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South-East Asia Coral Bleaching Rapid Response: Final Report

Prepared by Colette R. Thomas and Scott F. Heron
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Australian Department of Sustainability, Environment, Water, Population and Communities
U.S. National Oceanic and Atmospheric Administration
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Enquiries should be addressed to:

Dr Colette Thomas

colette.thomas@csiro.au
Ph: +61 7 4753 8564
Mob: +61 458 003 290

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Project title
Rapid Response to Coral Bleaching in South-East Asia (Phase I)

Principal investigator
Colette Thomas (CSIRO)

Research partners
U.S. National Oceanic and Atmospheric Administration
Reef Check Foundation Indonesia
University Malaysia Terengganu
Prince of Songkla University
Macquarie University

Research locations and protected area status

Research was undertaken in three countries of the Great Coral triangle region; Thailand, Malaysia and Indonesia (Table 1).

Table 1. Research locations visited during the project. NP = National Park, MP = Marine Park

Country	Region	Region number	Protected Area
Thailand	Pattaya	1	Nil
	Ko Tao	2	Nil
	Ko Samui	3	Nil
	Ko Phi Phi	4	Mu Ko Phi Phi NP
	Ko Racha	5	Nil
Malaysia	Perhentian	6	Perhentian MP
	Redang	7	Redang MP
	Tenggol	8	Nil
	Tioman	9	Tioman MP
Indonesia	Bali	10	Bali Barat NP
	Lombok	11	Nil
	North Sulawesi	12	Bunaken NP

Date report completed
05 April 2011

Period covered by this report
29 June 2010 - 13 August 2010

Data Custodian
CSIRO

Data Access
By request

2. EXECUTIVE SUMMARY

At the time of project inception in May-June 2010, eyewitness reports had indicated that mass bleaching was occurring in the Greater Coral Triangle Region including Thailand, Malaysia and Indonesia. These reports were consistent with NOAA remote sensing and forecasting, which reported significant to severe bleaching in South-East Asia. The bleaching in Thailand was reported to be the worst in 20 years, exceeding damage that occurred during the catastrophic global event of 1997-1998, which caused extensive coral mortality in 16% of the world's reefs.

The project aimed to measure the ecological, social and economic impacts of this event and strengthen our understanding of the underpinning biophysical drivers so that the community impacts of future events can be minimised. To do this we investigated the impacts of the bleaching on the reef ecology, diver perceptions of reef quality, and tourism economics across a range of dive destinations in three Greater Coral Triangle countries: Thailand, Malaysia and Indonesia.

This report covers Phase I which includes ecological and socio-economic data collection and initial analysis of ecological data. In-depth analysis of ecological and socio-economic parameters is to be undertaken in subsequent project phases.

2.1 Aims of the project

The aims of this project were to identify the effects of the 2010 mass coral bleaching event on local economies and ecosystems in Thailand, Malaysia and Indonesia. To do this we measured the bleaching using ecological surveys, and investigated the impact of bleaching on tourism and livelihoods by surveying or interviewing three key groups of reef users - tourist divers, dive guides and dive operators. Dive operators are those people who either own or manage a recreational diving business. Tourist divers are the paying customers of dive operators. Dive guides are experienced and highly qualified divers paid by dive operators to take tourist divers on a 'tour' of the reef. A quantitative analysis of the results is not yet available; however this report provides a qualitative analysis of how severe the event was at many locations in each country.

