

The Impact of the December 2004 Indian Ocean Tsunami on the Coral Reef Resources of Mu Ko Surin Marine National Park, Thailand



Report prepared by
Coral Cay Conservation



www.coralcay.org

James Comley, Director of Marine Science (jc@coralcayconservation.com)

Shay O'Farrell, Chief Technical Officer

Sarah Hamylton, Independent Marine Consultant

Chelsea Ingwersen, Independent Marine Consultant

Ryan Walker, Independent Marine Consultant

Work supported by

British Foreign and Commonwealth Office, HM Government, British Embassy, Bangkok



Centre for Remote Imaging, Sensing and Processing, National University of Singapore



Space Imaging South East Asia



United Nations Environment Program- World Conservation Monitoring Centre



British Airways



Emirates Airlines



Executive Summary

At the invitation of the Department of Marine & Coastal Resources, the Department of National Park, Wildlife & Plant Conservation, and the Ministry of Natural Resources of the Royal Thai Government; the UK based NGO, Coral Cay Conservation (CCC), undertook a study of the coral reefs of the Surin Islands Marine National Park to assess the level of damage that had occurred as a result of the tsunami of December 26th 2004. A team of CCC marine scientists carried a programme of underwater surveys around the islands; the first week spent identifying and quantifying specific indicators of tsunami-induced damage, the second undertaking a preliminary assessment of the current state of the extant marine resources of the islands. This document presents the results of the former assessment.

A project-specific methodology was developed for this study, with a high resolution IKONOS™ satellite image being processed to ascertain the nature of the reefal areas and to identify survey locations. The surveys took place around the islands at a series of spatially representative sites. In total, 1424 sub-transects were surveyed, equating to over 28 kilometres of reef. These data were imported to a Geographic Information System (GIS), which georeferenced them to the satellite image, and allowed the data to be processed to produce 'maps', facilitating visual interpretation of the data. The GIS outputs have been used to recommend appropriate sites for the implementation of a programme to monitor the rate and extent of coral recovery.

Live hard coral cover was found to be exceptionally high on the north-east coast of the island of North Surin, with an average value of 75% and a maximum value of 90%. Interesting patterns developed in the data set where areas of high proportional tsunami related coral damage were found in areas that previous to the tsunami did not have substantial live hard coral cover. Whilst at the localised scale, the tsunami would have far-reaching ecological consequences on these areas, overall, in the Surin National Park, it was calculated that only 8% of the pre-tsunami coral quantity or coverage may potentially have been lost to the tsunami if all of this damaged coral subsequently now dies. Encouragingly however, signs of coral regrowth were discovered and documented. It would appear that healthy coral reef systems such as those of Surin can begin to regenerate rapidly even in the aftermath of a natural event as momentous as a tsunami.

Table of Contents

1	Introduction.....	1
2	Methodology.....	4
2.1	Survey Technique.....	4
2.1.1	Benthic indicators.....	5
2.2	Data Analysis.....	7
2.2.1	Geographical Coordinates.....	7
2.2.2	Geographic Information System.....	7
3	Results.....	9
3.1	Key Results.....	9
3.1.1	Pre-Tsunami Rubble Cover.....	9
3.1.2	Live Hard Coral Cover.....	11
3.1.3	Tsunami-Damaged Coral.....	13
3.1.4	Tsunami-damaged coral at different depths.....	17
3.1.5	Contribution of each damage class to tsunami damage.....	20
4	Discussion.....	21
4.1	Recommended Sites For Monitoring Of Recovery.....	25
	References.....	26

List of Figures

Figure 1.1	Surin Marine National Park	3
Figure 3.1	Pre-tsunami rubble cover	10
Figure 3.2	Total live hard coral cover	12
Figure 3.3	Quantity of damaged coral weighted for pre-tsunami coral cover	14
Figure 3.4	Proportional amount of damaged coral within each region	16
Figure 3.5	Proportion of coral damaged at shallow sites	18
Figure 3.6	Proportion of coral damaged at deep sites	19
Figure 3.7	Proportional contribution of each damage class to tsunami-damage...	21

List of Tables

Table 1.1	Study Aims, Objectives and Outputs	3
Table 2.1	Data gathered by each team during survey dives.....	5
Table 3.1	Mean, minimum and maximum calculated rubble cover at survey sites in regions around Ko Surin.....	9
Table 3.2	Mean, minimum and maximum calculated live hard coral cover at survey sites in regions around Ko Surin.....	11
Table 3.3	Mean, minimum and maximum calculated quantity of coral damage weighted for the cover of pre-tsunami coral cover at survey sites in regions around Ko Surin.	13
Table 3.4	Mean, minimum and maximum calculated coral damage values at survey sites in regions around Ko Surin.....	15
Table 3.5	Mean, minimum and maximum calculated coral damage values at shallow survey sites in regions around Ko Surin.....	17
Table 3.6	Mean, minimum and maximum calculated coral damage values at deep survey sites in regions around Ko Surin.....	17

1 Introduction

The contribution of healthy coral reefs to many South East Asian communities is enormous. Physically, they help to mitigate the impacts of normal oceanic waves on coastal zone erosion. Ecologically, they provide the base of many of the macro floral and faunal communities in the nutrient-poor waters normally associated with tropical seas. Socially, human communities within such regions have evolved around the activities associated with small-scale artisanal inshore fisheries. Economically, these fisheries have traditionally supported the livelihoods of these communities, and the rapid expansion of the global tourism industry increasingly provides the opportunity for many coastal communities to augment their incomes. As human populations within the regions continue to grow rapidly, this can help to offset the relative decline in the standard of living that can be a symptom of resource stretching.

Noteworthy hotspots of biodiversity are found in within the national waters of Thailand. Of the 33 phyla that exist in marine habitats, 30 are found within Thai borders (Crosby, 2000), wherein reefs have the highest diversity per unit area of any marine ecosystem. Furthermore, by functioning as recruitment and nursery areas for offshore stocks, Thailand's reefs sustain high offshore fishery yields that represent a major source of income in most coastal provinces. Any threat to the viability of these reef systems may be considered to have profound and far-reaching implications for the nation as a whole.

The tsunami in the Indian Ocean on the 26th December 2004 requires no introduction. After an immediate focus on the rescue and well being of the survivors, national and international attention turned to the long-term implications on the livelihoods of the coastal communities of the region.

In January 2005, a subcommittee of the Royal Government of Thailand set up the Coral Reefs and Related Marine Ecosystems task force. Headed by the Department of Marine and Coastal Resources, this group, along with the Department of National Parks, outlined the need to assess coastal resource damage from the tsunami in areas of strategic national importance. It was agreed that the British Government, through the

Foreign and Commonwealth Office, would support Coral Cay Conservation (CCC) in undertaking a programme of damage-assessment in Surin Marine National Park.

Founded in 1986, CCC is dedicated to *‘providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests’*. In collaboration with government and non-governmental organisations within any given host country, CCC provides a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes.

In February and March 2005, CCC marine scientists conducted a primary data-gathering programme in Surin Marine National Park, which was gazetted as a National Park of Thailand in 1981 (figure 1.1). With an area of 135km² and consisting of 5 main islands, the Park is located in the Andaman Sea, approximately 60km west of the Phangnga Province. The Surin Islands lie within the geographical area that was impacted by the tsunami.

