided into four periods, i.e. 1) before May 2009, 2) September – December 2009, 3) February – May 2010, and 4) September – November 2010.

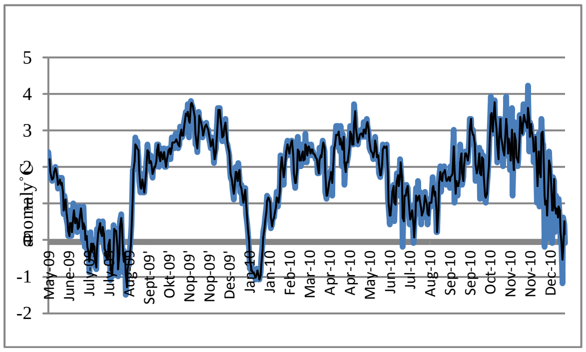

Figure 2:. Temporal patterns in sea surface temperature anomalies (°C) at Spermonde Archipelago relative to the mean of 29.08 °C.

Coral Community

Spermonde Archipelago has a high diversity of corals: 78 genera and subgenera and 262 species (Moll 1983). A LIPI study (1996) recorded 239 species of hard corals in the vicinity of Kapoposang Island, or approximately 40% of the 590 coral species so far recorded in Indonesia. The dominant genera were *Acropora, Porites, Fungia, Montipora, Pocillopora, Seriatopora, Favia* and *Favites* and rare genera were *Catalaphyllia, Cynarina, Blastomussa, Plerogyra, Tubastrea, Trachyphyllia, Nemenzophyllia*, etc (Yusuf and Rani 2006). Critc-Coremap LIPI (2008) recorded 111 species of coral in 15 families on Buton Reefs at 14 sites. Several research sites (e.g. Kance Bungi Reef) were dominated by massive corals, including *Porites, Favia, Favites, Montipora, Goniopora, and Fungia.* However, dominance of *Acropora, Fungia, Pocillopora* and *Seriatopora* was observed at other locations.

Changes in Live Coral Cover

Coral reef monitoring revealed increases in coral cover from 2007 to 2009, but a decrease in 2010 on Spermonde Reefs (Table 1). On Buton reefs, live coral cover increased every year, except in 2009 and 2010.

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 (Critc Coremap LIPI 2006-2010)

Bleaching Prevalence of Coral Colonies

Coral bleaching in Sulawesi Indonesia have quantified in 2010 (Fig.3). At category of healthy coral colonies, it was recorded that 42% and 24% were found at Buton and Spermonde Reefs, respectively. In contrast, intensity of coral bleaching (partly and whole) was higher in Spermonde reefs compared to Buton reefs. More coral colonies in Buton Reefs were covered by algae than those in Spermonde Reefs.

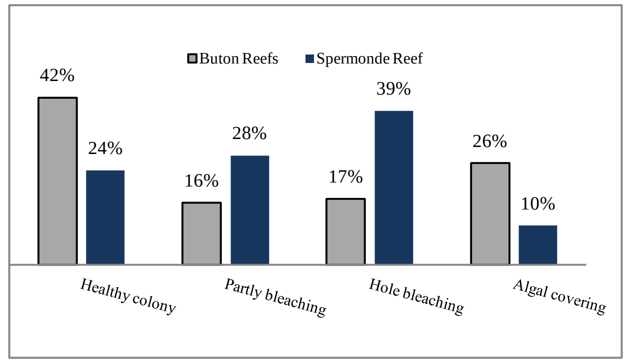

Figure 3:. Prevalecies of bleaching of coral colonies in Buton and Spermonde Reefs in 2010.

From this data, it may be assumed that 1) in general, more coral colonies in Buton Fringing Reef having resistant ability compared to those in Spermonde Reef. 2) species diversity and density of coral colonies in Spermonde Reef are higher, therefore, the proportion of bleached corals is higher as well. 3) After several months corals in Spermonde Reef quickly recovered and not dying unlike in Buton, wherein prior to bleaching coral colonies were wrapped by algae.