2.2 Highlights from the field

2.2.1 Remote Sensing

Sea surface temperatures higher than 1 °C above the usual summertime maximum are sufficient to cause stress on corals (Glynn and D'Croz, 1990), and corals are sensitive to the accumulation of thermal stress over time (Gleeson and Strong, 1995; Berkelmans et al., 2004). NOAA Coral Reef Watch monitors this thermal stress globally using the Degree Heating Week (DHW) product (Liu et al., 2003; Liu et al., 2005; see http://coralreefwatch.noaa.gov for details and current conditions). The DHW measures the accumulated thermal stress that corals have experienced over the past 12 weeks (inclusive). Temperatures have to be at least 1 °C greater than the maximum monthly mean value to accumulate; that means that a DHW value of 2 °C-weeks is equivalent to one week of values at 2 °C, or two weeks of values at 1 °C, and so on (for more detail on the DHW metric, visit;

http://coralreefwatch.noaa.gov/satellite/methodology). For the South-East Asia region, the local long-term-average warmest month (and therefore peak bleaching season) occurs in March or April in southern Indonesia, May in northern Indonesia and the Thai/Malaysian peninsula and May-July surrounding the Philippines.

By mid-February 2010, thermal stress had begun to accumulate to the south of Indonesia, reaching levels where bleaching could be expected by mid-March, and continuing to intensify into April, but subsiding thereafter. By late-April/early-May, thermal stress monitoring showed accumulations of stress on both sides of the Thai-Malaysian peninsula and further north-east toward the Philippines. During May and into June, when temperature in this region usually begins relaxing from the summer peak, both eastern and western sides of the peninsula experienced increasing thermal stress, to a level of severity where widespread bleaching and significant mortality were expected. By August, thermal stress had begun to dissipate along the western peninsula coast, followed in September by stress levels in waters east of the peninsula. It is notable that the oceanic thermal anomaly described here extended north-east to the Philippines and beyond. Other agencies have also reported bleaching in these areas.

2.2.2 Field Observations

The passage of thermal stress as measured by satellite imagery matches the timing and progression of bleaching observations in the surveyed countries. In Thailand by mid-late May, severe bleaching was seen along the Andaman Coast and throughout the Gulf of Thailand including Cambodia and Vietnam. Only in the Inner Gulf of Thailand was the bleaching less than catastrophic; mild bleaching was reported in May, and more severe bleaching in June. Through this same period, reefs in peninsular Malaysia showed a similar bleaching response, though with a lesser severity of bleaching. Surveys undertaken in June near Bali, Indonesia, showed significant levels of coral mortality but no observed bleaching; this is consistent with the observations of thermal stress in April, where bleached corals either recovered or contributed to the observed mortality.

Despite the fact that our teams were in the water within weeks of the first bleaching reports, the timing of thermal stress meant that in some cases sea surface temperatures had peaked before the field teams arrived (Table 3). So although corals at some sites were no longer actively bleaching, many were recently bleached and at the time of monitoring had either subsequently recovered or died. For this reason, measures of bleaching without an accompanying assessment of subsequent coral mortality will underestimate the full impact of the event. Results of preliminary analysis presented in Table 2 show that high levels of bleaching were recorded at two-thirds of the surveyed sites. Given that in Indonesia, the peak of thermal stress had passed by the time these observations could be recorded, we consider this an underestimate of the true severity and extent of the bleaching.

Table 2. Bleaching extent across all sites

Extent of Bleaching*	No. sites	% of sites
None (<10%)	5	10
Medium (10-50%)	11	23
High (>50%)	32	67

* measured on hard coral

The initial stage of the project focused on setting up protocols and initiating surveys to capture immediate bleaching impacts and identify the scale of the mass bleaching event in South-East Asia. We successfully surveyed several dive sites within each affected region, capturing the peak of the bleaching in Malaysia and Thailand, and the tail of the event in Bali and Lombok (Table 3).

Table 3. Sites and dates that the Tourist Diver and Dive Guide Surveys were deployed, compared to periods of peak thermal stress.

