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Authors: Lazuardi, Muhammad Erdi, Sudiarta, I Ketut, Ratha, I Made Jaya, Ampou, Eghbert Elvan, Nugroho, Suciadi Catur, et al.

Source: Bali Marine Rapid Assessment Program 2011: 69

Published By: Conservation International

URL: https://doi.org/10.1896/054.064.0105

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Chapter 4

The Status of Coral Reefs in Bali

Muhammad Erdi Lazuardi, I Ketut Sudiarta, I Made Jaya Ratha, Eghbert Elvan Ampou, Suciadi Catur Nugroho and Putu Liza Mustika

4.1 INTRODUCTION

Live coral coverage is important to support reef fish communities, provide renewable resources (e.g., seafood, seaweed, medicines), protect shorelines and attract domestic and international divers to foster the local economy (Chabanet et al. 1997; Cesar 2000; Musa 2002). The overall coral coverage of Bali is an indicator of coral health and is important for future management actions (Hill & Wilkinson 2004). Healthy and diverse coral coverage also contributes to visitor satisfaction (Musa 2002), which may eventually be linked to repeat visitation, visitors promoting the tourist package to others, and increased local income (see Mustika 2011).

Cesar (2000) has listed several classical threats to coral reefs, for example, poison fishing, blast fishing, over fishing, coral mining, sedimentation, urban pollution and waste, coral bleaching and unsustainable tourism. All of these threats are currently present in Bali. Accordingly, a circum-Bali snapshot of coral coverage should give an understanding of the overall health status of coral reefs in Bali. This chapter includes information on substrate coverage, hard coral genus composition and the Mortality Index of the coral reef ecosystem surveyed.

4.2 METHODS

4.2.1 Time

The Bali Marine Rapid Assessment Program (MRAP) was conducted from 29 April to 11 May 2011. Coral reef data were taken from 27 out of 32 sampled sites.

4.2.2 Survey location

Survey locations were potential Marine Protected Area (MPA) sites suggested by various stakeholders. The locations were also chosen based on ecosystem representativity. Sites within the locations were also chosen based on representativity per location. Table 4.1 and Figure 4.1 present the survey locations and sites.

4.2.3 Survey method

A modified point intercept transect method was used for coral reef data collection (English et al. 1997), utilizing transect lines of 2 × 50m parallel to the coastline at two depths (5–7m and 10–14m). Survey points were made every 0.5m per transect. Benthic substrates observed were hard corals (to genus level), soft corals, dead corals, rubbles, other fauna and abiotic components.

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Table 4.1. Survey sites and locations during the Bali MRAP 2011

	Site	Location	Site #	Geographical coordinates	
				Longitude	Latitude
1	Kutuh	Nusa Dua	4	115.20685	-8.84418
2	Nusa Dua	Nusa Dua	5	115.23918	-8.79997
3	Melia Bali	Nusa Dua	6	115.23660	-8.79276
4	Terora	Nusa Dua	1	115.22960	-8.77044
5	Sanur Channel	Sanur	3	115.27136	-8.71027
6	Glady Willis	Sanur	2	115.26820	-8.68409
7	Tanjung Jepun	Padangbai	9	115.50976	-8.51941
8	Gili Batutiga/Mimpang	Candidasa	7	115.57488	-8.52524
9	Gili Tepekong	Candidasa	10	115.58612	-8.53141
10	Gili Biaha	Candidasa	11	115.61290	-8.50379
11	Seraya	Seraya	12	115.68918	-8.43350
12	Gili Selang	Seraya	13	115.71062	-8.39677
13	Bunutan	Amed	15	115.67892	-8.34503
14	Jemeluk	Amed	16	115.66142	-8.33737
15	Kepah	Amed	17	115.65391	-8.33384
16	Tukad Abu	Tulamben	18	115.61071	-8.29312
17	Tulamben Drop off	Tulamben	19	115.59726	-8.27829
18	Geretek	Tejakula	20	115.41447	-8.15106
19	Penuktukan	Tejakula	21	115.39587	-8.13868
20	Takad Pemuteran	Pemuteran	24	114.66682	-8.12953
21	Sumberkima	Pemuteran	25	114.60703	-8.11196
22	Anchor Wreck	P. Menjangan	26	114.50653	-8.09171
23	Coral Garden	P. Menjangan	27	114.51936	-8.09158
24	Post 2	P. Menjangan	28	114.52685	-8.09687
25	Pulau Burung	Teluk Gilimanuk	30	114.45142	-8.16267
26	Klatakan Barat	Melaya	31	114.45432	-8.23189
27	Klatakan Timur	Melaya	32	114.45653	-8.23306

4.2.4 Data Analysis

The output of data collection is: the percentage of live coral coverage and composition of hard coral genera; percentage of algae coverage, other biota, rubble, abiotic components; and a Mortality Index.

