Wakatobi Marine National Park Monitoring Program:
A Summarising Report

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Information included herein represents a report of the scientific monitoring program implemented by the Coral Reef Research Unit, University of Essex (CRRU) and Operation Wallacea, in collaboration with The Indonesian Institute of Science (LIPI) and The Wallacea Foundation (TWF), over a six year period from 2002 to 2007.

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Geography and the Study Site

Sulawesi is the fourth largest island in Indonesia with an area of 159,000km^2 and lies between Borneo to the west and the Mollucas Islands to the east. Sulawesi also lies on the theoretical division between fauna and flora characteristic of Asia and Australia (The Wallace Line) and is consequently an extremely important area for global biodiversity, evolutionary biology and biogeography (Tomascik *et al*., 1997).

Sulawesi has four provinces, including Sulawesi Tenngarra (Southeast Sulawesi) which encompasses the Southeast peninsula of the island and the large islands of Buton, Muna and the Tukang Besi archipelago. It lies between latitudes 3^o – 6^o S and 120^o 45' – 124^{o}06' E. The Tukang Besi islands had been subject to very little research and before 1996 research had been limited to a Dutch expedition in 1985 largely to investigate the topography and geology of the area, although some coral identification was conducted at some sites during this survey (Best *et al*., 1989). The Wakatobi Marine National Park, the location of this long-term reef monitoring programme is located with the Tukang Besi Archipelago.

The Wakatobi Marine National Park

The Wakatobi Marine National Park is the second largest MPA in Indonesia at 13900km^2 and was established in July 1996. The park is classified as IUCN Category II, a National Park managed mainly for ecosystem protection and recreation. The park consists of four main islands, Wangi Wangi, Kaledupa, Tomia and Binongko, giving the area the Wakatobi acronym. There are also two large atolls to the west of the main island chain, Karang Kapota and Karang Kaledupa. The park contains a population of approximately 98,000 who belong to two distinct ethnic groups. The *Butonese* people are land based farmers, traders and craftsmen and comprise about 95% of the local population. The *Bajo* people are traditional fishermen, living mostly in semi permanent villages erected on the reef flats. They are sometimes referred to as 'sea gypsies' as many still spend part of the year, living on their boats during fishing excursions. Fish is the most important protein source for local people and the *Bajo* provide the largest proportion of fish produce solid in local markets (Cullen 2007)

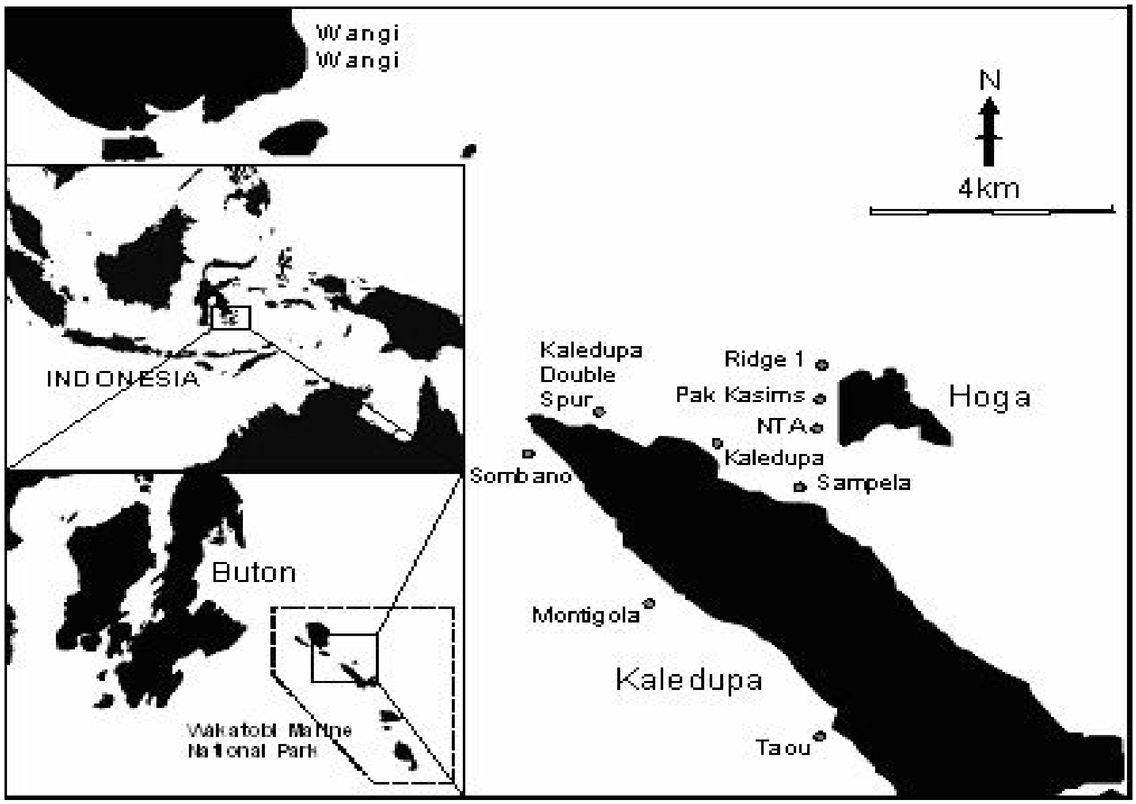

Figure 1 Location of the study sites within the Wakatobi Marine National Park, southeast Sulawesi, Indonesia

Aims and Objectives of the monitoring programme

The reef based monitoring programme aimed to increase our understanding of how:

1). The abundance and diversity of scleractinian corals change annually in different areas of the study area subjected to varying management practices, pressures and anthropogenic stressors.