Country	Region	Sites	Date surveyed	Thermal peak
Thailand	Pattaya	Ko Sak, Ko Rin, Ko Mannwichai, Ko Krok, Ko Klung Badan	29 Jun – 8 Jul 2010	mid-June 2010
	Ko Tao	Chumphon Pinnacles 1 & 2, Southwest Pinnacle, Shark Is, Au Leuk, Twin Peaks, Japanese Gardens, Unknown#2, Unicorn, Three Rocks, Sairee Rf, Chalok Ban Kao	9 - 27 Jul 2010	
	Ko Samui	Hin Daeng (Red Rock), Mango Bay, Sail Rock, White Rock	11 – 19 Jul 2010	
	Ko Phi Phi	Viking Cave, Shark Pt, Bida Nai, Bida Nok, Maya Wall, Unknown#1, Hin Bida,	15 Jul – 1 Aug 2010	late-May 2010
	Ko Racha	Staghorn, Lucy's Reef, Kon Kare Bay, Home Run	14 Jul – 5 Aug 2010	
Malaysia	Perhentian	Tanjung Basi, Sugar Wreck, Tokong Laut, Terumbu Tiga, Seabelle, Tanjung Lang, Batu Nisan, Batu Layar	10 – 13 Jul 2010	early-June 2010
	Redang	Redang House Rf, Paku Is, Paku Kecil, Mak Cantik, Wreck, Terumbu Kili, Steven's Stone, Tanjung Tokong, Big Mount/Whale Mt, Stingray Garden, Che Isa, Southern Tip, Tanjung Cina Terjun, Tanjung Lang	30 Jun – 6 Aug 2010	
	Tenggol	Tokong Timur, Tanjung Api, Turtle Point, Amazing Grace	9 – 16 Jul 2010	
	Tioman	Soyak Is, Renggis, Batu Malang, Pirate Rf, Salang House Reef, Chebeh Is., Not For Everybody, Tomok, Magician Rock, Genting, Fan Canyon	1 – 17 Jul 2010	
Indonesia	Bali	Bali Barat, Pemuteran, Tulamben, Amed	30 Jun – 17 Aug 2010	late-Apr 2010
	Lombok	Gili Air, Gili Meno, Gili Trawangan	3 – 30 Jul 2010	
	North Sulawesi	Bunaken	3 – 19 Jul 2010	mid-June 2010

Different regions were likely to have different distributions of diver experience. Consequently the study also aimed to capture a range of tourist perspectives about ecological change, and relate those perspectives and changes to economic impacts. Experienced divers are likely to

have different responses to ecological change than novice divers. This kind of information can help contribute to vulnerability assessments (refer to Dive Operator Interviews section for more information) by identifying whether tourism operators are located in the market segments that are particularly vulnerable to coral bleaching. Certification levels have been shown to correlate with other experience measures (Miller 2005) and preliminary findings reported here use SCUBA certification level as a proxy for diver experience, as shown in Table 4.

Table 4. SCUBA certification details were elicited in the Tourist Diver Survey to help create diver experience profiles

Experience Category	SCUBA Certification
Novice	Discovery Diver
	Open Water Diver
Experienced	Advanced Open Water Diver
	Rescue Diver/Dive Master
	Dive Instructor

Our teams partnered with a variety of dive operators to ensure that the full breadth of the tourism industry was sampled (partnerships are summarised in Table 5). The rapid response has provided an excellent base from which to investigate long term changes in coral reef ecology and tourism livelihoods, should further funding become available. At times weather and sea conditions were such that survey teams were prevented from getting to some sites. However as Table 6 shows, dive sites were surveyed across a wide range of expected diving capability and bleaching impact.

Table 5. Research partnerships instrumental to the success of the project. With the exception of field assistants, Marine Park employees and volunteers, partners are counted as organisations, not individuals.

Country	Partnership type	No. Partners
Thailand	Dive operators	18
	Research Institutes	1
	Field Assistants	8
Malaysia	Dive Operators	6
	Resorts	1
	NGOs	1
	Field assistants	4
	Marine Park Employees	3
	Volunteers	2
Indonesia	Dive Operators	18
	Resorts	13
	NGOs	1
	Sports Clubs	1

Table 6. Project regions categorised by observations of maximum bleaching extent (measured in Ecological Surveys), and observations of tourist diver experience (measured by the Tourist Diver Surveys). Regions which had less than 10% of respondents within a diver experience category have omitted from the table. Thailand = green font; Malaysia = purple font; Indonesia = blue font.