Live coral coverage was calcuated based on the following formula:

$$L = \frac{\sum Li}{N} \times 100\,\%$$

Remarks:
- L n=Percentage of sightings
- Li n=The amount of sighting i
- N n=The amount of sampling sites per 100 m

Live coral (hard and soft) percentage was based on the categories of Gomez & Yap (1988):

- Bad : 0–24.9 %
- Medium : 25–49.9 %
- Good : 50–74.9 %
- Excellent : 75–100 %

Mortality Index is an index for estimating the health or condition of a coral reef ecosystem (Gomez & Yap 1988). The formula is as follows:

$$MI = \frac{\text{Percentage of dead corals}}{\text{Percentage of live corals + Percentage of dead corals}}$$

Remarks : MI=Mortality Index

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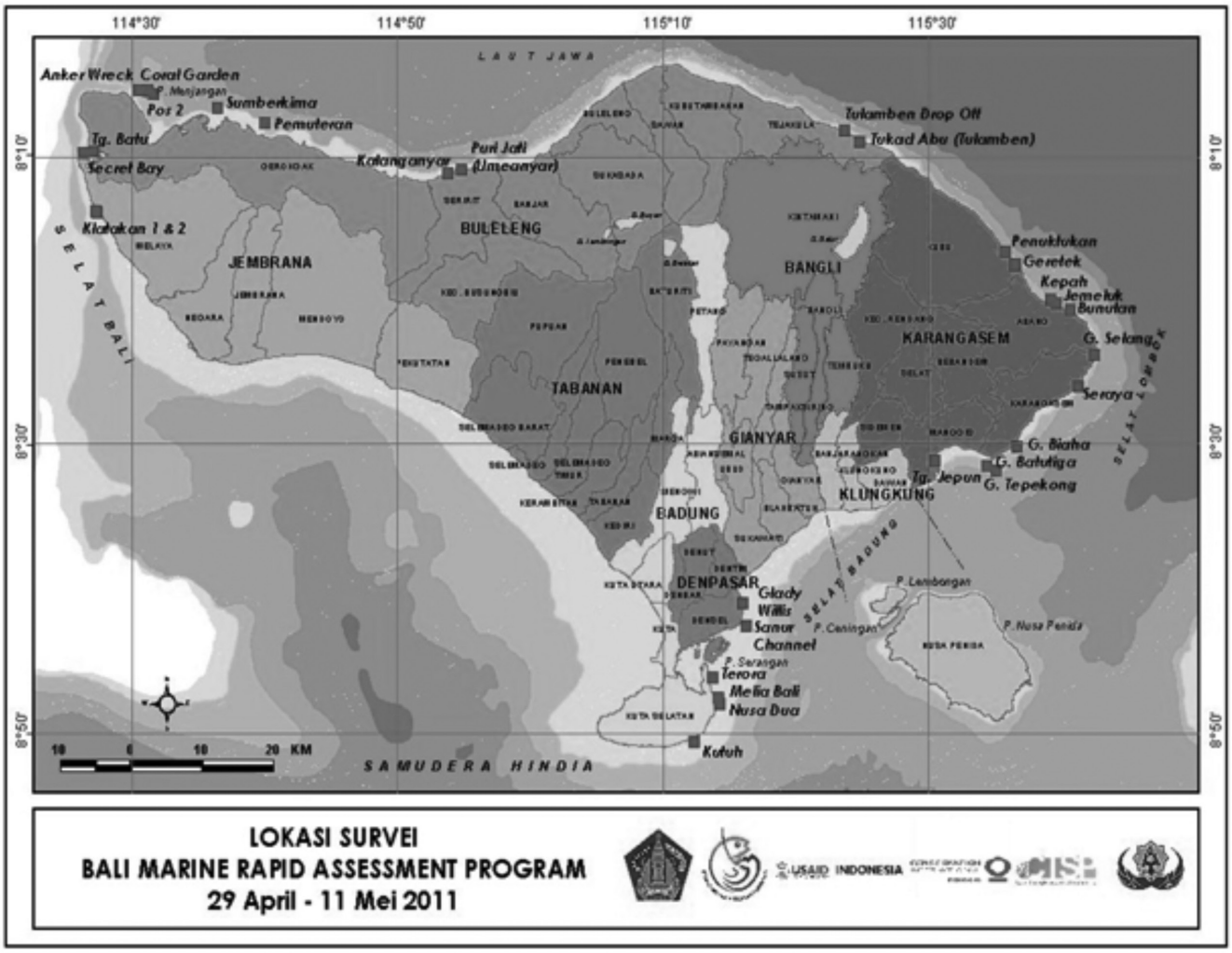