2. The characteristics of benthic biological and non-biological features change annually in different areas of the study area subjected to varying management practices, pressures and anthropogenic stressors.

3. The abundance and diversity of fish associated with coral reefs change annually in different areas of the study area subjected to varying management practices, pressures and anthropogenic stressors.

The coral reef monitoring program was first established in 2002 when 108 permanent transects were laid (marked at the start, middle and end by embedding galvanised pools) at 12 sites around the study area in replicates of three at the reef flat (5m horizontal distance on the landward side from the reef crest), reef crest and upper reef slope (defined by habitat type and a depth of 10 m). For the six north-east Kaledupa sites (Ridge 1, Kaledupa Double Spur, Kaledupa, Pak Kasims, Hoga NTA and Sampela), surveys were repeated annually for six years, whereas for the west Kaledupa sites (Sombano, Montigola and Taou), the surveys were repeated after a five year interval. Specifically the following data were collected as part of the monitoring program:

a. The percentage cover, diversity and community structure of hard corals as assessed by a 50 m continual line intercept transect
b. The percentage cover of soft corals as assessed by a 50m continual line intercept transects.
c. The percentage cover of macro algae as assessed by a 50m continual line intercept transect.
d. The percentage cover of dead coral and coral rubble as assessed by a 50m continual line intercept transect.
e. The density, diversity and the community and functional structure of coral reef fish as assessed by a 50 m by 5 x 5 m 25 minute restricted effort belt transect.
f. The abundance of threats present in the form of bleaching, disease and predators, such as Crown Of Thorns starfish (COTs) and *Drupella*.

Site descriptions (refer to figure 1)

Hoga No Take Area

The Hoga No Take Area is off the west coast of Pulau Hoga (GPS: 05°28.40S 123°45.45E) and falls within a voluntary No Take Area that was established in 2001. The reef crest is about 150m offshore, adjacent to sea grass beds. The reef drops vertically from the crest to a depth of just over 30metres, from where a sandy slope forms into slightly deeper waters. The site is characterized by many overhangs and small caves. Limited fishing does occur at this site as compliance with the no-take area is not total, although fishing is generally artisanal and by single hook and line.

Pak Kasim's

This site is located around 500 metres to the north of the No Take Area along the same stretch of the west Hoga fringing reef (GPS: 05°27.569S 123°45.179E). The reef crest is almost 200 metres offshore, again adjacent to seagrass beds. The reef aspect is not as vertical as within the NTA, and slopes at between 40 and 70 degrees. The reef bottoms out at around 50 metres into a sandy slope. There are some spur and groove formations with sandy gullies in between. Although this site is outside the NTA, it is not believed to be subject to extensive fishing. There is some evidence of fish traps and limited gleaning at low tide.

Ridge 1

This site is one of the least impacted within the area, situated to the north west of Hoga island on a barrier over one kilometre offshore (GPS: 05°26.565S 123°45.138E). The ridge runs from north to south with the outer slope dropping to over 100 metres and the inner slope somewhat shallower. The reef slopes at around 70 degrees on both sides with the crest remaining under several metres of water at all tides, with effectively no reef flat. This means no gleaning occurs at this site. Some artisanal line fishing occurs here and there is increasing evidence of bomb fishing along lengths of the ridge.

Kaledupa

The Kaledupa site is on the north eastern side of the island of Pulau Kaledupa (GPS: 05°28.22S 133°43.47E). The reef is around 300 metres offshore across a seagrass bed, with some areas of mangrove along the shoreline. There is an extensive well developed reef flat community that extends for tens of metres back from the reef crest. The reef slopes at an angle of around 50 degrees and descends past the 50 metre mark to a sloping sandy bottom. The reefs in this area are exposed to moderate levels of subsistence fishing, but again there is evidence of bomb fishing in the form of rubble craters (maximised during 2003).

Sampela

This site is adjacent to the Bajo village of Sama Bahari (Sampela) which is built on the reef flat (GPS: 05°28.975S 123°44.95E). The site is also subject to large sediment loads and reduced light availability due to this large sediment load (Crabbe and Smith, 2002, 2003, 2004, 2005, 2006). Adjacent intertidal mangroves and subtidal seagrass flats have been highly impacted by anthropogenic activities. The transects were located on a protected reef which slopes at 45 degrees down to a depth of around twelve metres. The geography of adjacent reef systems results in lagoonal characteristics and seasonally high resuspended sediment loads.

Kaledupa Double Spur

This site is located near the northern most tip of Pulau Kaledupa (GPS: 05°27.432S 123°42.412E) and has a very varied topography. There are steep walls with high benthic cover, interspersed with shallow, often rubble strewn, sandy slopes. Several spurs stick out from the main reef and descend past 50 metres seawards. Again this site experiences moderate levels of subsistence fishing, usually with hook and line gears.