Extent of Bleaching*	**Diver experience**	
(% of colonies)	Novice	Experienced
Low (<10%)	Ko Samui	Ko Samui
	Perhentian	Perhentian
	Redang	Redang
	Bali	Bali
	Lombok	Lombok
	Nth Sulawesi	Nth Sulawesi
Moderate (10-50%)	Pattaya	Pattaya
		Ko Tao
	Perhentian	Perhentian
	Redang	Redang
	Tenggol	Tenggol
	Tioman	Tioman
	Bali	Bali
	Lombok	Lombok
Severe (>50%)		Ko Tao
	Ko Samui	Ko Samui
	Ko Phi Ph	Ko Phi Ph
	Ko Racha	Ko Racha
	Perhentian	Perhentian
	Redang	Redang
	Tenggol	Tenggol
	Tioman	Tioman
	Bali	Bali

* Prior to the Ecological Survey at North Sulawesi and Lombok, ReefCheck surveys observed bleaching in up to 55% of colonies (Reef Check Foundation). However at the time of the Ecological Survey, the number of corals observed to be actively bleaching had declined to ≤3%; indicating that by the time the survey took place many corals had either already recovered or died.

3. METHODS

The project aimed to measure the economic impacts of the 2010 mass bleaching event in South-East Asia to strengthen our understanding of the underpinning biophysical drivers so that the community impacts of future events can be better anticipated and consequently minimised. The impacts of the bleaching on the reef, diver perceptions of reef quality, tourism economics and livelihood vulnerability were investigated for a range of tourist types across a range of dive destinations in these three countries of the Greater Coral Triangle region. Human ethics requirements were fulfilled according to the CSIRO Ethical Conduct in Human Research Policy.

3.1 Objective 1: Rapid Response Protocol Development

A robust protocol for collecting rapid response data during mass bleaching events was developed. This protocol can provide a standard approach for future rapid response coral bleaching efforts internationally. The protocol comprises three instruments: 1) an Ecological Survey; 2) a Dive Guide Survey; and 3) a Tourist Diver Survey. Dive operators were also interviewed in selected destinations to examine economic vulnerability to bleaching events.

3.1.1 Ecological Survey

The objective of the Ecological Survey was to measure and define the severity and extent of bleaching in each location, as well as measure a range of reef characteristics that allow the ecological status of the reef to be determined. These surveys provide a scientific perspective on the status (benthic composition) and condition (bleached or unbleached) of the reefs, which can be used to benchmark bleaching impact in space and time.

3.1.2 Tourist Diver Survey

Tourist divers are unlikely to see the reef in the same way as scientists, and the perspective on reef condition will vary according to how much experience they have in diving coral reefs (Miller, 2005; Dickson and Hall, 2006). We are interested in learning not only about the effects of the mass bleaching event on the ecology of the reefs, but also how bleaching impacts local communities that depend on these reefs for their livelihoods. To do this we developed the Tourist Diver Survey to measure the perceptions and subsequent intentions of tourists exposed to different levels of bleaching in different reef environments.

To understand how tourist divers perceived different ecological conditions, we needed to know what each tourist was looking at and how they perceived it. The Tourist Diver Survey did not assess diver's ecological knowledge, but rather sought to understand how tourist divers perceive and value the amenity of the dive experience. To do this the survey used three types of information: 1) diver satisfaction ratings; 2) diver evaluations of reef condition; and 3) diver perceptions of reef ecological condition.

The diver satisfaction ratings considered how happy divers were with the type and amount of coral life they saw. Inclusion of questions about diver's willingness to pay for various dive conditions and evaluations of reef condition provide an opportunity to understand how

ecological change influences economic factors in the dive tourism industry (Arin and Kramer, 2002; Park et al., 2002; Asafu-Adjaye and Tapsuwan, 2008; Ransom and Mangi, 2010).