Figure 4.1. Coral reef monitoring sites during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

Table 4.2. Codes and categories for benthic life forms

Categories		Code
Hard Coral		
Acropora	Branching	ACB
	Digitate	ACD
	Encrusting	ACE
	Submassive	ACS
	Tabular	ACT
Non *Acropora*	Genus names	-
Dead Coral		DC
Dead Coral with Algae		DCA
Other Fauna		
Soft Coral		SC
Sponges		SP
Zoanthids		ZO
Others		OT

Categories		Code
Algae	Algal Assemblage	AA
	Coralline Algae	CA
	Halimeda	HA
	Macro Algae	MA
	Turf Algae	TA
Abiotic	Sand	S
	Rubble	R
	Silt	SI
	Rock	RC

Source: English et al., 1997

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The Mortality Index ranges between 0–1. A near 0 Mortality Index indicates that the coral reef ecosystem is healthy with low mortality. On the other hand, a near 1 Mortality Index indicates an unhealthy coral reef ecosystem with high mortality.

4.3. RESULTS AND DISCUSSION

4.3.1 Percentage of substrate coverage

Benthic substrates were grouped into hard coral, soft coral, algae, other biota (i.e. sponge, zoanthid and other benthic biota), dead coral (i.e. dead coral and algae-covered dead coral), rubble and other abiotic components (sand, rock and mud).

4.3.2 Percentage of hard coral cover

Hard cover percentage at the 5–7m depth ranged from 21.5 % to 68.0 %. Site 26 (Anchor Wreck, Menjangan Island) had the highest hard coral cover, while Site 32 (East Klatakan, Melaya) had the lowest hard coral cover. The average hard coral cover at the 5–7m depth was 45.3 %. On average, hard coral still dominated other substrates, for example abiotic (17.3 %) and rubble (11.3 %).

Hard coral cover at 10–14m ranged between 11.0 % and 76.0 %. Site 10 (Gili Tepekong) had the highest hard coral cover, while Site 4 (Kutuh) had the lowest hard coral cover. The average hard coral cover at this depth was 32.8 %. On average, hard coral still dominated other substrates, for example abiotic (14.9 %) and rubble (13.6 %). Overall, the average of hard coral cover in Bali was 38.2 %, ranging between 11.0 and 76.0 %.

4.3.3 Coverage of other substrates

Soft corals were observed to dominate Sites 4, 5, 6, and 12 with the average percentage of cover ranging between 57.5 and 62.0 %. On the other hand, abiotic substrates dominated Sites 2, 15, 18, 24, and 32 with the average percentage of cover ranging between 36.3 and 48.0 %.

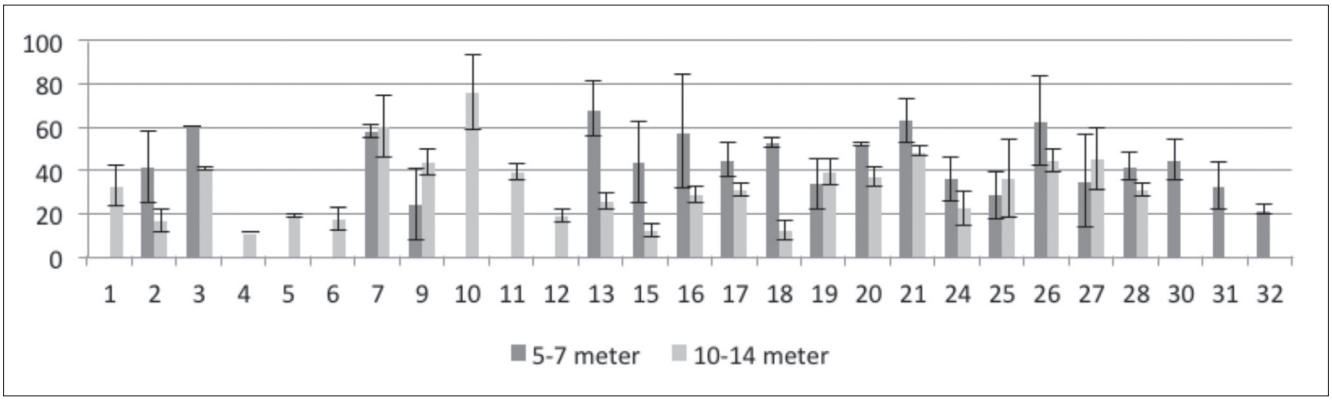


Figure 4.2. Hard coral coverage at 5–7m and 10–14m on survey sites during the Bali Marine Rapid Assessment Program