Sombano

The reefs at Sombano are on the western side of Kaledupa island at the northern end (GPS: 05°30.117S 123°42.008E). There is a small settlement on the mainland of Kaledupa at this location separated from the reefs by extensive seagrass beds that extend for over 300m towards the steeply sloping reef that drops of into deep water. As with the Kaledupa Double Spur site, the area is known to local fisherman as a spawning ground and the villagers glean the reefs heavily at low tide, but leave other areas aside for the farming of *Agar agar*, which also covers large areas of the reef flat.

Montigola

The reefs at Montigola are adjacent to a Bajo village on the western side of Kaledupa island (GPS: 05°32.939S 123°44.600E), but of a much smaller scale than that at Sampela. The reefs are several hundred metres offshore separated from the village on the reef flat. The reefs are heavily gleaned as at Sampela and exploited in an artisanal manner with hook and line from small dugout canoes. The reefs are fairly steep slopes with areas of gentle sandy slope in between, often strewn with coral rubble. The reefs descend past 30m and then drop steeply into the depths.

Taou

The reefs at Taou are similar in structure and distance from shore as those to the north at Montigola. The village of Taou is on the south western side of Kaledupa island (GPS: 05°35.238S 123°45.320E), and is exploited locally using artisanal methods. There are more extensive rubble strewn areas at this site, while the reef flat is covered with seagrass beds. There are some small areas of mangrove forest along the shoreline. As at Montigola the reefs decline fairly steeply to over 30 metres in depth and then descend almost vertically into the depths.

Methodology and Protocols

Benthic assemblage

The main group studied were the hermatypic corals (Order Scleractinia); other groups of sessile reef organisms to be monitored included the soft corals (Alcyonacea), sponges (Porifera), macro algae and Crustose Coralline Algae. The area of coral rubble, dead corals and area of bare substratum available for recruitment was also recorded.

Monitoring was carried out within three "reef zones";

a) the reef flat, (1-2m depth),
b) the reef crest (2-6m depth) and
c) upper reef slope (9-12m depth).

A combination of survey methods were used to quantify spatial and temporal changes in the benthic community. The principal technique used was the continuous Line Intercept Transect (English *et al*., 1996), combined with belt transects (Loya, 1978). After generating species-area curves, three 50 metre long transect tapes were laid along depth contours parallel to the shoreline for each depth at each site, giving a total of nine transects per site with total length of 450m. All life forms intercepting the transect line were recorded to genus with the length intercepting the transect tape recorded to the nearest centimetre. All transect data were square root transformed to satisfy the distribution and variance assumptions of ANOVA. Data was analysed using the statistical computer package SPSS.

Fish Assemblage

Fish community structure was assessed using a modified protocol devised by the Australian Institute of Marine Sciences. A time and distance restricted belt transect was used to characterise the fish community using standard underwater visual techniques. A 50 m by 5 (horizontal) x 5m (vertical) belt transect was used and a sampling effort of 25 mins was deemed appropriate (from preliminary studies and effort vs richness plots). The species of fish were identified and absolute abundances were recorded. Nine 50m belt transects were completed at each site (three replicates within each zone as described for the benthic intercept transects) with a horizontal gap of at least 20m between transects within a zone. This gave a total effort of $11250m^3$ per site. In an attempt to control natural variability in fish densities (e.g. due to diurnal influences on behaviour) sampling was limited to between 0900 and 1500 hrs.

Results

Habitat Quality Assessment: Benthic transects

The percentage of hard coral cover declined significantly ($F_{5,260}$=60.8;p<0.001) for all of the study sites within the park over the study period from 2002 to 2007 (Figure 2a). There was a significant interaction in coral cover between year and site ($F_{25,260}$=3.0;p<0.001) demonstrating that the rates of declined over the study period differed between sites. Only coral cover within the NTA did not declined significantly over the study period.