Diver experience can affect perceptions and values of reef condition (Young and Loomis, 2009). Recreation specialization theory proposes that outdoor recreation can be placed on a continuum from general interest and low involvement to expert interest and high involvement, with each level involving a change in behaviours, skills, and directions (Bryan, 1977). Specifically, the theory proposes that as specialisation increases so does the resource dependency of the recreationist (Ditton et al., 1992). Analysis of these survey results is proposed in Phase II of the project to determine whether highly specialized divers are more critical of resource condition and negative impacts than novice divers.

Here we rate experienced divers as those holding a minimum of Advanced Open Water certification, and the remainder as novices (Harriott et al., 1997; Musa, 2003; Dearden et al., 2006). Total number of dives has been found to correlate with certification level (Miller 2005); however more complex diver experience indices that account for factors such as total number of dives; years of diving experience; level of interest and knowledge in coral reefs; and motivations for diving also exist (Rice, 1987; Barker and Roberts, 2004; Miller, 2005; Dearden et al., 2006; Garrod, 2008). Many of these attributes have been measured in the Tourist Diver Survey, and similar analyses of diver characteristics can thus be developed in Phase II.

Diver perceptions of ecological condition are an important mechanism for linking diver experiences with ecological change. Perceptions were evaluated by providing a series of images that divers used to ‘rate’ the ecological status of the reef(s) they visited, without requiring them to understand the technicalities of the science.

3.1.3 Dive Guide Survey

The perceptions of Tourist Divers must be calibrated for comparison with reef condition as determined by the Ecological Survey. Dive Guides are necessarily “experienced” divers and the Dive Guide Survey was developed to understand how these diver perceptions are affected by ecological change.

The Dive Guide Survey questioned dive guides about the ecological attributes of the dive that matched attributes measured in the Ecological Survey (see Table 7). By matching attributes in this way we calibrated Dive Guides against scientific measures of ecological impact, then used the Dive Guides’ assessments to understand what tourist divers were seeing and responding to in their surveys.

Table 7. Triangulation of reef attributes measured with Tourist Diver, Dive Guide and Ecological Surveys

Ecological Survey	Dive Guide Survey	Tourist Diver Survey
% cover hard coral bleaching	% cover hard coral bleaching	% cover of coral bleaching
% cover recently dead coral	% cover recently dead coral	% cover dead coral
Visibility	Visibility & sea conditions	Rate visibility & sea conditions
Reef condition	Reef condition	Reef condition (match to image)
Degree of colony bleaching	Degree of colony bleaching	
% cover hard coral	% cover hard coral	
% cover soft coral	% cover soft coral	
% cover sand	% cover sand	
% cover rubble	% cover rubble	
Reef fish abundance	Number of large & small reef fish	
Coral genera observed	Coral growth forms observed	

3.1.4 Dive Operator Interviews

Dive operators were also interviewed so as to better understand their economic vulnerability. Interviews addressed the destination's main characteristics; the nature of dive operations conducted there; the impact of events (including coral bleaching) on the viability of diving in this destination; and what management strategies were considered appropriate.

3.2 Data Collation and Quality Control

Survey instruments were drafted and reviewed by a panel of experts prior to pre-testing in the field. The pre-tested survey instruments were presented at a workshop and a common understanding of their implementation and transcription was agreed. During the workshop, spreadsheet templates and accompanying code books, to be used by field teams for electronic data collation, were explained and trialled with Country Leaders. The Country Leaders were responsible for training their own field teams in survey implementation prior to survey initiation.

Tourist Diver and Dive Guide Surveys were conducted in person, usually on the return trip of the dive boat and occasionally at the dock (e.g., during rough weather when many tourists were seasick, surveys were held off until the boat had docked), and were recorded on printed copies of the instrument. Paper copies were transcribed by the field teams into the spreadsheet template at the field base.