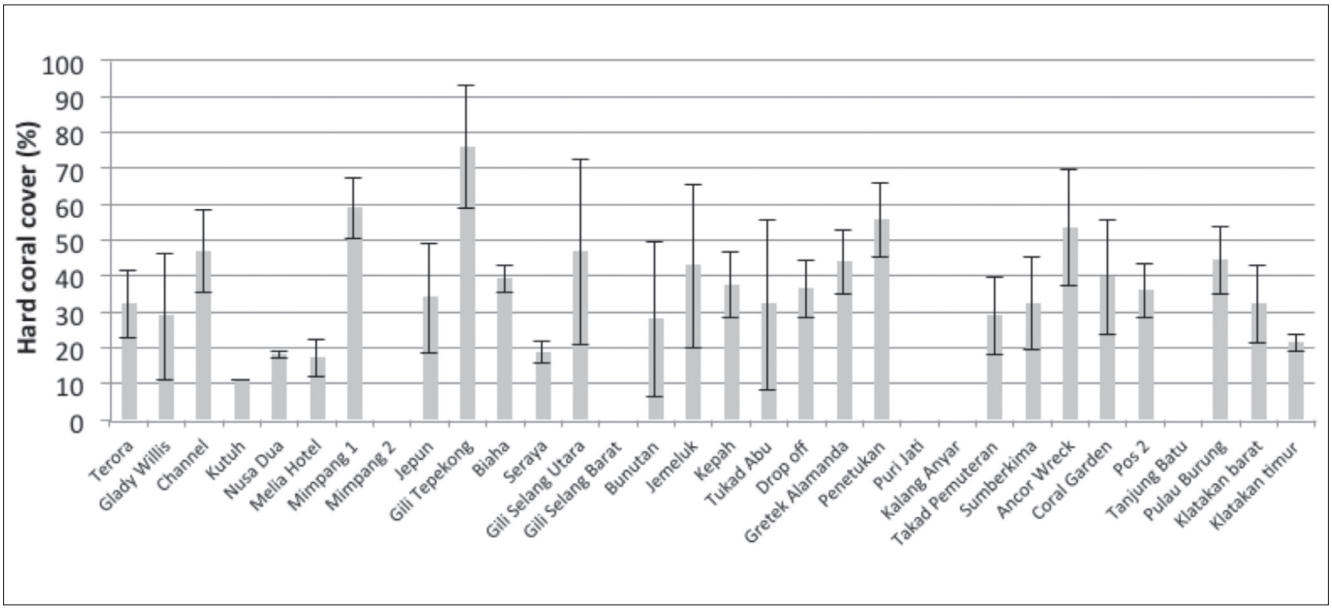


Figure 4.3. The hard coral coverage at survey sites during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

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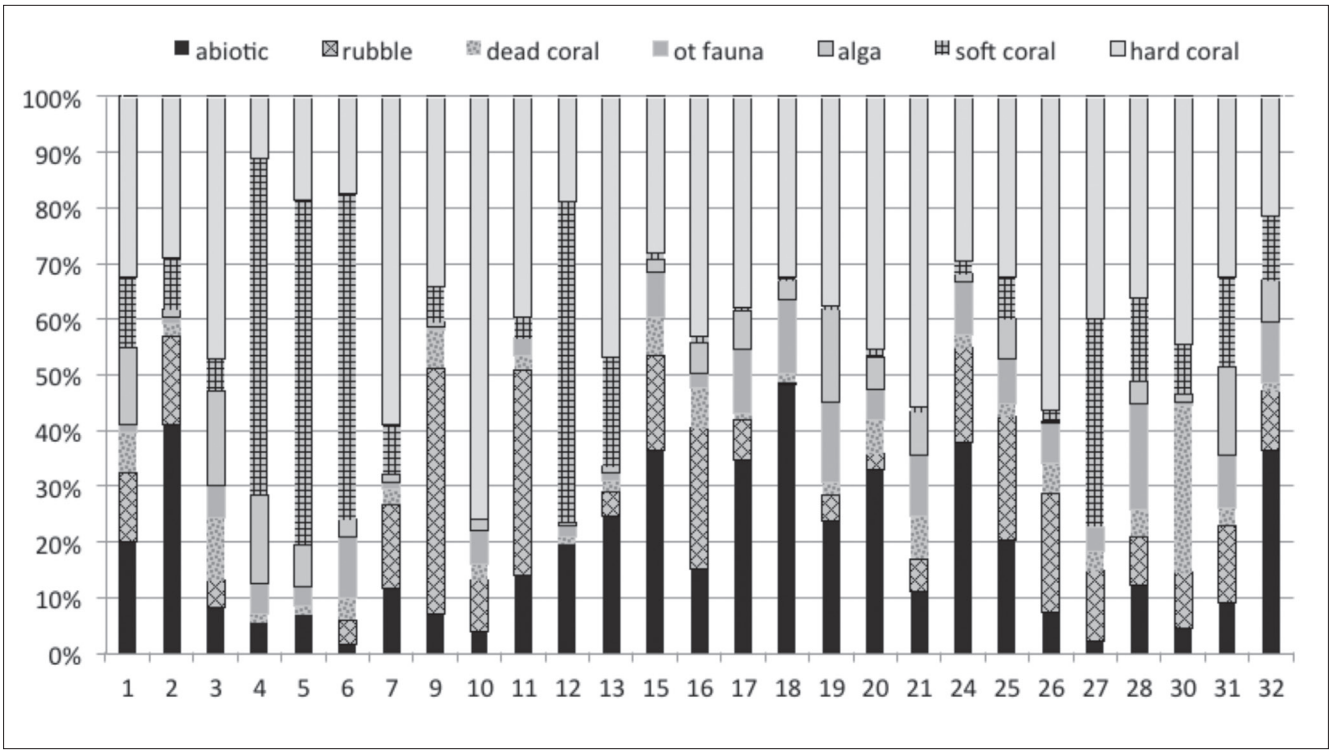