Field surveys were carried out in conjunction with representatives of the Marine Biodiversity Conservation Group of Ramkhanhaeng University and Department of National Parks personnel. Throughout the duration of the data-gathering programme, hands-on training was provided to in-country partners on a range of marine science techniques including field survey design, remote sensing applications and data analysis using GIS software (table 1.1). The survey protocol was designed to facilitate data comparison at the local, national and regional levels and was created in collaboration with in-country partners to compliment previous unpublished work carried out in the study region.

Aims	Objectives	Anticipated Outputs
Tsunami-Impact Assessment	Design and undertake a detailed survey of the impacted coral reefs Establish an ecological database to facilitate future monitoring	Inventory of nature and extent of tsunami impact Interpretation of results Recommendations for recovery-monitoring sites Baseline ecological database of the reefs of Surin
Capacity Building	Provide training and field work experience for Ramkhanhaeng University students in survey design and data collection Provide training in data analysis for coral reef mapping using remote sensing and GIS techniques	Broaden technical skill-base in the application of coral reef data collection, management and interpretation techniques

Table 1.1 Study Aims, Objectives and Outputs

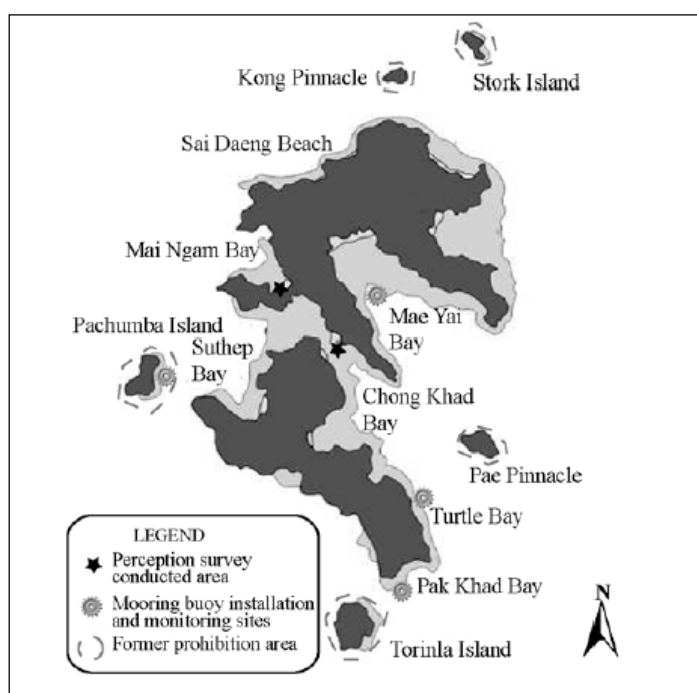


Figure 1.1 Surin Marine National Park (source: Worachananant *et al*, 2004)

2 Methodology

A site-specific data-gathering methodology was developed after initial inspection of selected damaged areas, with benthic-indicator categories being adapted from *Tsunami Damage to Coral Reefs; Guidelines for Rapid Assessment and Monitoring* (International Coral Reef Initiative/International Society for Reef Studies, 2005). This is hoped to facilitate the comparison of the Surin Islands data with those gathered at other tsunami-assessment sites.

2.1 Survey Technique

A survey programme was undertaken to collect these data from a spatially representative sample of the reefs. Two belt-transect surveys were conducted at each selected site, one 'shallow' and one 'deep' (at 4m and 10m depth below low tide mark respectively). Each belt-transect followed the reef at a consistent depth (reef topography allowing), which would be approximately parallel to the shoreline.

A pair of divers surveyed each depth contour, with the start point being ascertained from a handheld GPS unit (*Garmin 12*) aboard the dive boat. The first diver swam above the reef along the appropriate depth contour for a distance of 20m, which was measured out with a fibreglass tape. An underwater compass was used to determine the bearing of each 20m sub-transect. The first diver would then maintain their position above the reef, reeling in the tape whilst the second diver followed the depth contour, recording benthic data within a 5m belt (2.5 metres either side of the transect line) as they swam. These data were recorded as the estimated contributions of each predetermined benthic indicator, expressed as percentages (table 2.1). The 20m x 5m spatial resolution was selected to allow the identification of discreet areas of damage, and to facilitate accuracy, as each 1m² equates to 1% of the sub-transect area.

Sub-transects were continuous, with the end-point of each becoming the start-point of the next. A minimum of 10 sub-transects (200m distance) was surveyed on each dive, although there was no preset maximum limit, the latter being determined by allocated dive times. As each of these sub-transects could be processed separately during analysis, this was considered appropriate. These data were recorded *in-situ* on an

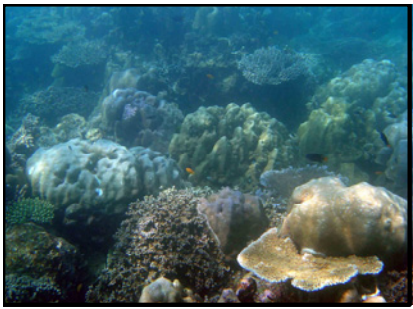
underwater slate, and were transferred into an *Access* (Microsoft Corporation) database immediately after each dive.

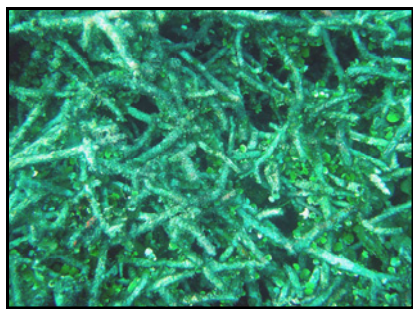
Period of survey dive:	Data recorded:
Start point of transect	GPS coordinates
During each 20m sub-transect	Sub-transect reference number
	Compass bearing
	Live coral cover (% of sub-transect area)
	Pre-tsunami rubble (% of sub-transect area)
	Coral collapsed on sliding sand slope (% of sub-transect area)
	Up-turned coral (% of live coral cover)
	Broken coral (% of live coral cover)
	Sediment smothered coral (% of live coral cover)

Table 2.1 Data gathered by each team during survey dives

2.1.1 Benthic indicators

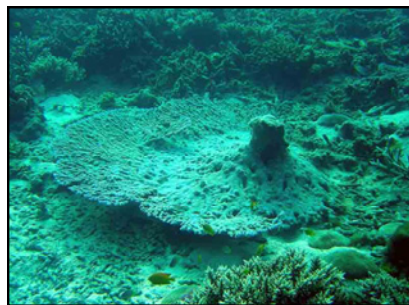
The selected benthic indicator categories were defined thus:

<p><input type="checkbox"/> Live Coral Cover:</p> <p>Living coral, whether intact, broken or upturned.</p>	
---	--

<p><input type="checkbox"/> Pre-tsunami Rubble:</p> <p>Rubble originating from coral considered to have been dead prior to the tsunami event. This rubble was generally unconsolidated, with obviously worn or indistinguishable corallites, usually oxidised to a much darker colour than that associated with recently killed coral.</p>	
---	--

❑ **Up-turned Coral:**

Living coral heads that are largely intact structurally, but whose bases have been broken, usually resulting in the colony being up-turned or knocked over. Not including 'mushroom' corals (non-scleractinian, free-living corals of the family *fungiidae*), commonly found up-turned on reefs.