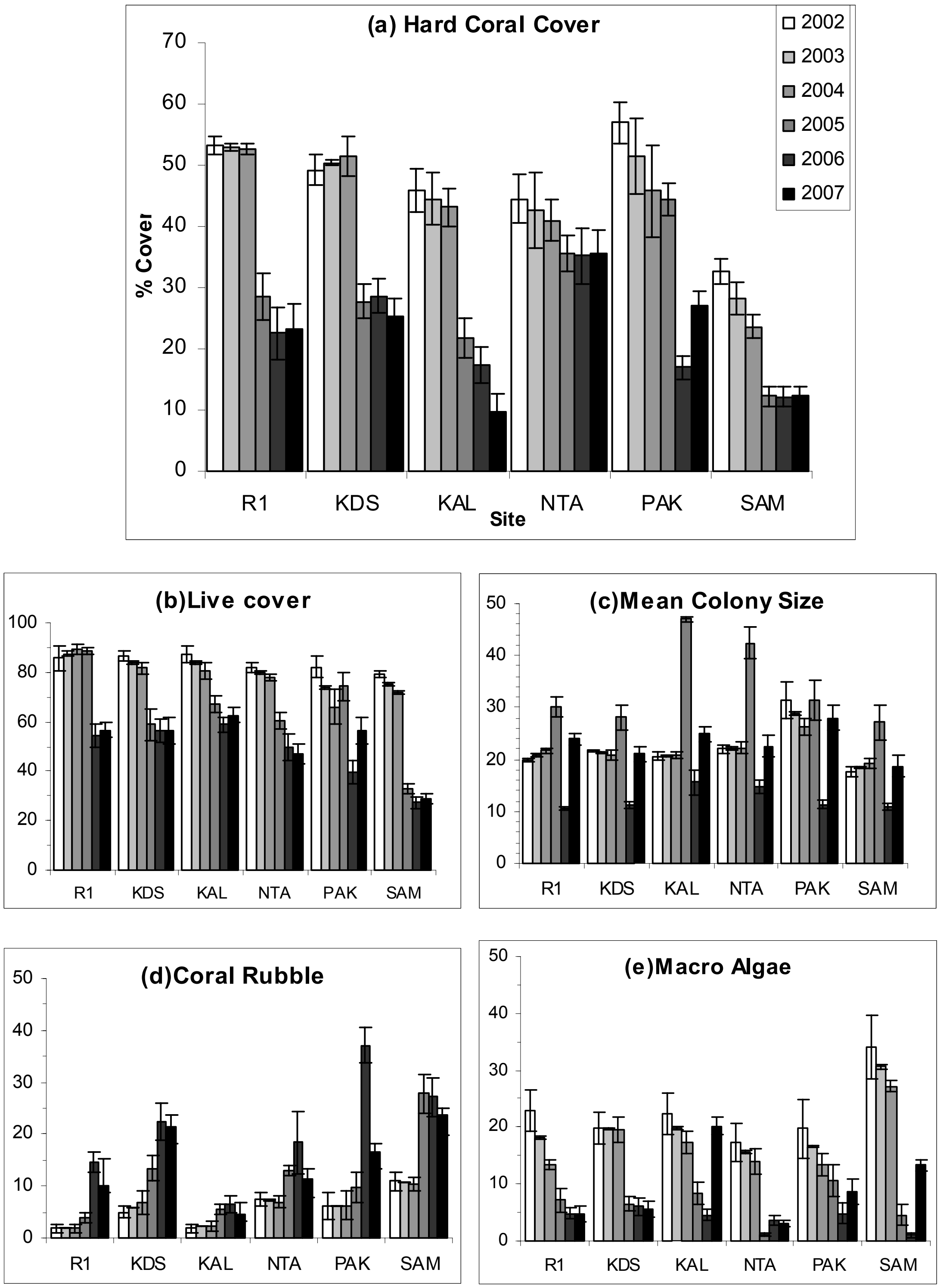

Figure 2 Percentage cover of five benthic attributes at the six study sites, over six years. (a) Hard coral cover, (b) total live benthic cover, (c) Mean hard coral colony size in centimetres, (d) percentage coral rubble cover, (e) macro-algal cover (means ± SE, n = 3in all cases)

In terms of between sites within years, Sampela was found to have significantly lower coral cover than all the other sites ($p<0.001$), while the Kaledupa site was also shown to be significantly different to all the other sites ($p<0.01$), showing the largest decline.

The total live cover (including hard corals, soft corals and sponges) showed a similar pattern to the hard coral (Figure 2b), with no significant difference over the first three years of the study, but then a steep decline and then no difference for the remaining three yearsT. he total live cover has declined from a mean of 83.7(±1.3)% in 2002 to just 51.3(±5.0)% in 2007.

The mean hard coral colony size (Figure 2c) was found to be significantly different between the study years ($F_{5,257}=54.0;p<0.001$), with *post-hoc* tests identifying that the mean colony size for 2005 was significantly larger at all sites ($p<0.001$), while the mean colony size in 2006 was significantly smaller at all sites ($p<0.001$). There was no significant difference in mean colony size between the first three years of the study and the final year when the mean colony size was 20.0(±0.8)cm across all sites. There were significant between site differences in mean hard coral colony size ($F_{5,257}=19.2;p<0.001$). The mean hard coral colony size was originally recorded at 22.2(±1.9)cm, in 2002, and was 23.2(±1.3)cm in 2007.

The abundance of coral rubble increased throughout the study at all sites (Figure 2d). With regard to between site differences, Sampela consistently had the highest coral rubble cover ($p<0.01$), The negative association between hard coral cover and coral rubble cover can be seen clearly in Figure 3. A linear regression was carried out which found a significant relationship between hard coral cover and coral rubble cover ($F_{1,44}=42.89,p<0.001$), with an $r^2=0.67$. The coral rubble cover was originally recorded at 5.6(±1.4)% in 2002, and increased to 14.6(±1.9)% in 2007.