Figure 4.4. Average coverage of benthic substrates at survey sites during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

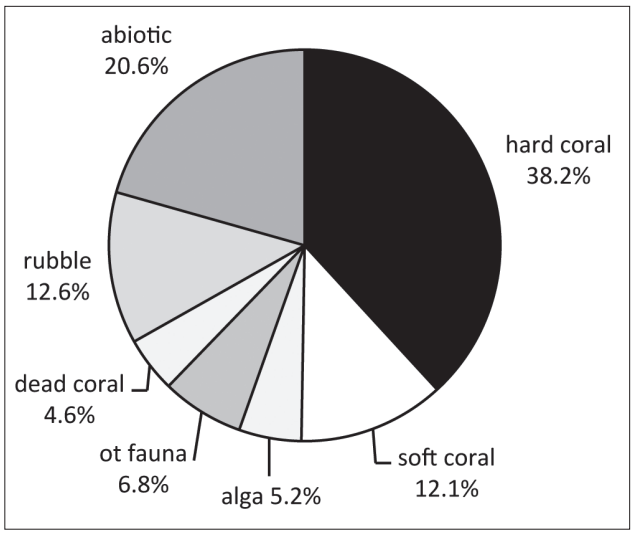


Figure 4.5. The average composition of total substrate coverage during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

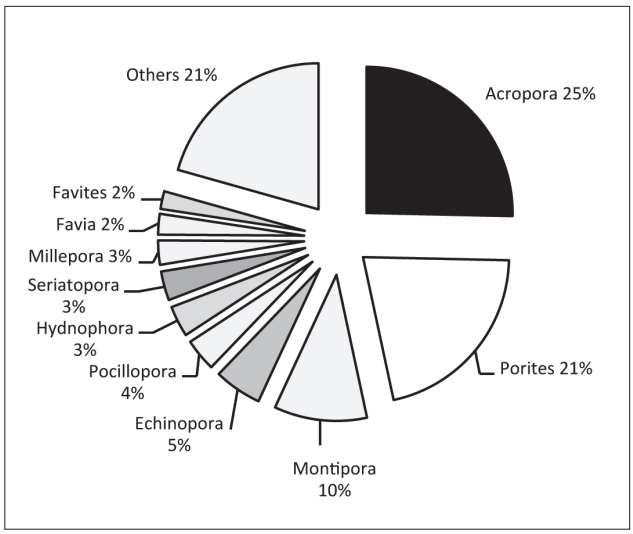


Figure 4.6. The average composition of the ten genera that dominated hard corals found during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

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Sites with the highest rubble coverage were Site 9 (Jepun, on average 44.3 %), Site 11 (Biaha, on average 37.0 %), and Site 16 (Jemeluk, on average 25.3 %). Rubble coverage at other sites ranged between 0 and 22.3 %.

The highest dead coral cover (i.e. dead coral + dead coral with algae) was at Site 30 (Burung Island, Gilimanuk, on average 30.0 %). Other sites had dead coral cover ranging from 1.0–11.3 %. The average algal coverage was between 0 and 17.0 %; other fauna coverage was between 0.5 and 19.0 %.