❑ **Broken Coral:**

Living coral colonies (or fragments thereof) that have recently been broken, evidenced by obvious fracture zones that are still visibly white.



❑ **Sediment Covered Coral:**

Living coral that is considered to have an above normal level of sediment deposit coating its surface.



❑ **Coral Collapsed on Sliding Sand Slope:**

Colonies that have been displaced on the reef slope, where sand-slides have been initiated by, or have caused, localised reef-structure collapse.



2.2 Data Analysis

2.2.1 Geographical Coordinates

The geographical coordinates for the start of each sub-transect were calculated trigonometrically in an *Excel* (Microsoft Corporation) spreadsheet, using the known start-point and length (20m) of the previous sub-transect, and the angle of change (from the compass bearing). For the first sub-transect of the series, the start-point was known from the GPS coordinates. These start-points allowed the data to be represented spatially in a Geographic Information System (GIS).

Universal Transverse Mercator (UTM) map projection in the WGS-84 datum was chosen as the format for recording geographical coordinates. The linear nature of UTM (ground distances being measured in metres rather than angular degrees) facilitated the importing of ‘ground-measurements’ into the GIS.

2.2.2 Geographic Information System

This report made use of an Ikonos high-resolution image of the Surin Islands. The image was acquired after the December 2004 tsunami on the 25th of January 2005 and was supplied to this program by the Center for Remote Imaging, Sensing and Processing facility of the University of Singapore and Space Imaging South East Asia. Throughout this report, the image is displayed referenced to a Universal Transverse Mercator projection (zone 48N) on a WGS-84 datum.

After correction for sunlight ‘glint’ from the sea surface, this image was imported as a layer into ESRI *ArcView*. The high spatial resolution of Ikonos imagery allows for fine-scale analysis of reef morphology. The database containing the survey data was ‘live-linked’ to the GIS, allowing further layers to be built within the system.

By using the Inverse Distance Weighted function within *ArcView* GIS software, it was then possible to extrapolate the damage indicator values into areas of the image adjacent to the survey sites, thus producing a continuum of indices to highlight trends in damage cover. The survey sites locations were chosen with sufficiently high

spatial resolution to allow for accurate representation of the true damage levels in areas to which this extrapolation technique was applied.

These techniques were applied to produce GIS based data-contour ‘maps’ of the survey region, to facilitate visual interpretation of the large quantity of data gathered (figures 3.1 to 3.7).

3 Results

During the course of the data gathering phase of the study, 1424 sub-transects were surveyed, equating to over 28 kilometres of reef. These data were used in the production of the GIS outputs presented in figures 3.1 to 3.7. Although these outputs are designed to facilitate visual interpretation of the data, it is appropriate herein to discuss some of the key results.

3.1 Key Results

3.1.1 Pre-Tsunami Rubble Cover

There was a moderate to high level of pre-tsunami rubble recorded at most sites, with similar minimum values being recorded for each region (figure 3.1 and table 3.1). The eastern mouth of the channel between North and South Surin contained the site with the highest single value (97%).

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)
Minimum	3	6	11	4	5	8
Maximum	50	94	97	75	95	60
Mean	8	52	24	19	31	18

Table 3.1 Mean, minimum and maximum calculated rubble cover at survey sites in regions around Ko Surin. Refer to figure 3.1 for regions.

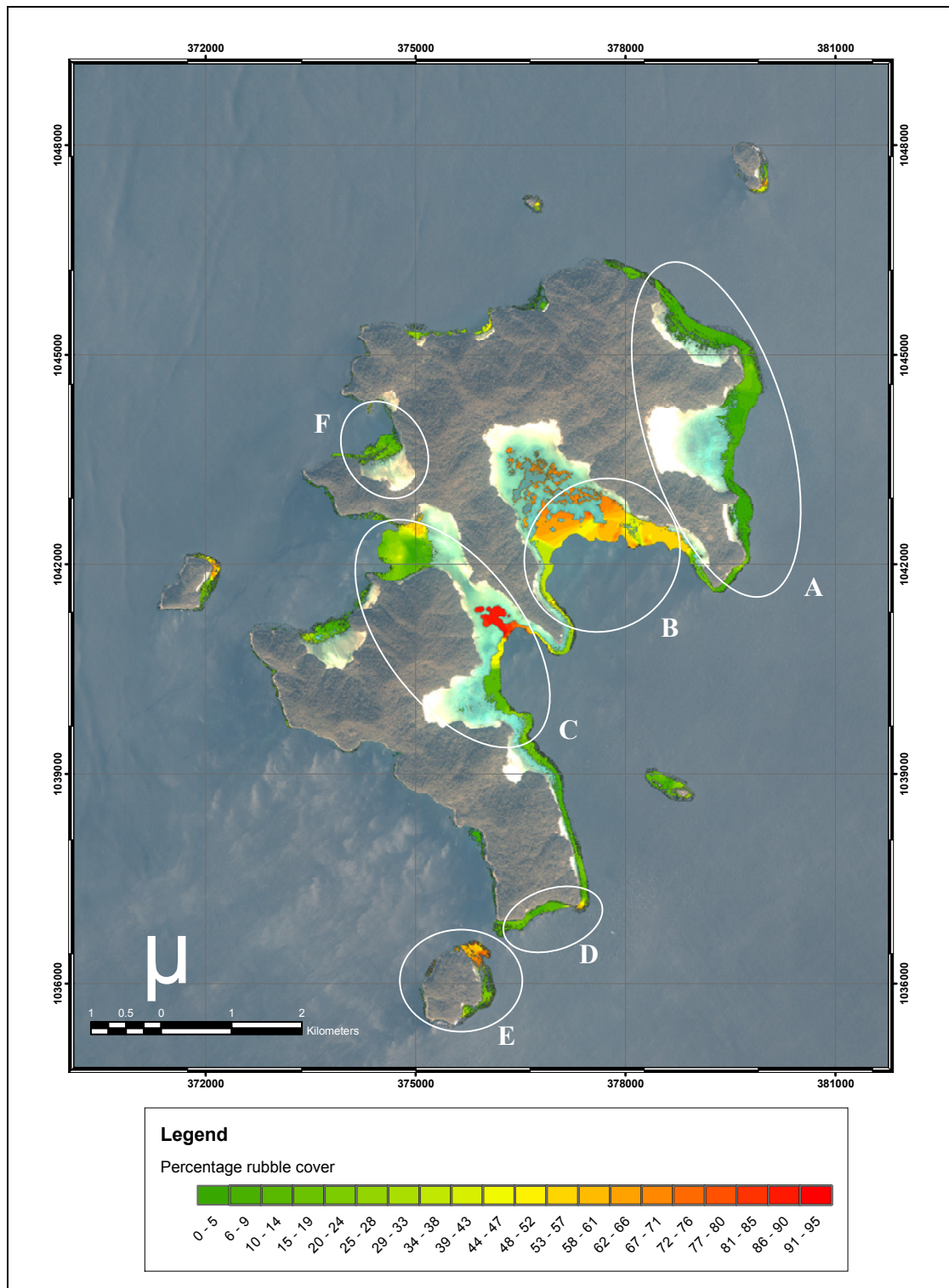


Figure 3.1 Pre-tsunami rubble cover

3.1.2 *Live Hard Coral Cover*

Coral cover was found to be very variable around the islands (figure 3.2 and table 3.2). By far the highest values were recorded in Region A, with a maximum value of 90% and a mean of 75%. Coral cover was lowest in Regions B and E, with mean values of 29% and 24% respectively. The low coral cover in Region B is consistent with the high level of pre-tsunami rubble found here. Coral cover was also relatively low in the channel area (Region C), with a mean of 34%.