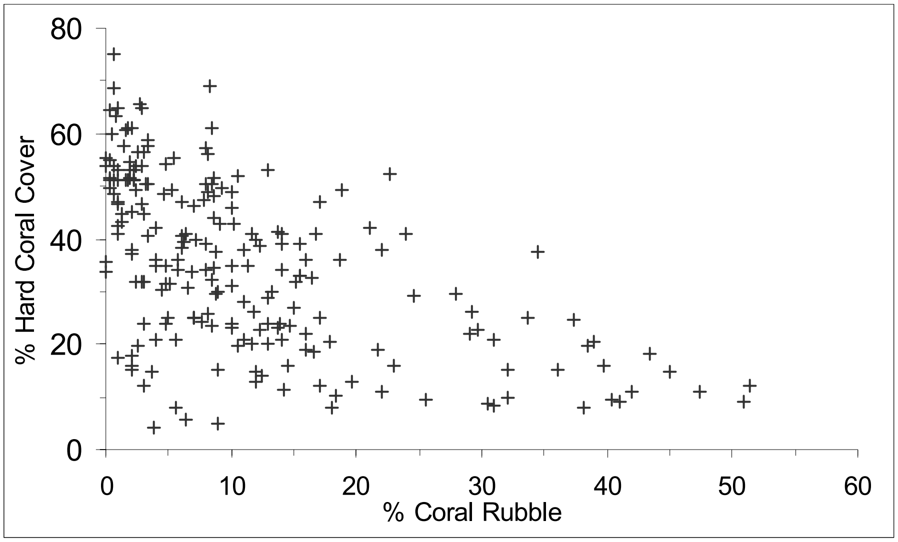

Figure 3 Association between hard coral cover and coral rubble cover

The Macro-algal cover (Figure 2e) varied significantly between years ($F_{5,257}$=81.9;p<0.001) and also between sites ($F_{5,257}$=8.1;p<0.001), a significant interaction between site and year was also recorded ($F_{25,257}$=3.8;p<0.001). The data for 2007 suggests that the macro-algal cover is still significantly lower than for the first three years (p<0.001), but significantly higher than for the 2005 and 2006 surveys (p<0.01). The mean macro-algal cover was originally recorded at 22.7(±2.4)% in 2002, and has declined to 9.3(±2.6)% in 2007.

Fish assemblage

The mean fish abundance (Figure 4) was found to be significantly different both between years ($F_{5,253}$=24.0;p<0.001) and between sites ($F_{5,253}$=20.7;p<0.001). Tukey *post-hoc* tests found that there was no significant difference in mean fish abundance over the first four years of the study from 2002 to 2005, nor between data collected in 2006 and 2007. There was however a significant difference in mean fish abundance between these two groups (p<0.001). Sampela had a lower abundance of fish than all other sites (p<0.001), while the NTA site showed a significantly higher abundance of fish than all other sites (p<0.001), with the exception of the Ridge 1 site. There was also an interaction between the year and site ($F_{25,253}$=2.5;p<0.01) with the NTA site having higher mean fish abundance for the first four years of the study, but showing no significant difference to the other sites (except Sampela) for the final two years.

For the mean fish species richness (Figure 5), there were significant differences found between years ($F_{5,253}$=60.2;p<0.001) and between sites ($F_{5,253}$=18.4;p<0.001). There was no significant interaction between year and site. The Ridge 1 site showed no significant difference in fish species richness over the first four study years, but then, like all of the sites showed a significant decline between 2005 and 2006(p<0.001). All the other sites were shown to have increasing fish species richness over the study period. The Sampela site consistently had the lowest species richness.

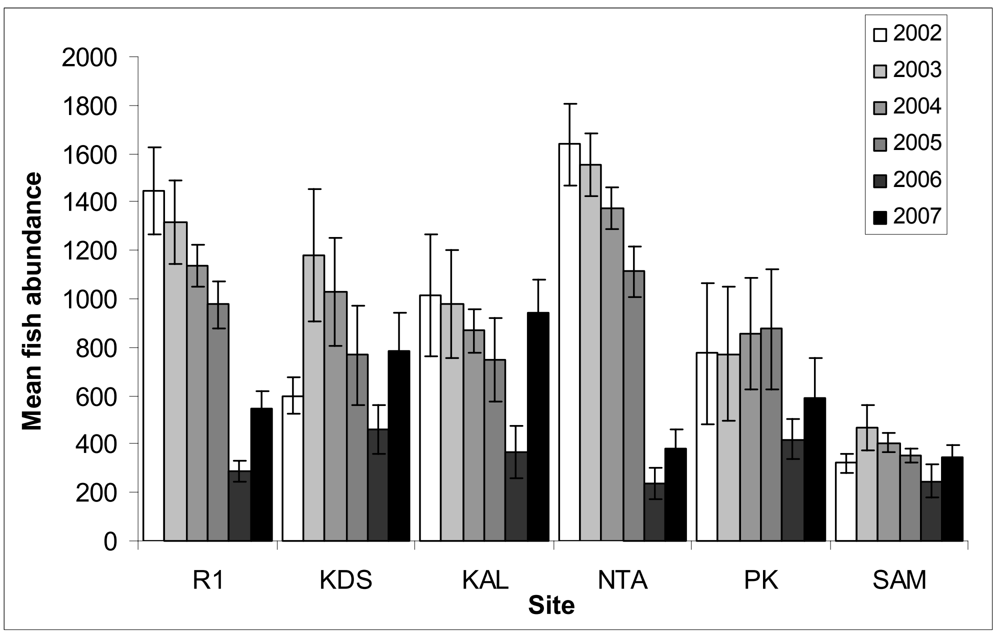

Figure 4. Mean(±s.e.) fish abundance per 1250 m^3 at each of the six study sites over six years