Overall, hard corals dominated the substrates at the 5–7m and 10–14m depths (average coverage 38.2 %), outranking abiotic components (20.6 %), rubbles (12.6 %), soft corals (12.1 %), other biota (6.8 %), algae (5.2 %) and dead coral (4.6 %).

4.3.4 Live coral cover (Hard Coral + Soft Coral)

The 5–7 m water depth

The percentage of live corals (hard coral + soft coral) at the 5–7m water depth ranged between 31.5 and 85.0 %. Site 27 (Coral Garden, P. Menjangan) had the highest percentage, while Site 25 (Sumber Kima) had the lowest percentage. The overall status of live coral cover at the 5–7m depth in Bali is as follows:

Data unavailable (7 sites) : Sites 1, 4, 5, 6, 10, 11, and 12
Bad : –
Medium (9 sites) : Sites 2, 9, 15, 17, 19, 24, 25, 31, and 32
Good (9 sites) : Sites 3, 7, 16, 18, 20, 21, 26, 28, and 30
Excellent (2 sites) : Sites 13 and 27

The coral cover at the 5–7m depth was good with a live coral coverage of 54.2 %.

The 10–14 m water depth

The live coral cover (hard coral and soft coral) at 10–14m ranged between 12.0 and 80.5 %. The highest coverage was at Site 5 (Nusa Dua), the lowest coverage was at Site 18 (Tukad Abu). The overall status for live coral cover at the 10–14m depth in Bali is as follows:

Data unavailable (3 sites) : Sites 30, 31, and 32
Bad (3 sites) : Sites 15, 18, and 24
Medium (14 sites) : Sites 1, 2, 3, 9, 11, 13, 16, 17, 19, 20, 21, 25, 26, and 28
Good (3 sites) : Sites 4, 7, and 27
Excellent (4 sites) : Sites 5, 6, 10, and 12

The coral cover at 10–14m was medium with live coral coverage of 47.7 %.

Overall, live corals at the 5–7m and 10–14m bathymetries were good with average coral cover of 50.4 %.

4.3.5 The composition of hard coral genera

The observed hard coral genera consisted of reef-building corals (zooxanthellae) and non reef-building corals (non zooxanthellae). The point intercept transect method recorded 54 hard coral genera with 0.01–9.67 % coral cover per site (average 38.16 %). *Acropora* was the dominant genus with 9.67 % average coverage, outranking *Porites* (8.12 %) and *Montipora* (3.92 %). These three genera were dominant across all sites.

Table 4.3. The average status of live corals and Mortality Indexes on survey sites during the Bali Marine Rapid Assesment Program, 29 April–11 May 2011

Site no.	Site	Depth	Genus	% cover
3	Sanur Channel	5–7 m	Acropora (*branching*)	31.00 %
7	Batu Tiga/ Mimpang	5–7 m	Acropora (*branching*)	56.00 %
7	Batu Tiga/ Mimpang	10–14 m	Acropora (*branching*)	46.00 %
7	Batu Tiga/ Mimpang	10–14 m	Acropora (*branching*)	58.00 %
9	Tj. Jepun	5–7 m	Acropora (*branching*)	29.00 %
9	Tj. Jepun	10–14 m	Acropora (*branching*)	35.00 %
10	Gili Tepekong	10–14 m	Echinopora	26.00 %
10	Gili Tepekong	10–14 m	Echinopora	74.00 %
13	Gili Selang	5–7 m	Acropora (*branching*)	50.00 %
13	Gili Selang	5–7 m	Acropora (*branching*)	47.00 %
15	Bunutan	5–7 m	Porites	32.00 %
16	Jemeluk	5–7 m	Acropora (*submassive*)	24.00 %
16	Jemeluk	5–7 m	Porites	23.00 %
19	Tulamben Drop off	10–14 m	Montipora	27.00 %
25	Sumberkima	5–7 m	Acropora (*branching*)	22.00 %
26	Anchor Wreck	5–7 m	Porites (*branching*)	45.00 %
26	Anchor Wreck	5–7 m	Porites (*branching*)	43.00 %
26	Anchor Wreck	10–14 m	Porites (*branching*)	22.00 %
27	Coral Garden	5–7 m	Porites (*branching*)	26.00 %
27	Coral Garden	10–14 m	Porites (*branching*)	23.00 %
30	Pulau Burung	5–7 m	Seriatopora	51.00 %