In addition, Spermonde Reef are located in the route of the Indonesian throughflow is 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 in the proportion of the four stages of effect of coral bleaching as observed on June 2010 and November 2010. There was increasing 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 back to the normal condition. Similarly, the proportion of clean skeleton until November 2010 has decreased and changed to dead coral colonies wrapped by algae.

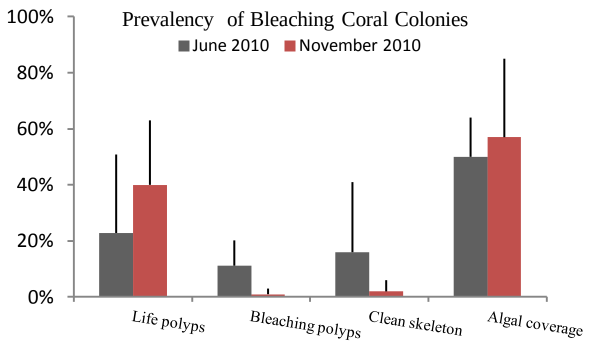

Figure 4: Four categories of coral bleaching prevalence changes on June and November 2010.

Bleaching and Resistant colonies of Coral genera

Several quite predominant coral genera in each coral reef community such as *Acropora*, *Porites*, *Favites*, *Montipora* and *Fungia*. The expected number of resistant coral generas were higher than those bleaching susceptible 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 Buton. 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 is better than Buton reef. It is a noteworthy that in the 2009 coral bleaching in the Spermonde Reefs slightly higher expectation values were observed than in 2010.

Bleaching Prevalencies of Coral Families

Figure 6 below is displayed prevalence of coral bleaching summarized within family group taxa. Intensity of coral bleaching for family Pocilloporidae and Euphyllidae was recorded as the highest 100%, n=1), while bigger coral polyps of Family Mussidae had 95% of bleaching prevalence.

More than 50% Agariciidae and Poritidae had a prevalence of healthy polyps during the study on June 2010, both of these are more resistant to the SST anomalies than others. Whereas, prevalence of Faviidae, Acroporidae, Oculinidae, Mussidae, Pocilloporidae, Pectinidae and Euphyllidae was exceeded 50% of the bleaching category.

During the study Bleaching polyps for Acroporidae was 31% with Acroporidae exhibiting bleaching earlier than when this study was initiated. Family Pectinidae showed the weakest responses to SST anomalies, and the worst response showing soft corals (Alcyonidae) disintegrating.

Observed in Buton reefs showing Euphyllidae, Mussidae and Pocilloporidae had prevalence of healthy polyps as much as 50%. Whereas for Acroporidae, Agariciidae, Faviidae, Fungiidae and Poritidae showing healthy polyps of less than 50% that may more than 50% survivorship. Acroporidae exhibited more than 50% being covered by algae by June 2010. It meant that this coral suffered by bleaching with greater sensitivity than others. On the other hand, Euphyllidae had been counted the healthy polyps for more than 60%showing ability to adapt to the hight SST anomalies.

Local Knowledge of Climate Change and Bleaching

Marine and coastal areas that were vulnerable to climate change, and their impacts were felt by local communities. According to the local communities in Sulawesi, climate change is relevant to extreme weather events. Their perception and direct impact to their lives were explore. Some 77% of the respondents (n=26) knew about climate change. They considered that extreme natural events are mederate experience in the recent past.