All data were centrally collected and quality assessed. For each country, a least 5% of the transcribed responses were checked against the original surveys and showed very high consistency, yielding an error rate of just 11%.

3.3 Objective 2: Map of Bleaching Location and Severity

Satellite based NOAA Coral Reef Watch monitoring data showed that the main belts of thermal stress were centred around latitudes 10-12 °N (Figure 1). Thermal stress was more prolonged in the north, especially between the Philippines and Vietnam. There were only relatively small regions of prolonged thermal stress in equatorial latitudes, for example the Gulf of Tomini in northeast Sulawesi. Stress levels (DHW) of 4 °C-weeks have been linked to ecologically significant levels of coral bleaching; above 8 °C-weeks, widespread bleaching and significant mortality are expected (Liu et al., 2003; Eakin et al., 2010). Data on coral response to thermal stress were collected during Ecological Surveys and are summarised in Figure 2, which shows the extent and severity of bleaching at each site visited during the survey period.

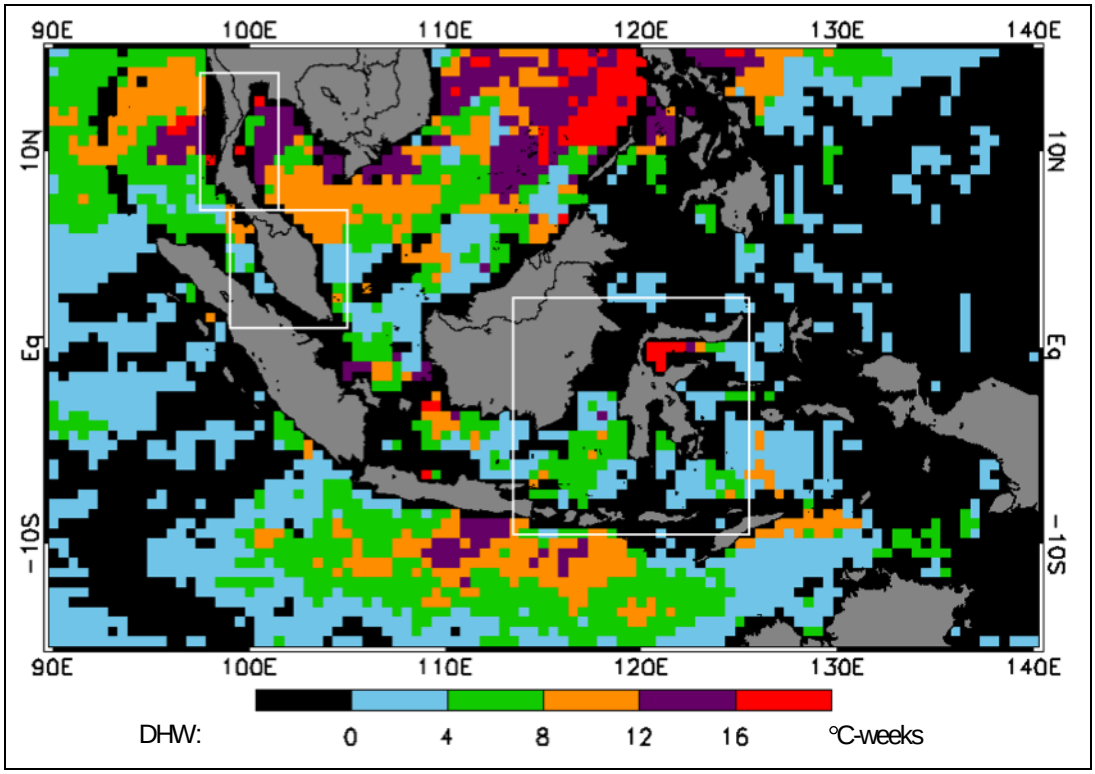

Figure 1. Maximum accumulated thermal stress across South-East Asia during 2010 as determined by the Degree Heating Week (DHW) near real-time monitoring of NOAA Coral Reef Watch. Ecological survey results for the insets are summarised in Figure 2.