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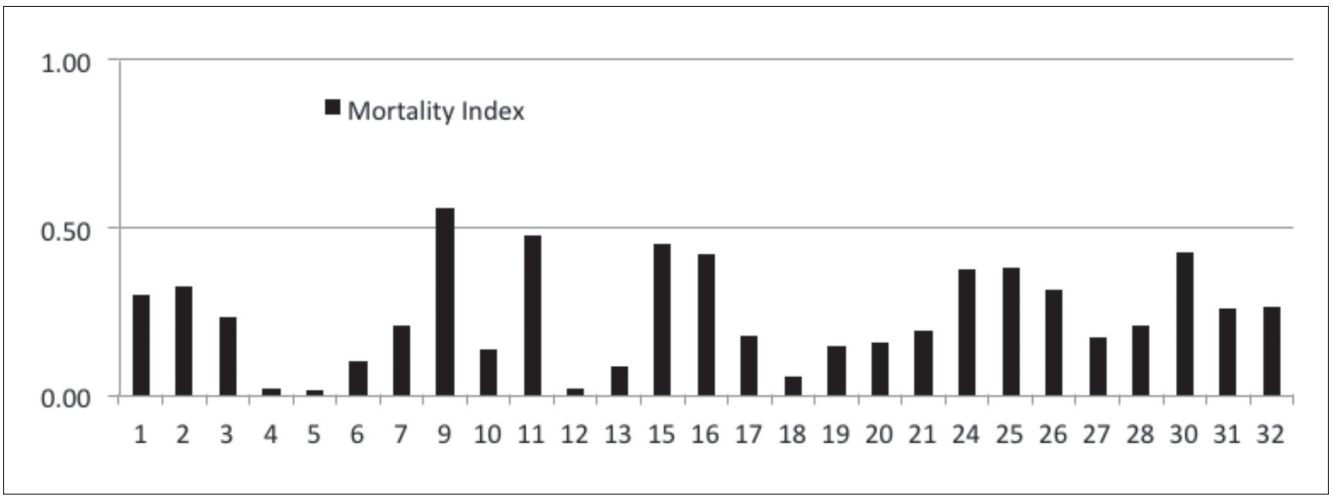


Figure 4.7. The coral reef Mortality Indexes at survey sites during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

Table 4.4. The average status of live corals and Mortality Indexes on survey sites during the Bali Marine Rapid Assesment Program, 29 April–11 May 2011

Site #	Site name	Location	Live coral status	Mortality Index
1	Terora	Nusa Dua	Medium	0.30
2	Glady Willis	Sanur	Medium	0.32
3	Channel	Sanur	Good	0.23
4	Kutuh	Uluwatu	Good	0.02
5	Nusa Dua	Nusa Dua	Excellent	0.02
6	Melia Hotel	Nusa Dua	Excellent	0.10
7	Batu Tiga/Mimpang	Candi Dasa	Good	0.21
9	Jepun	Padang Bai	Medium	0.56
10	Gili Tepekong	Candi Dasa	Excellent	0.14
11	Biaha	Candi Dasa	Medium	0.48
12	Seraya	Seraya	Excellent	0.02
13	Gili Selang Utara	Gili Selang	Good	0.09
15	Bunutan	Amed	Medium	0.45
16	Jemeluk	Amed	Medium	0.42
17	Kepah	Amed	Medium	0.18
18	Tukad Abu	Tulamben	Medium	0.06
19	Drop off	Tulamben	Medium	0.15
20	Gretek Alamanda	Tejakula	Medium	0.16
21	Penuktukan	Tejakula	Good	0.20
24	Takad Pemuteran	Pemuteran	Medium	0.38
25	Sumberkima	Pemuteran	Medium	0.38
26	Anchor Wreck	P. Menjangan	Good	0.31
27	Coral Garden	P. Menjangan	Excellent	0.17
28	Pos 2	P. Menjangan	Good	0.21
30	Pulau Burung	Gilimanuk	Good	0.43
31	Klatakan Barat	Melaya	Medium	0.26
32	Klatakan Timur	Melaya	Medium	0.27

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The entire group of hard coral genera consisted of *Acropora* (25.3%), *Porites* (21.3%) and *Montipora* (10.3%). Deconstructed, the *Acropora* comprised branching *Acropora* (75%), tabulate *Acropora* (15%), submassive *Acropora* (7%), encrusting *Acropora* (2%) and digitate *Acropora* (1%). Figure 4.6 describes the ten major genera of hard corals found during the survey.

Acropora dominated the hard coral cover at Sanur Channel, Batu Mimpang, Tanjung Jepun, Gili Selang, and Sumberkima. The 10–14m bathymetry of Gili Tepekong was dominated by *Echinopora*. *Porites* dominated Bunutan, Jemeluk, Anchor Wreck and Coral Garden. Slightly below *Porites*, submassive *Acropora* were found in Jemeluk at the 5–7 m depth. *Montipora* dominated the 5–7m depth of Tulamben Drop off. *Seriatopora* dominated the Burung Island of Gilimanuk.

