Substrate stabilisation to promote recovery of reefs damaged by blast-fishing

Komodo National Park (Taman Nasional Komodo), Indonesia – 1998-2008

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Project in collaboration with The Nature Conservancy, Putri Naga Komodo, and Taman Nasional Komodo

Site information and project design

Across Indonesia, blast fishing has caused an estimated loss of up to US$3 billion in coastal protection services, fisheries, and tourism revenue. About half of the coral reefs in the 1,817 km² Komodo National Park (KNP) have been damaged by blast fishing that has occurred in the area since the 1950s. In 1980 the area was declared a national park, and in 1986 a UNESCO World Heritage site. In 1995 park authorities initiated a patrolling program to cut down on illegal fishing activities. Park officials estimate that blast fishing has decreased by 80% or more since patrols began enforcing regulations. Komodo National Park (Figure 1) has a 25 year management plan that includes 7 types of marine and terrestrial zones that limit the use and abuse of natural resources, and set aside specific areas for settlement, fishing and tourism.

Although blast fishing is now relatively rare within the park, heavily blasted sites have left large rubble fields of dead coral fragments that do not recover naturally despite good water quality and plentiful coral larvae. The coral rubble moves with the current and limits natural regeneration by abrading or smothering new coral recruits. To facilitate coral growth the structural foundation of the reef must be restored and rubble stabilized. There are physical restoration structures such as Reef Balls^{TM} and EcoReefs available but these are not likely to be economically feasible for marine parks in developing nations. Low cost rehabilitation methods to stabilize substrate using locally available materials have shown promising results in restoring the structural foundation and facilitating new coral growth and may be a solution for parks such as KNP where blasting bans are successfully enforced and coral larvae are abundant, but where little natural recovery occurs.

The physical restoration goals of this project were to increase hard coral coverage, and thus marine biodiversity, in blasted areas of KNP by stabilizing the substrate using low-cost, low-tech techniques.

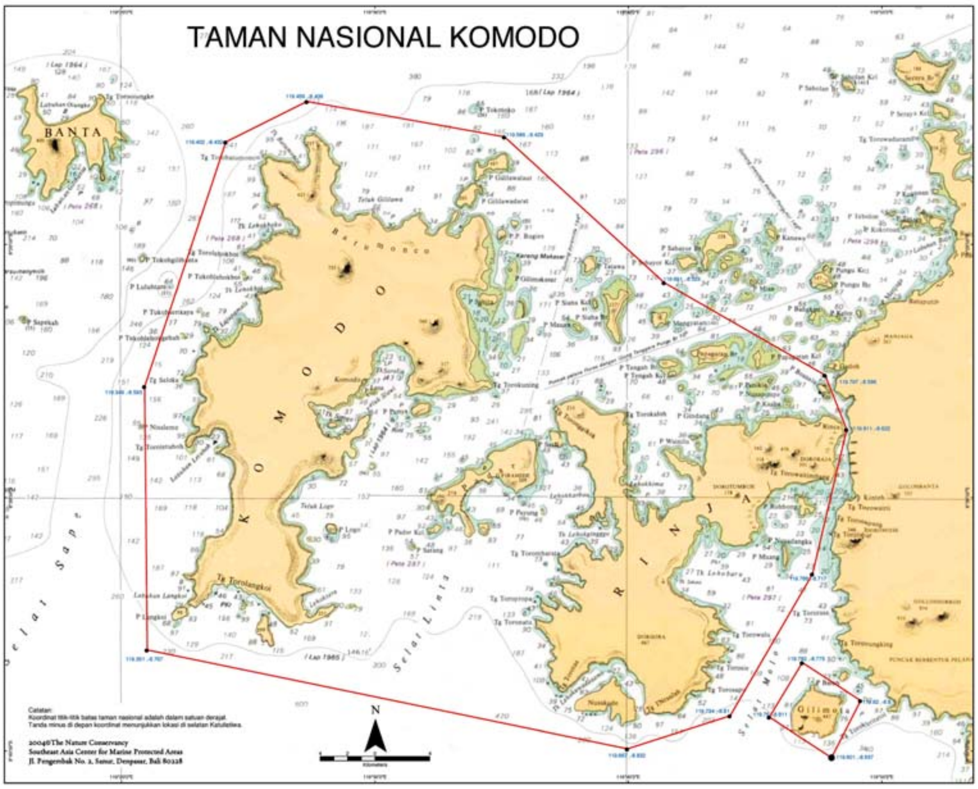

Figure 1: Map of Komodo National Park showing boundaries in red. *Source:* http://www.komodonationalpark.org/

Additional goals were to determine the most effective and economically viable configuration of rock piles for increasing coral growth and limiting rubble encroachment.