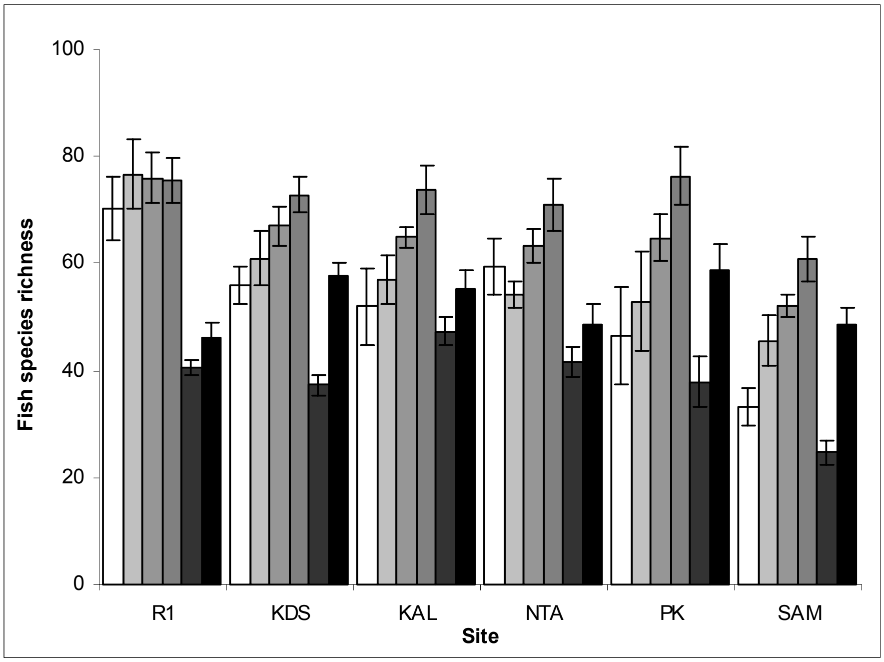

Figure 5. Mean(±s.e.) fish species richness per 1250m^3 at each of the six study sites over six years [Key as in Figure 4.5]

Examples of fish taxa specific changes

The species richness of the grouper family (Figure 6) did not show any significant difference over the study period, but did show significant differences between sites ($F_{5,251}$=10.8;p<0.001), with the NTA site showing significantly more species of grouper than Ridge 1 (p<0.01) and also more species than the four other sites (p<0.001).

There were significant differences in the species richness of the Butterflyfish (Chaetodontidae) both between years ($F_{5,251}$=9.6;p<0.001) and between site($F_{5,251}$=28.2;p<0.001), but there was no significant interaction between the two factors. Over the six years of the study there was a decline in the number of Butterflyfish species at Ridge 1(p<0.001), NTA(p<0.05) and Sampela(p<0.05), whereas the number of species remained constantly low at the other sites.

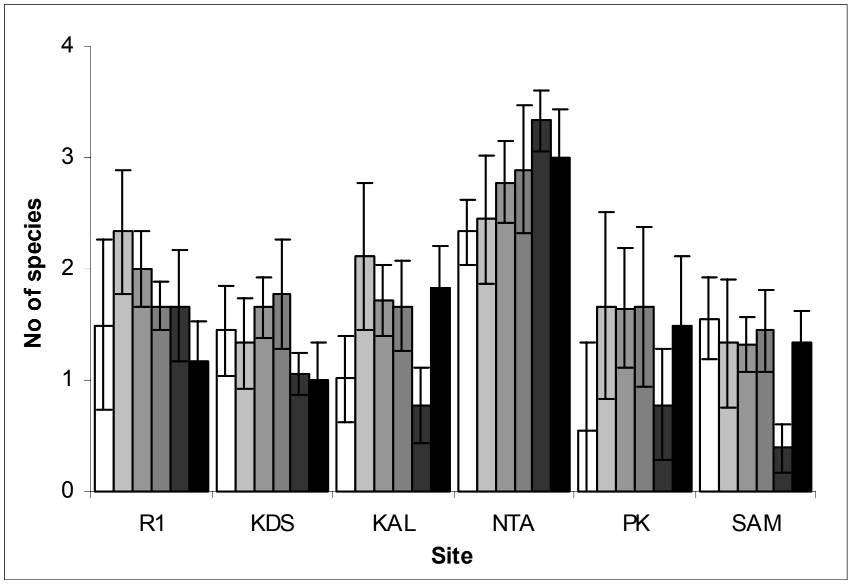

Figure 6 Mean (±s.e.) number of Grouper (Serranidae and Epinephelidae) species present at each of the six study sites over six years [Key as in Figure 4.5]