4.3.6 Mortality Index

The Mortality Index is a measure of coral mortality or the status of coral health. The Mortality Index of all survey sites in Bali ranged between 0.02 and 0.56.

Sites 4 (Kutuh) and 5 (Nusa Dua) had the lowest Mortality Index, which indicated that both sites had the lowest coral mortality and the highest coral health compared to other sites. Site 5 had excellent coral cover. However, both sites were dominated by soft corals. The highest Mortality Index was found in Site 9 (Jepun), which indicated an unhealthy coral reef ecosystem with high coral mortality.

The total average Mortality Index for survey sites in Bali was 0.24. Based on the above histogram, the reefs in Bali were relatively healthy with low mortality.

4.4 CONCLUSION

The data collected from the 27 sites showed that Bali's coral reefs were in good condition with an average overall coral cover of 52.3%. The average hard coral cover was 38.2%. The average Mortality Index was 0.24. These statistics indicated relatively healthy reefs with low mortality.

Based on the percentage of live coral cover (hard and soft corals), the best coral reefs at a 5–7m bathymetry were found at Site 27 (Coral Garden, P. Menjangan) while the worst was found at Site 25 (Sumber Kima). The best live coral cover at a 10–14m bathymetry was found at Site 5 (Nusa Dua), the worst was found at Site 18 (Tukad Abu). When translated into the categories of Gomez and Yap (1998), the coral reefs at survey sites in Bali were on average good (ranging from medium to excellent). The best live coral cover was found at Site 5 (Nusa Dua) with 80.5% coverage (i.e. excellent). The worst live coral cover was found at Site 29 (Bunutan) with 29.0% coverage (i.e. medium). Overall, the coral coverage at the 5–7m depth was better than that at the 10–14m depth.

The dominant hard coral genera were *Acropora*, followed by *Porites* and *Montipora*. *Acropora* was dominated by the branching form. A total of 54 hard coral genera were recorded during the survey.

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Appendix 4.1. List of hard coral genera and the average coverage per survey site during the Bali Marine Rapid Assessment Program, 29 April–11 May 2011

No.	Hard coral genera	Sightings in all transects (n=3,358 points across 88 transects)	Average coverage
1	Acropora	851	9.67 %
2	Porites	715	8.12 %
3	Montipora	345	3.92 %
4	Echinopora	177	2.01 %
5	Pocillopora	121	1.38 %
6	Hydnophora	115	1.31 %
7	Seriatopora	108	1.23 %
8	Millepora	90	1.02 %
9	Favia	77	0.88 %
10	Favites	66	0.75 %
11	Galaxea	63	0.72 %
12	Stylophora	52	0.59 %
13	Goniastrea	42	0.48 %
14	Fungia	36	0.41 %
15	Psammocora	35	0.40 %
16	Cyphastrea	30	0.34 %
17	Lobophyllia	29	0.33 %
18	Pectinia	27	0.31 %
19	Montastrea	26	0.30 %
20	Porites s	26	0.30 %
21	Symphyllia	26	0.30 %
22	Oxypora	22	0.25 %
23	Mycedium	21	0.24 %
24	Turbinaria	21	0.24 %
25	Goniopora	20	0.23 %
26	Leptoseris	20	0.23 %
27	Platygyra	19	0.22 %
28	Echinophyllia	18	0.20 %
29	Merulina	18	0.20 %
30	Tubipora	18	0.20 %
31	Diploastrea	16	0.18 %
32	Euphyllia	15	0.17 %
33	Leptoria	11	0.13 %
34	Pachyseris	8	0.09 %
35	Siderastrea	7	0.08 %
36	Ctenactis	7	0.08 %
37	Alveopora	6	0.07 %
38	Herpolitha	6	0.07 %
39	Pavona	6	0.07 %
40	Physogyra	6	0.07 %
41	Anacropora	5	0.06 %
42	Caulastrea	4	0.05 %
43	Halomitra	4	0.05 %
44	Astreopora	3	0.03 %
45	Gardineroseris	3	0.03 %
46	Oulophyllia	3	0.03 %
47	Podabacia	3	0.03 %
48	Tubastrea	3	0.03 %
49	Acanthastrea	2	0.02 %
50	Sandalolitha	2	0.02 %
51	Coeloseris	1	0.01 %
52	Scapophyllia	1	0.01 %
53	Cycloseris	1	0.01 %
54	Plerogyra	1	0.01 %

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