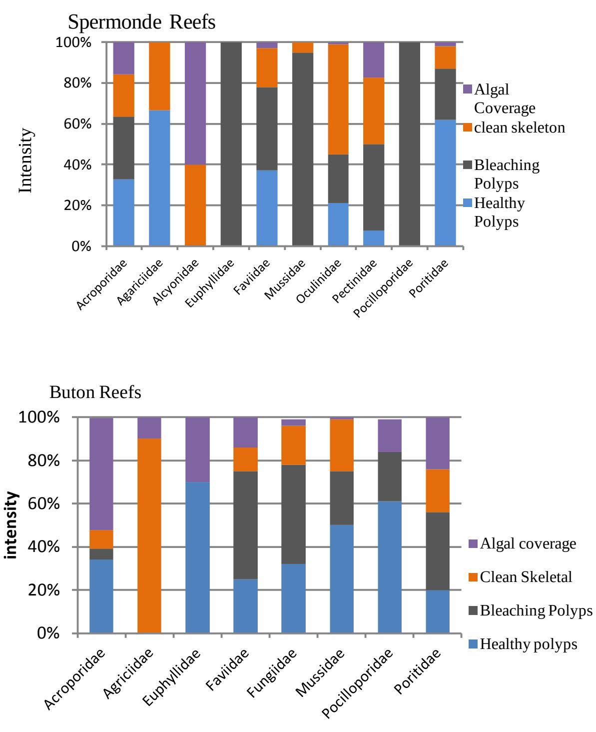

Figure 6: Four categories of bleaching prevalecies of coral families on Spermonde Reef and Buton Reefs. The categories: healthy polyps, bleached polys, clean skeleton, algal coverage.

Fishermen often understood extreme weather as a symptom of climate change is directly experienced by the human race. For example, bad weather at sea, along rain season with strong wind and big waves as this manifestation. What is felt by the people due to the weather variability is actually their reference to the phenomenon of climate change.

Local fishermen refer to the climate change phenomenon to include: long term raining season, storm, higher waves and increase sea surface temperature. Among these phenomena, prolonged rain is also part of the phenomenon of climate change scoring the highest in their perception 47%. Prolonged rain with strong winds was assessed as both an important phenomenon by 29% of the respondent. On the other hand, 16% of the high wave phenomenon as a result of tight wind. These are the predominant perception of local fishermen about the climate change.

They were less familiar with the SST, wherein only 8% of respondents understand that the SST as an impact related to climate change or coral bleaching. According to the local fishermen, coral bleaching has been observed since May 2010 by (35%) of respondents. About 54% of respondents characterized bleaching as linked to climate change ranking it in the lowcategory.

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 fish catch. It also found in this study where 81% of respondents said that there is less of fish catches during the bleaching.

Discussion

This study showed significant degradation in both quantity and quality coral reefs in 2010 as seen in Spermonde Reef and Buton reefs. This phenomenom provided a strong evidence of bleaching effects on the coral communities.

Severe coral bleaching in the Spermonde Archipelago, covering around 70,000 ha of patch and fringing reefs. Our recent observation for the coral reef conditions indicate that coral bleaching were only observed in the last few years, especially significant in 2010. Otherwise, mass bleaching in Indonesia for the year (2010) were recorded in many reef from western Aceh to Ambon and in few areas 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 tempareture in the last 2 year 2009-2010 indicated that the temperature anomally rate was around 2.27^{o}C warmer (during April-May 2010) which higher 3,8^{o}C compared to the average yearly water temprature. This was a stimulating factor that initiated a bleaching event. The maximum SST anomaly in this research is closely similar to the occurrence in Palau where heating up to 3.9 degree than normal was seen. It was causing some corals to die in 1998 (Hoegh-Guldberg 2002) to 70-90 %. A study in Wakatobi Reef on December had prevalence 23.55% - 50.94% of bleaching. Whereas in Buton Reefs, bleaching was seen to be 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 the individual and species respons to SST anomally were different in time and space. Some react to bleaching directly, and others was resistant. Monitoring of natural bleaching events have 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 the 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 to *Platygyra* and *Porites* wherein it took longer to bleach, recover and die. On this study, soft coral taxa dramatically died and were completely disintegrated in June 2010 in Spermonde. The Soft corals species that had turned into white colonies were *Sinularia spp, Sarcophyton spp,* and *Lobophytum spp.*

All fishermen had known of this phenomenon perceiving less reef fishes in coral reefs and should take several months to adapt. Since there are significant numbers of local fishermen depending on coral reef resources, the severity of the bleaching event might potentally have serious potential impacts for them. Therefore, adaptive strategic management need to be developed both locally and nationally to cope with the potential effects of climate changes.

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