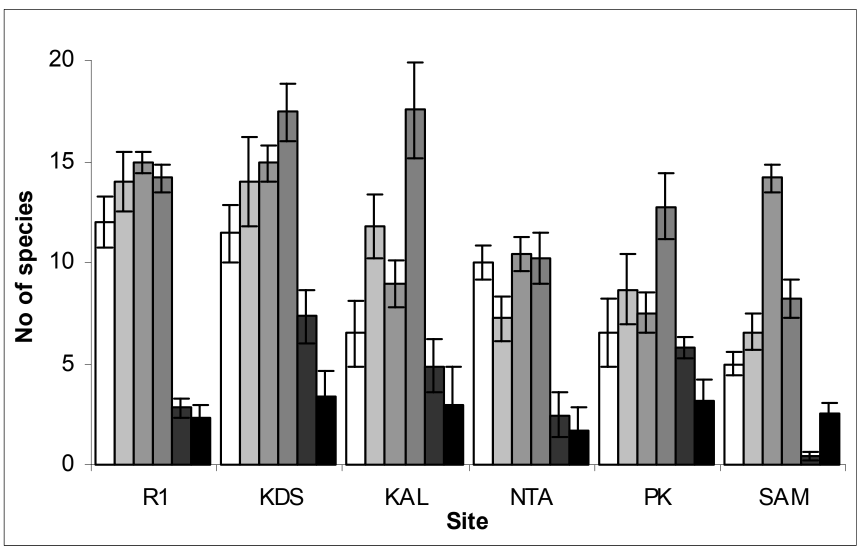

Figure 7 *Mean (±s.e.) number of Scaridae species present at each of the six study sites over six years [Key as in Figure 4]*

Ridge 1 showed the highest number of Butterflyfish species starting at 11.0(±1.2) in 2002 which declined to 8.2(±1.4) in 2007. The Sampela site had 5.6(±1.3) in 2002 which reduced to 4.2(±0.7) by 2006, but returned to 5.0(±1.1) in the 2007 survey. There was no significant difference in numbers of Chaetodont species between the other sites.

The number of parrotfish species (Scaridae – see Figure 7) varied between both year ($F_{5,251}$=66.2;p<0.001) and site ($F_{5,251}$=33.7;p<0.001), and there was also significant interaction between the two ($F_{5,251}$=2.4;p=0.001). All sites showed a large decline in the richness of the Scaridae between 2005 and 2006. Before this time there was no significant difference in scarid richness at the Ridge 1, Kaledupa Double Spur or the NTA sites. For Kaledupa and Pak Kasims there was a peak in scarid richness in 2005, and for Sampela where the richness was lowest (p<0.001), the peak richness occurred in 2004 (Figure 7).

Wakatobi MNP assessment: results summary for the northern Kaledupa and Hoga region

Final data obtained during 2007 are dependent on the starting values obtained during 2002. Arguably a better measure of the park responses is to examine the rates of change. This section examines the rates of change in key variables across all sites combined.

Over the six years of the study the mean value of hard coral cover for the Wakatobi MNP (Figure 8) declined by 48 % (normalised against starting values and suggesting a 8 % decrease per year) from 46.7(±3.4)% in 2002 to 22.2(±4.0)% in 2007 (see Figure 8). The hard coral cover varied significantly between the six years of the study ($F_{5,35}$=13.7;p<0.001), with there being no significant difference between the 2002, 2003 and 2004 data, then a significant decline (Tukey p<0.001) to the values for 2005, 2006 and 2007 between which there was no significant difference.

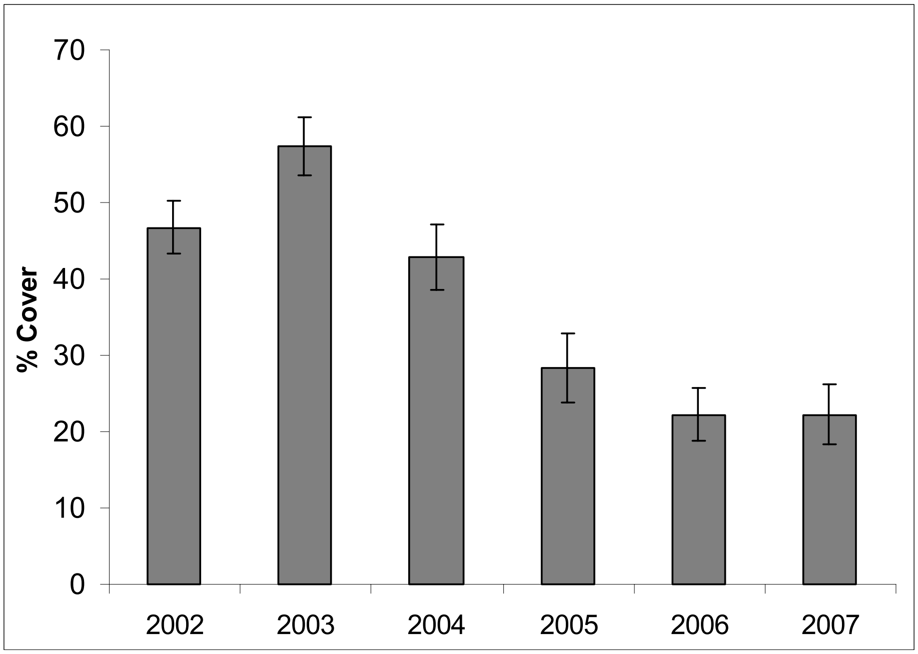

Figure 8. Mean(±s.e.)hard coral cover within the Wakatobi over the six year period (mean ± SE, n =3 in all cases)