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)
Minimum	57	14	15	31	19	45
Maximum	90	40	54	65	30	59
Mean	75	29	34	50	24	52

Table 3.2 Mean, minimum and maximum calculated live hard coral cover at survey sites in regions around Ko Surin. Refer to figure 3.2 for regions.

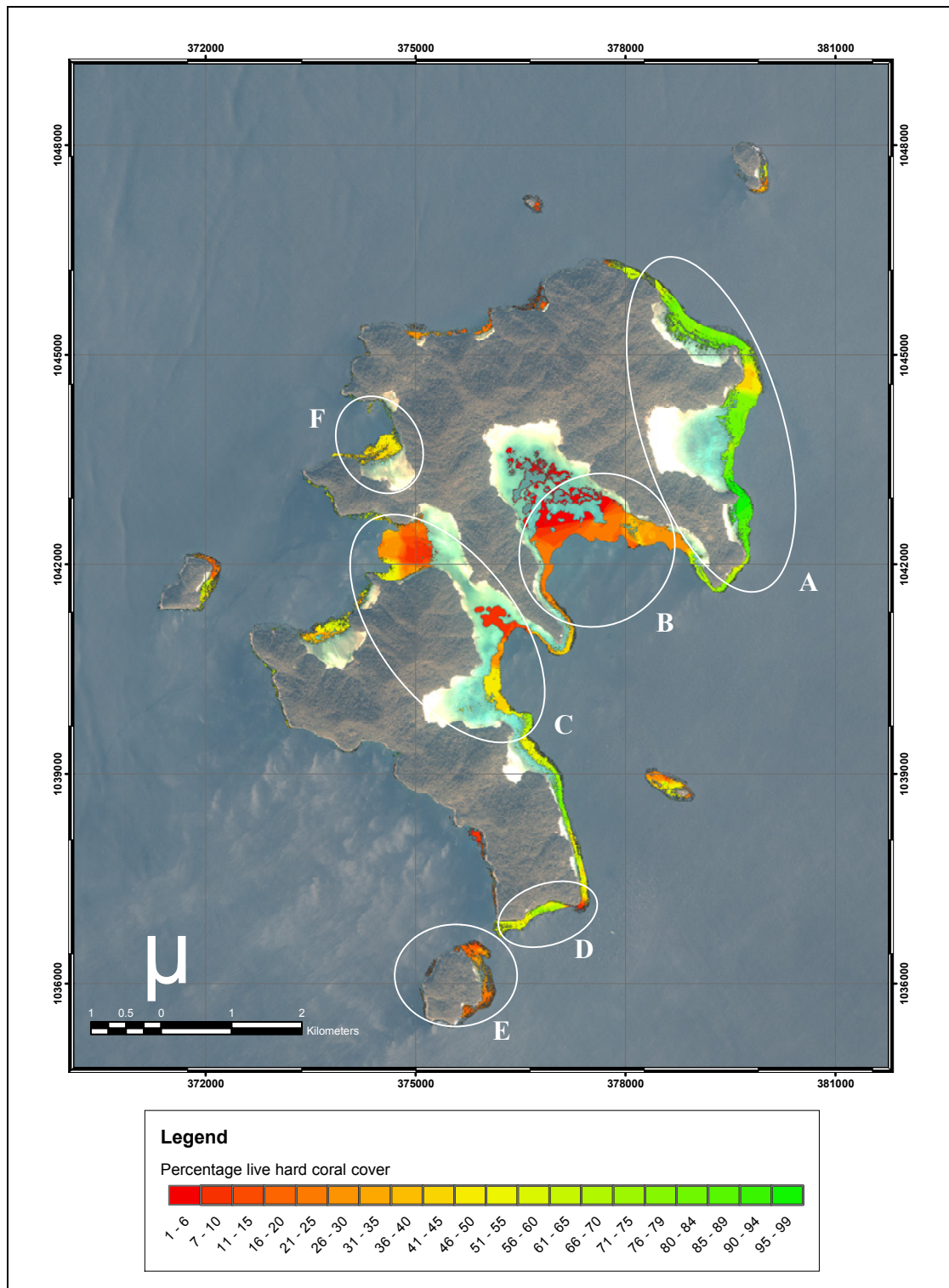


Figure 3.2 Total live hard coral cover

3.1.3 Tsunami-Damaged Coral

For the purposes of this report, coral damage attributable to the December 2004 tsunami-event is considered using two indices: the first to identify the regions of the Surin Islands that have suffered the highest quantity of coral damage or loss in coral coverage, and the second to highlight regions where a large proportion of pre-tsunami coral cover has been damaged, regardless of whether this was high or low.

For the first index, the quantity of damaged coral was weighted to account for pre-tsunami coral cover (figure 3.3 and table 3.3). The values calculated for this analysis show the overall quantity or loss in coverage as a result of tsunami induced coral damage to be low, with a mean value of 8%. Region F had the lowest incidence of tsunami-damaged coral loss (mean coverage loss of 4%), with Region A showing the most significant impact (mean coverage loss 17%).

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)
Minimum	2	5	0	2	0	1
Maximum	32	12	19	15	15	7
Mean	17	8	6	9	8	4

Table 3.3 Mean, minimum and maximum calculated quantity of coral loss weighted for the cover of pre-tsunami coral cover at survey sites in regions around Ko Surin. Refer to figure 3.3 for regions.