Methods used

Preliminary studies were conducted to determine an effective and economical method to stabilize rubble (loose, dead coral fragments) at blasted sites. Three stabilization techniques were tested in a pilot study: netting, concrete slabs, and rock piles. Although corals recruited to all three methods initially, the netting was eventually covered by rubble, the concrete slabs were frequently overturned, and rubble started filling in around the rock piles. Because the size of the rock piles could be increased and built up higher above the rubble fields, they showed the most promise as a viable rehabilitation technique. Current conditions and presence of coral larvae at different locations were also studied.

For large-scale rehabilitation, four sites with large areas of rubble with limited live coral cover were selected, so that rocks could be unloaded from boats without damaging existing coral. Limestone rocks were quarried in nearby western Flores and transported by truck and boat to the study sites. At each of these sites, four rock pile designs were installed from March to September 2002 using approximately 140 m^3 of rock per installation. The differing configurations were tested in order to determine which arrangement of rocks best supports coral recovery and decreases rubble encroachment for the same cost. The rocks were thrown into the water from boats and then rearranged where necessary by divers using SCUBA at depths of 5-10 m. The four treatments are as follows (Figure 2):

1. Rock piles 1-2 m^3 in size spaced 2-3 m apart (covers most area per m^3 of limestone rock, but leaves the majority of the rubble unstable within treatment area).
2. Complete coverage of the area with rock piled c. 75 cm high (no loose rubble within treatment area, but covers least area per m^3 of limestone rock deployed).
3. Spur and groove rows perpendicular to the prevailing current c. 75 cm high and 2 m wide, spaced 2-3 m apart (based on naturally occurring reef formations in high wave energy locations and may enhance settlement of coral larvae by creating turbulent flow as spurs block the current).
4. Spur and groove rows parallel to the current c. 75 cm high, 2 m wide, spaced 2-3 m apart (based on naturally occurring reef formations and may allow rubble to be flushed through the grooves).

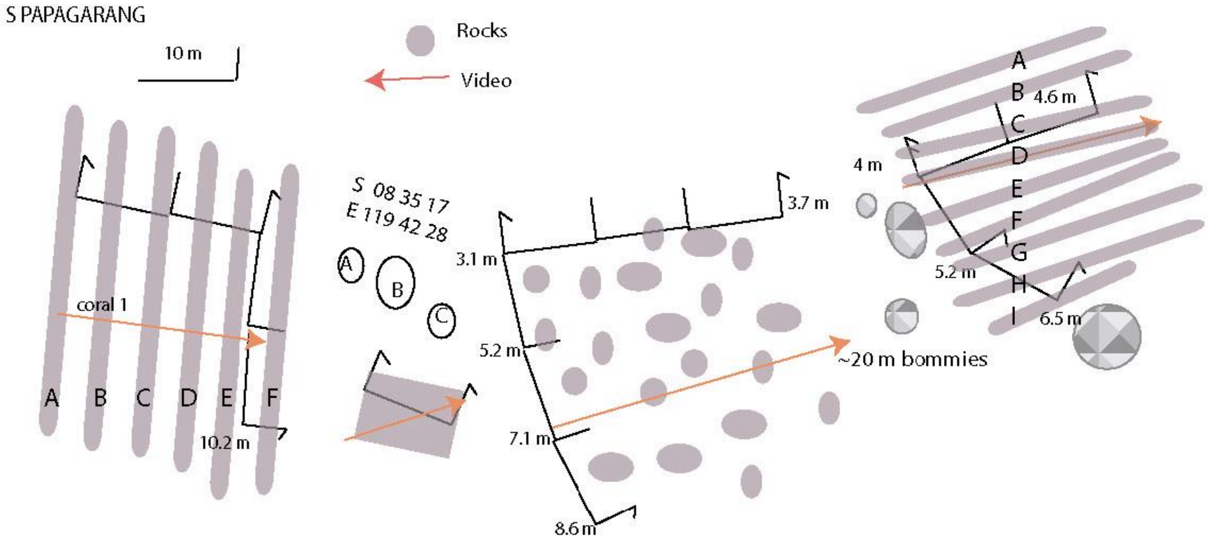

Figure 2: An example of the layout of rock piles on one study site (Papagarang) showing (from left to right) spur and groove rows perpendicular to current, complete coverage, rock piles, and spur and groove rows parallel to current.