4. RESULTS

Ecological Survey observations (Figure 2) of Thailand show that severe bleaching and mortality were observed on both the Gulf of Thailand (regions 2 and 3) and Andaman (regions 4 and 5) coasts, with some sites showing 100% of hard coral succumbed to bleaching and related mortality. Surveys from the eastern peninsula of Malaysia (regions 6-9) showed less severe but still widespread bleaching across the sites. In southern Indonesia (regions 10 and 11), surveys were undertaken following the peak of thermal stress (see Table 3). As such, corals had likely passed the bleaching peak and were in the throes of recovery or had recently died. Further north near Bunaken (region 12), corals appeared to have been unaffected during this thermal stress event, consistent with the low level of thermal stress observed in that area.

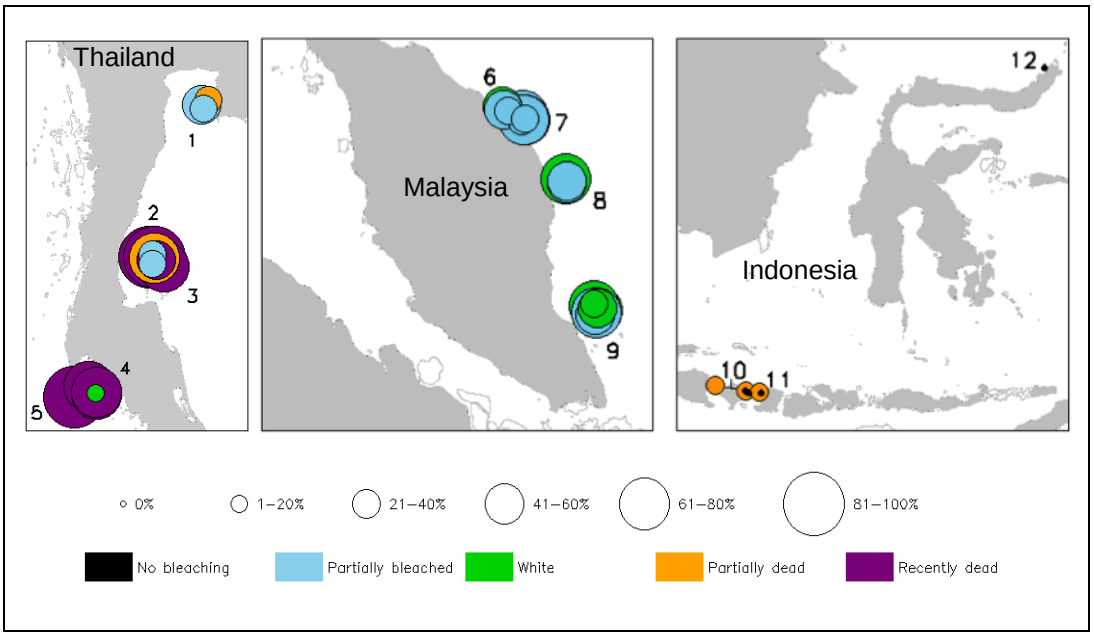

Figure 2. The extent (size) and predominant severity (colour) of observations during the 2010 mass bleaching event in South-East Asia. Bleaching extent is reported as the areal percentage of hard coral bleached, and severity is reported as the maximum observed intensity of bleaching using bleaching categories adapted from Marshall and Schuttenberg (2006). Numbers indicate regions as listed in Table 1.

Compilation of the Tourist Diver survey data showed that the representation of Novice vs Experienced divers (Table 5) was well-balanced across most regions (Table 8). In only one instance was a Diver Experience Level represented by fewer than 10% of respondents. This distribution is favourable for maximising potential outcomes in planned future analyses (proposed for Phase II).