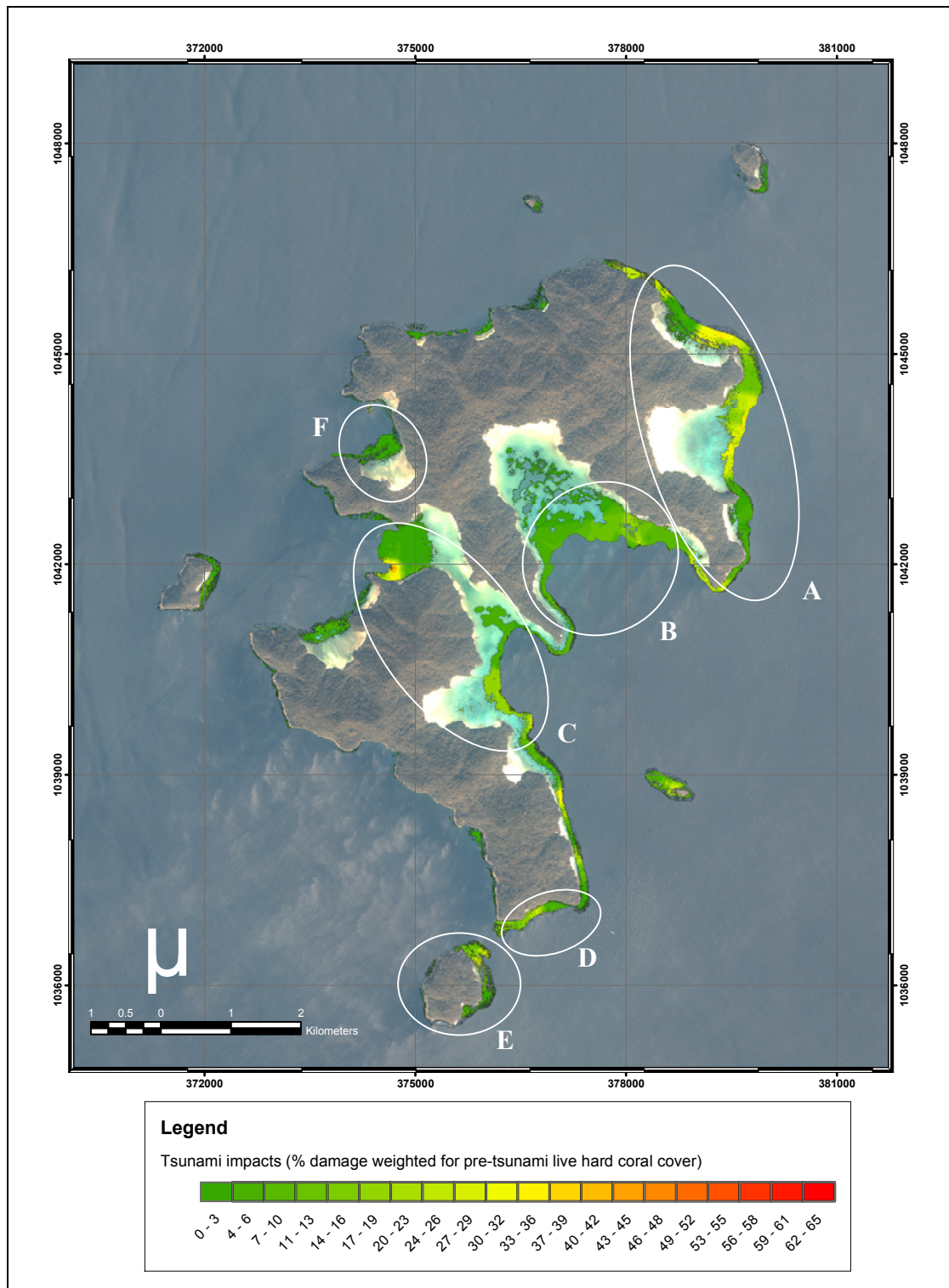


Figure 3.3 Quantity of damaged coral weighted for pre-tsunami coral cover

For the second index (figure 3.4 and table 3.4), damaged coral is expressed as a percentage of the coral present in the area. Ecosystems that were comprised of small amounts of coral prior to the tsunami would not have had as much coral to lose as other ecosystems comprised of high live coral cover. Even in ecosystems containing low levels of coral cover, tsunami-damage may have had a significant impact on the functioning of the system. The overall calculated mean proportion of coral damage attributed to the tsunami throughout all areas surveyed was 18%.

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)
Minimum	3	24	1	8	0	2
Maximum	40	32	43	27	62	12
Mean	23	29	22	17	33	7

Table 3.4 Mean, minimum and maximum calculated coral damage values at survey sites in regions around Ko Surin. Refer to figure 3.4 for regions.

As an illustration, although Region E sustained a far lower quantity of coral damage than Region A (8% versus 17% - table 3.3), the local ecological impact is arguably more significant, as Region E has had a higher percentage of its coral damaged than Region A (33% versus 23% - table 3.4).

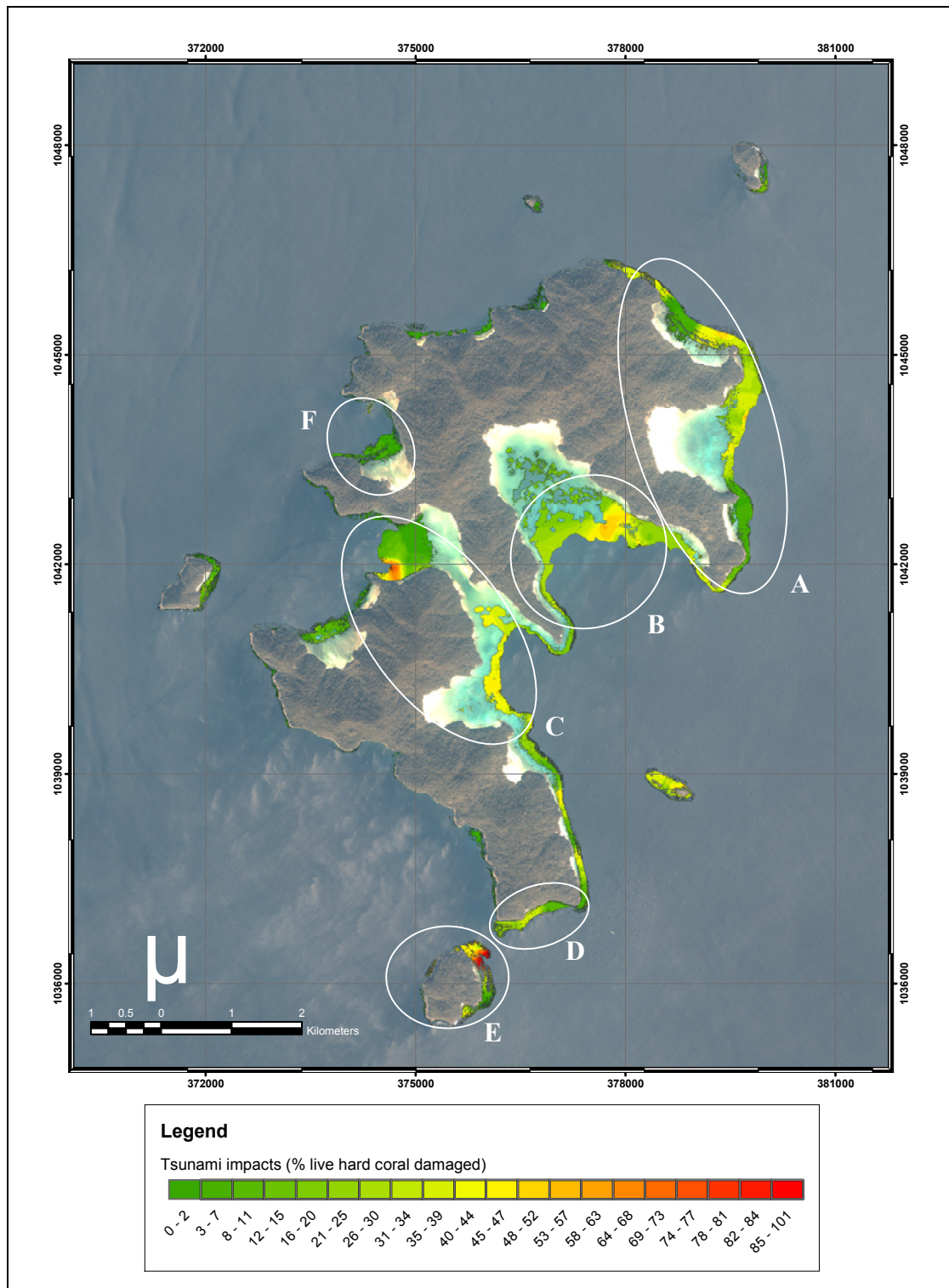


Figure 3.4 Proportional amount of damaged coral within each region

Taken together, the GIS outputs produced by these indices (figures 3.3 and 3.4) can be used to suggest appropriate sites for monitoring the recovery of the Surin Islands, with significantly damaged coral areas being located in Regions A to E.