Monitoring

In March 2003 the treatment installed first at each site was surveyed in six 1 m x 1 m quadrats. Data gathered included number, size, life-form, and taxon of scleractininan and soft coral, as well as sponges and other sessile organisms present within the 1 m^2 quadrat. Sites were surveyed again in Fall 2004 and Spring 2008 with all treatments in each site examined in the same manner. Due to the difficulty of identifying corals, trained scientists completed the surveys. Data from all 6 quadrats at each treatment site were pooled for analysis and to obtain coverage per m^2 of hard coral for each treatment. Control rubble sites near each rehabilitated site were also surveyed to collect data on natural regeneration of corals in rubble fields.

Results

After 6 years, hard corals colonizing the newly rehabilitated areas (Figure 3) covered as little as 8% of the rocks (hard coral coverage/m^2) at the least successful location (complete coverage at Gililawa), and as much as 43% at the most successful (parallel rows at Papagarang).

There was high variability between configurations and between sites, with no clear best configuration option (Figure 4).

Figure 3: New coral colonies, anemone, and fish aggregating on a rehabilitated rock pile; note rubble in background (Photo: H. Fox).

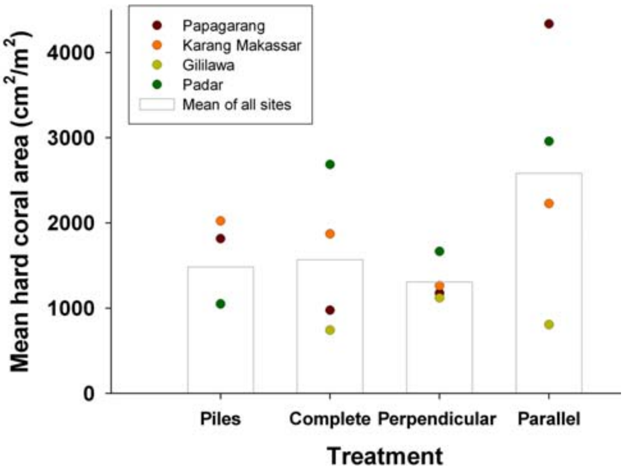

Figure 4: Mean hard coral coverage in cm^2/m^2 for each rock pile configuration after 6 years.

While the parallel rows had the highest average coral coverage (cm^2/m^2) it was not statistically significantly higher than the other treatments. The one constant is the limited coral growth at Gililawa, a low current site, for all rock pile configurations. Over the course of the study little to no natural regeneration occurred at untreated blast sites (Figure 5). Even at the least successful treatment sites, hard coral coverage was greater than at control sites.

Lessons learnt

There was high variability between locations not only in terms of coral growth but also with rubble encroachment. Rubble filled in at high current sites (around piles and between grooves of perpendicular and parallel rows, and some rubble on top of complete coverage sites), and there was sedimentation at low current sites, with the most success at moderate current levels (which in KNP, can still be quite strong). Percentages of live coral cover increased significantly in treated areas where the substrate was stabilized, as compared to untreated sites, over the course of the study. Aggregation of fish increased almost immediately after rock piles were installed. Some tabulate corals became victims of their own success, falling off of rock piles which could no longer support their weight. Perhaps some type of cement to strengthen piles could eliminate this problem, but this would complicate installation considerably. Further studies could help determine the best configurations for differing current/depth conditions. Rocks can be an effective and inexpensive method for stabilizing substrate after a blast event. This technique may be viable for parks that have easy access to rocks and boats in which to transport them, as well as coral larvae present and good water quality. However, the variability in coral re-growth and uncertainties about long-term success should serve as an additional incentive to invest in effective reef management that, among other things, halts this destructive fishing practice.