4.1 Management responses

In response to the bleaching event, the Malaysian government closed all Marine Park dive sites that showed more than 60% damage; by July 2010, twelve sites in Tioman, Redang and Paya Islands had been closed to tourists, including three entire islands around Tioman Island, five sites in Redang Island and two sites at Paya Island (AFP, 2010; Anon., 2010a,b, 2011; Majid, 2010).

For reasons of maritime safety, most National Parks in Thailand's Andaman Sea are routinely closed during the south-west monsoon (May-Oct), however the Krabi (including Phi Phi) and Trang Provinces are exceptions to this, and remain open throughout the monsoon. In response to the bleaching event, Thai authorities took the unusual step of also closing several sites in these popular tourist areas, in January 2011. Two Ecological Survey sites at Hat Noppharat Thara - Mu Ko Phi Phi NP were part of these atypical closures, however most diving operations on Phi Phi were unaffected (J True pers. comm.).

No site closures have been reported for Indonesia. Surveyed protected areas for each country are indicated in Table 1. Should additional funding be obtained, this information provides an excellent opportunity to study the effectiveness of site closure on coral reef recovery.

Table 8. Spatial coverage of diver experience; percentage of divers at each experience level per region.

Country	Region	Diver Experience %	
		low	high
Thailand	Pattaya	28.8	71.2
	Ko Tao	9.8	90.2
	Ko Samui	56.1	43.9
	Ko Phi Phi	52.7	47.3
	Ko Racha	52.0	48.0
Malaysia	Perhentian	37.8	62.2
	Redang	55.6	44.4
	Tenggol	50.0	50.0
	Tioman	46.9	53.1
Indonesia	Bali	46.8	53.2
	Lombok	62.7	37.3
	North Sulawesi	36.7	63.3

5. CONCLUSIONS

Ecological and socio-economic survey instruments developed during this project provide a basis for rapid response efforts following future coral bleaching episodes to examine ecosystem and community impacts and their interconnections. Guided by satellite monitoring of thermal stress, ecological impacts on coral ecosystems observed in this project were consistent with predicted levels.

The data collected during this project can be used to identify sites for long-term monitoring of ecological and socio-economic impacts and recovery in subsequent phases of research (these phases are conditional on renewed funding). Candidate sites could be chosen based on the results of this study to have a spectrum of vulnerabilities to bleaching, and where local communities have varying dependence upon tourism income.

5.1 Future action

Our intention is to publish the protocol instruments and the development process; prior to formal publication, the project team are happy to discuss the instruments with interested parties.

The peak of the thermal stress in Bali and Lombok was in April-May. A rapid survey in the three Gili Islands (Lombok) by the Reef Check Foundation, Indonesia in early June 2010 showed bleaching of up to 55% of colonies. During the period covered by surveys in this project, the bleaching was recorded at $\leq 3\%$, indicating that the peak of the bleaching had passed, and corals were either in recovery or dead. There is a need for more detail ecological assessment to confirm the finding in Phase II.

Phase II of this project will seek to investigate relationships between ecological conditions and perceptions of economic value of coral reefs by the various user groups surveyed in Phase I (e.g., tourist divers, local business holders), possibly extending to fishers. Using these relationships, estimates of socio-economic impacts on broader communities can be derived. These impacts can then be used to identify and relate socio-economic drivers back into coral reef ecosystem governance and management. In addition, follow-up ecological surveys would provide information on ecosystem recovery, which would again relate back to the socio-economic findings, as well as the potential for information on downstream ecosystem effects (e.g., fish abundance). Funding support for Phase II is currently being sought.

The rapid response ecological and socio-economic protocols developed within Phase I have provided a set of tools for responding to subsequent bleaching events, particularly to evaluate links between ecosystem health and community status. Application of these tools with research efforts, as described in the Phase II plan, will lead to capacity for increased resilience of coral-reliant communities in the face of future coral bleaching events.

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The contents of this report are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U. S. Government.

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Contact Us
Phone: 1300 363 400
+61 3 9545 2176
Email: enquiries@csiro.au
Web: www.csiro.au

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