3.1.4 Tsunami-damaged coral at different depths

The proportion of coral damaged as a result of the tsunami was also examined separately at the shallow sites (figure 3.5 and table 3.5) and the deep sites (figure 3.6 and table 3.6). Although the overall mean value was greater for deep sites (23.9%) than shallow (12.5%), these values tend to even out when each site is analysed in isolation. The only key difference between the two depth contours at a local level was recorded in Region G (figure 3.6), where far higher mean values were observed for deep transects (62% - table 3.6), than shallow ones (14% - table 3.5).

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)	Region G (%)
Minimum	2	9	1	1	1	0	0
Maximum	37	37	50	28	28	27	85
Mean	12	23	11	15	15	13	14

Table 3.5 Mean, minimum and maximum calculated coral damage values at shallow survey sites in regions around Ko Surin. Refer to figure 3.5 for regions.

	Region A (%)	Region B (%)	Region C (%)	Region D (%)	Region E (%)	Region F (%)	Region G (%)
Minimum	0	19	0	16	0	0	30
Maximum	65	48	83	26	39	4	75
Mean	33	32	27	20	27	2	62

Table 3.6 Mean, minimum and maximum calculated coral damage values at deep survey sites in regions around Ko Surin. Refer to figure 3.6 for regions.

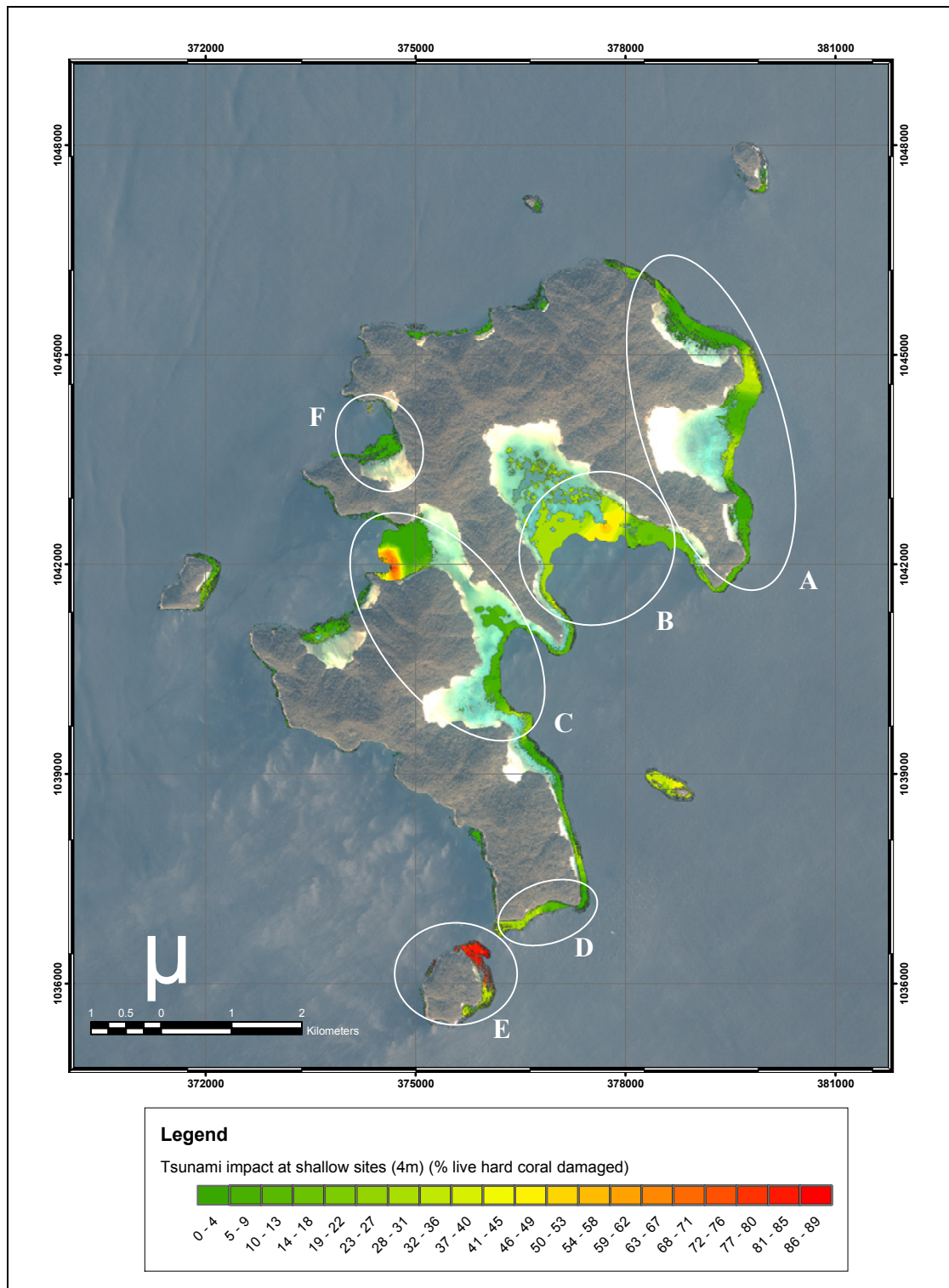


Figure 3.5 Proportion of coral damaged at shallow sites

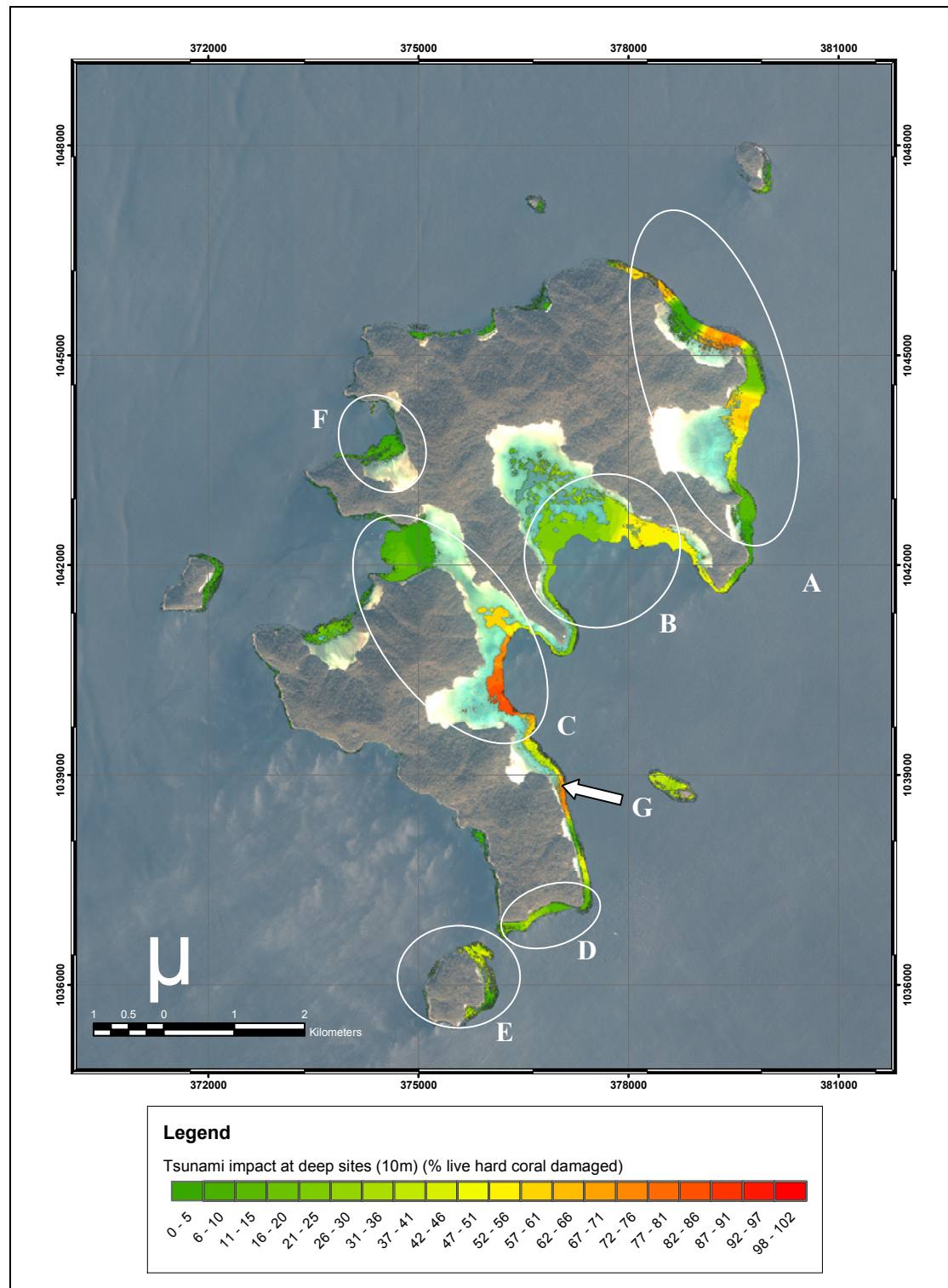


Figure 3.6 Proportion of coral damaged at deep sites