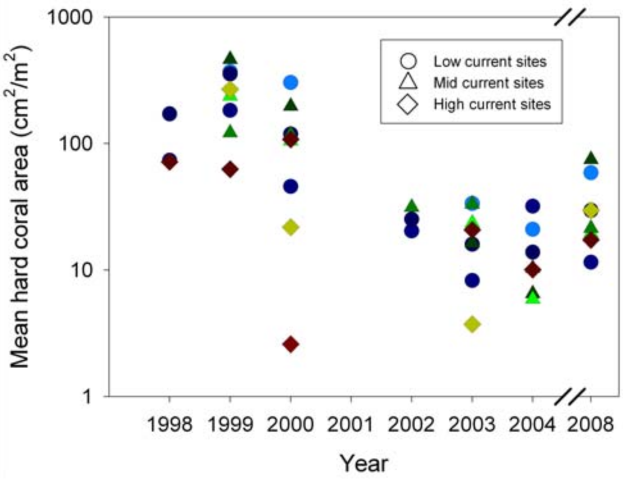

Figure 5: Mean hard coral coverage in cm^2/m^2 for each control site across time.

Resources required to stabilize c. 6000 m^2 of substrate

Funding was provided by The Nature Conservancy and The David and Lucile Packard Foundation. Physical rehabilitation total budget: c. US$30,000. Cargo boat rental for 76 trips (US$17,000) with 8-12 crew to load, transport and unload rocks, 1 boat driver, and 1 volunteer, coordinated by team of 2 divers (1 scientist and 1 park ranger), to finalize the rock configurations underwater. Speedboat to transport divers (fuel cost: US$3,380); 2275 m^3 of rock (910 truckloads, US$7,078); park ranger stipends: US$2,500; external consultants: US$10,000. Scientist salary costs were covered by The Nature Conservancy. Each follow-up monitoring trip required 8-10 boat days and two scientists trained in coral identification. Pile sizes were measured by park rangers. Estimated cost per m^2 of each design was: c. US$17 for complete coverage; c. US$5 for spur and groove rows; c. US$3 for piles; c. US$5 on average (see Table 1 for calculations).

Further information

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Table 1: Calculation of cost/m^2 per rock pile configuration. (Costs in US$)

Rock pile configuration	total # boat trips	total # truck loads	total area covered (m^2)	total rock cost	total boat cost	ranger + meals cost	total cost	cost/m^2
Piles	4	49	645	381.11	1066.67	186.67	1634.44	2.53
Piles	5	63	650	490.00	1333.33	233.33	2056.67	3.16
Piles	5	64	650	497.78	1333.33	233.33	2064.44	3.18
Piles	5	53	775	412.22	1333.33	233.33	1978.89	2.55
Piles total	**19**	**229**	**2720**	**1781.11**	**5066.67**	**886.67**	**7734.45**	**2.84**
Complete	5	56	90	435.56	1333.33	233.33	2002.22	22.25
Complete	4	51	100	396.67	1066.67	186.67	1650.00	16.50
Complete	4	50	130	388.89	1066.67	186.67	1642.22	12.63
Complete	5	64	115	497.78	1333.33	233.33	2064.44	17.95
Complete total	**18**	**221**	**435**	**1718.89**	**4800.00**	**840.00**	**7358.89**	**16.92**
Perpendicular rows	4	54	350	420.00	1066.67	186.67	1673.33	4.78
Perpendicular rows	4	50	385	388.89	1066.67	186.67	1642.22	4.27
Perpendicular rows	5	45	515	350.00	1333.33	233.33	1916.67	3.72
Perpendicular rows	6	78	535	606.67	1600.00	280.00	2486.67	4.65
Perpendicular rows total	**19**	**227**	**1785**	**1765.56**	**5066.67**	**886.67**	**7718.89**	**4.32**
Parallel rows	5	61	350	474.44	1333.33	233.33	2041.11	5.83
Parallel rows	5	45	380	350.00	1333.33	233.33	1916.67	5.04
Parallel rows	4	49	270	381.11	1066.67	186.67	1634.44	6.05
Parallel rows	6	78	490	606.67	1600.00	280.00	2486.67	5.07
Parallel rows total	**20**	**233**	**1490**	**1812.22**	**5333.33**	**933.33**	**8078.89**	**5.42**
TOTALS	**76**	**910**	**6430**	**7077.78**	**20266.67**	**3546.67**	**30891.12**	**4.80**