3.1.5 Contribution of each damage class to tsunami damage

Figure 3.7 illustrates the proportional amount that each damage class contributes to tsunami damage, along with the remaining amount of undamaged live hard coral. These proportions are displayed in pie charts, with an accompanying value to indicate the overall quantity of pre-tsunami coral cover at each site. Key areas of damage can be identified from this output, which can be used to suggest appropriate locations for the implementation of a recovery-monitoring programme, as outlined in section 4.1.

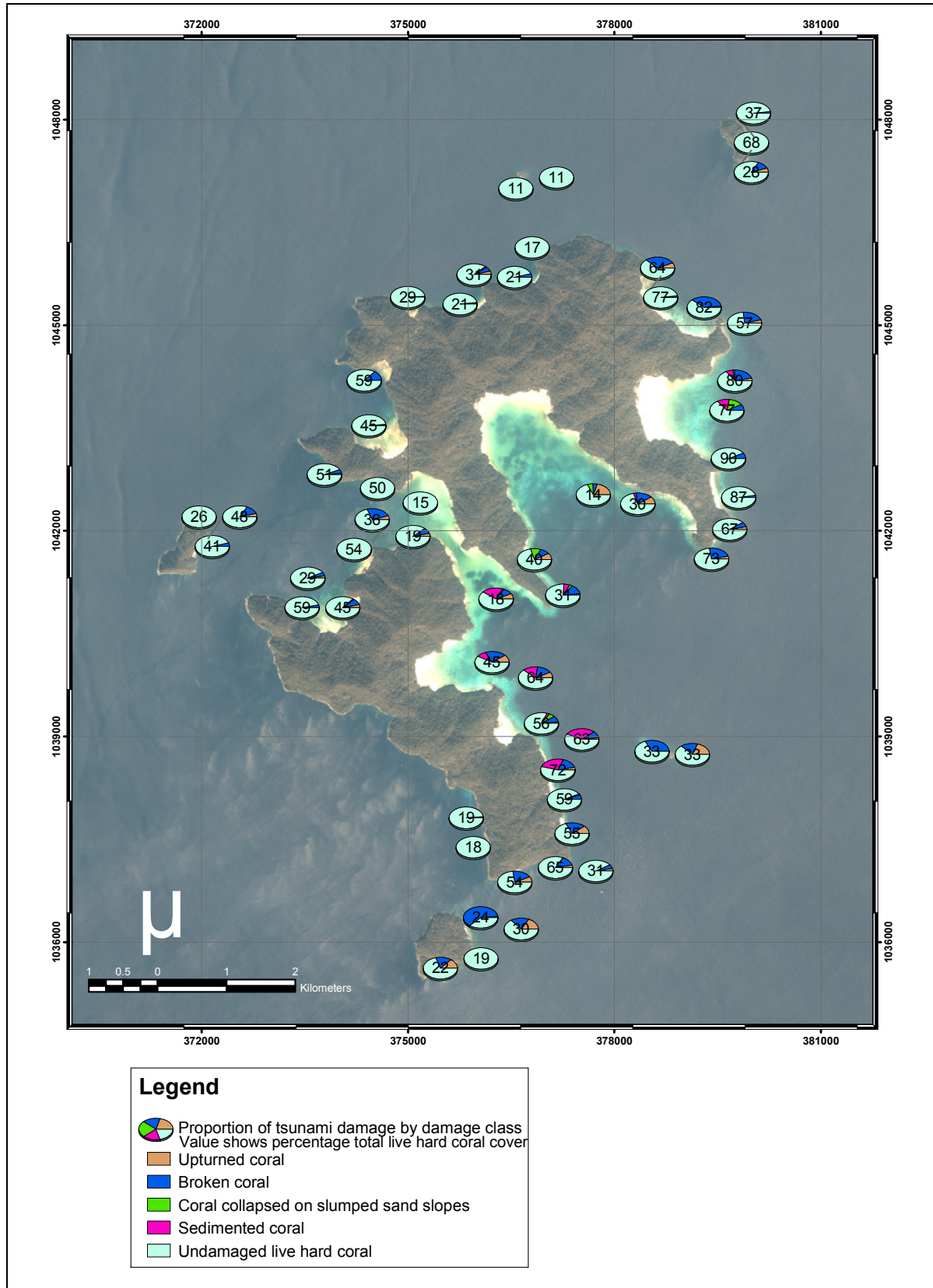


Figure 3.7 Proportional contribution of each damage class to tsunami-damage

4 Discussion

The enormous amount of energy generated by a tsunami might be expected to have severely detrimental effects on any coastal macro-biological system, and especially so on coral reef systems whose 'fragility' has often been noted. Early anecdotal reports and footage hinted at wide scale devastation of reefs that were subject to the recent tsunami impact. Although the level of actual effect in the wider Indian Ocean region has yet to be quantified at the time of writing, it seems likely that many areas of reef will have sustained moderate to severe damage.

Prior to the tsunami event, the Surin Islands had been confirmed as the most diverse reefs in Thailand (Worachananant *et al* (2000)).

Two measures of the tsunami damage have been reported in this document. The first indicates the proportion of the coral found at each site that was considered to be damaged. This index illustrates that there are some isolated sites where coral damage is very high. At the localised level, this will have a very severe impact on the ecological function of the coral reef system.

It is however interesting to note that there appears to be a correlation between the quantity of live hard coral or ecosystem health before the tsunami and the actual proportion of the coral that was subsequently impacted by the tsunami. One key site that illustrates this is the northern point of Ko Torinla which was found to have approximately 10% live hard coral cover, of which 60% was observed to have been damaged by the tsunami resulting in a 6% decline in coral coverage as a result of the tsunami. By contrast the area around the northern point of North Surin Island had on average 90% live hard coral cover before the tsunami, of which proportionately 35% was damaged by the tsunami, resulting in a potential coral coverage or quantity loss of 30%. Accordingly, when this imbalance is accounted for, the regional average loss in quantity or cover of coral throughout the Surin National Park is calculated to be only 8%.

Much of the reefal area was considered to be ecologically 'healthy' by the authors of this study, with 274 species of fishes and 70 species of 'hard' corals being identified during the subsequent reef resource assessment study undertaken (Coral Cay Conservation, 2005). However, some key sites, most notably in Region B (Mae Yai Bay), had high levels of coral damage, most of which were attributable to events prior to the tsunami.

The survey sites exhibited very low incidence of tsunami-affected coral that had subsequently bleached or had become infected by disease. In fact, it was observed that many of the broken branching *Acropora* corals had begun to regrow at the points at which they had fractured, and a number of up-turned tabulate *Acropora* colonies were observed to have begun to regrow upwards (towards the sea surface) from what had been their undersides (figure 4.1). It is likely that a reef system with a low level of external stressors will recover more quickly than a heavily exploited system, and the observed signs of early regrowth are encouraging. It would appear that a healthy coral reef system maybe capable of regenerating rapidly even in the aftermath of a natural event as momentous as a tsunami.

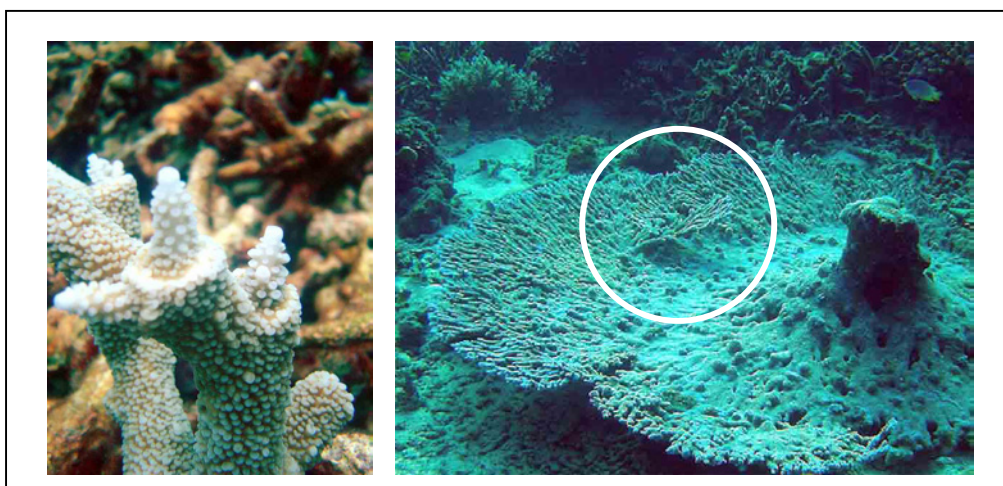


Figure 4.1. Regrowth of damaged coral colonies

Anthropogenic influences, on the other hand, can generate more persistent damage. Although a quantity of rubble would normally be present on a reef, in some areas of the Surin Islands, the values recorded for rubble are greater than those for live hard coral cover. Anecdotal evidence suggests that blast fishing has been utilised in the Surin Islands in the past, which may largely account for the large pre-tsunami rubble areas that have been recorded (figure 3.1). As much of this rubble may be taken as evidence of such activities, it is apparent that anthropogenic impacts, such as destructive fishing practices, can play a higher role in reef degradation than the impact of a natural event such as a tsunami. However, the relative contribution of the tsunami-event to the overall recorded damage will become increasingly difficult to gauge with the passage of time.

As coral reefs are dynamic systems and therefore prone to a vast array of physical, chemical and biological influences, evidence of temporally-isolated disturbances can quickly become hidden. There is a narrow window of opportunity within which any such assessment can be undertaken, and even within the 8-week interval between December 26th 2004 and the data-gathering phase of this study, reefal damage has become more difficult to categorise into that which was caused by the tsunami and that which was pre-existing. The approaching monsoon will likely hide most of the remaining evidence.

The particular human and physical geography of the Surin Islands may have helped to mitigate the level of damage sustained. In many low-lying areas of Thailand where reefs are alleged to have been heavily impacted, a large mass of seawater encroached on land before returning seawards. In the Surin Islands, cliffs or steep forested land flanked many of the survey sites. This may indicate that the mechanical damage caused by a large mass of seawater returning to the sea from land may have a greater impact than the tsunami wave-energy itself. It is also likely that debris from human settlements imported to the reefs by this returning seawater would play a significant role in the mechanical damage sustained by a reef. Thus it is worth noting that the incidence of terrigenous debris on the post-tsunami reefs was negligible, with discarded fishing gears and a few isolated tree branches being the only alien objects recorded.

4.1 Recommended Sites For Monitoring Of Recovery

Visual interpretation of the GIS outputs for coral damage (figures 3.3, 3.4 and 3.7) allows sites to be identified for the installation of a monitoring programme designed to quantify the rate and extent of the recovery of the reefs. Sites that returned high values for Quantity of Damaged Coral Weighted for Pre-tsunami Coral Cover (figure 3.3) and Proportional Amount of Damaged Coral Within Each Region (figure 3.4) may be considered appropriate for such a programme. In order to identify the influence of other external factors, control sites should also be utilised, located in areas with low coral damage. Sites for monitoring should include the western mouth of the channel (Region C), the northeast coast of Torinla Island (Region E), the north shore of Mae Yai Bay (Region B) and the most northeasterly headland of North Surin Island (Region A). If resources allow, a monitoring site would also be appropriate in the fore to mid reef areas of Region G, as indicated in figure 3.6.

References

Coral Cay Conservation (2005); *Coral Reef Resources of Mu Ko Surin National Park, Thailand*; Coral Cay Conservation Ltd, London, U.K.; www.coralcay.org

Crosby M.P., Brighthouse G., Pichon M. (2002); *Priorities and Strategies for Addressing Natural and Anthropogenic Threats to Coral Reefs in South East Asian Nations*; In *Ocean and Coastal Management*, 45: p121-137 (17); Elsevier Science

International Coral Reef Initiative/International Society for Reef Studies (2005); *Tsunami Damage to Coral Reefs – Guidelines for Rapid Assessment and Monitoring*; Version 1

Worachananant, S., Carter, R.W., Hockings, M., Reopanichkul, P. and Thamrongnawasawat, T. (2004); *Tourism Management in Surin Marine National Park, Thailand*; In *Coastal Zone Asia Pacific (CZAP)*, 5-9 September 2004: p757-763; Brisbane, Australia