There was no significant difference in the mean percentage cover of soft coral within the park over the study period (recorded at 20.5(±5.2)% in 2002 to 25.2(±6.0)% in 2007). A significant increase in the mean percentage of coral rubble (Figure 9a) found within the park was identified from the One-way ANOVA ($F_{5,35}$=4.8;p<0.01). Tukey *post-hoc* tests revealed that there was no significant difference between the value for the first four years of the study, then a significant increase (p<0.001) in 2006, which then reduced back to a level not significantly different from the first four years values. The mean value of coral rubble cover for the Wakatobi MNP increased from 6.8(±1.5)% in 2002 to 21.0(±4.3)% in 2006 (a > 300 % increase), and then declined slightly to 14.6(±3.0)% in 2007 (>200% increase from 2002). The macro-algal cover also change significantly over the study period ($F_{5,35}$=5.7;p<0.001), with no significant difference in the first three years (Figure 9b) with a 2002 value of 14.9(±3.4)%, then a steep decline in 2005 (p<0.001) to 6.4(±1.3)%, no significant change in 2006 and then a slight increase to 9.3(±2.6)% in 2007, that was significantly lower than at the start of the study (p<0.05).

There was a significant decline in the total live cover (Figure 9c) recorded throughout the study period ($F_{5,35}$=9.6;p<0.001). There was no significant difference in total cover over the first five years, with 80.5(±3.2)% recorded in 2002. The last two years values were not significantly different from one another, with a value of 51.3(±5.0)% in 2007, but there was a difference between these two groups (p<0.001). There was no significant difference in the number of hard coral colonies per transect or in the generic richness of the Scleractinian corals or the mean hard coral colony size over the study period.

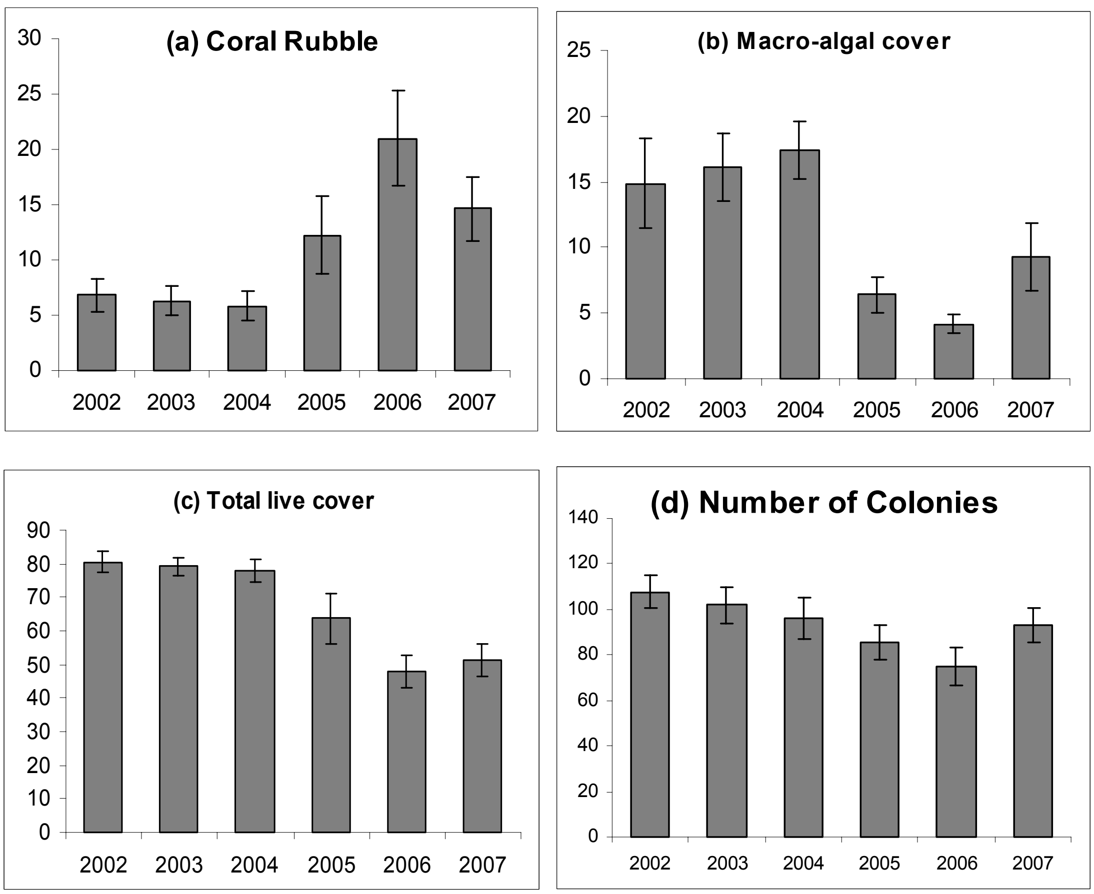

Figure 9 Mean (±SE, n =3.) values for four benthic attributes within the Wakatobi MNP over the six study years. (a) percentage coral rubble, (b) percentage cover of macro-algae, (c) percentage total live cover,(d) number of hard coral colonies per transect

The mean fish abundance within the Wakatobi MNP (Figure 10) showed significant variation over the study period ($F_{5,35}$=4.3;p=0.005). *Post-hoc* tests identified that there was no significant difference between the data from the 2002, 2003, 2004, 2005 and 2007 data, there was however a significant reduction in mean fish abundance in 2006. In 2002 the mean abundance was 925.7(±178.6), this reduced to 320.4(±70.4) in 2006, but was at 597.7(±94.6) by 2007.

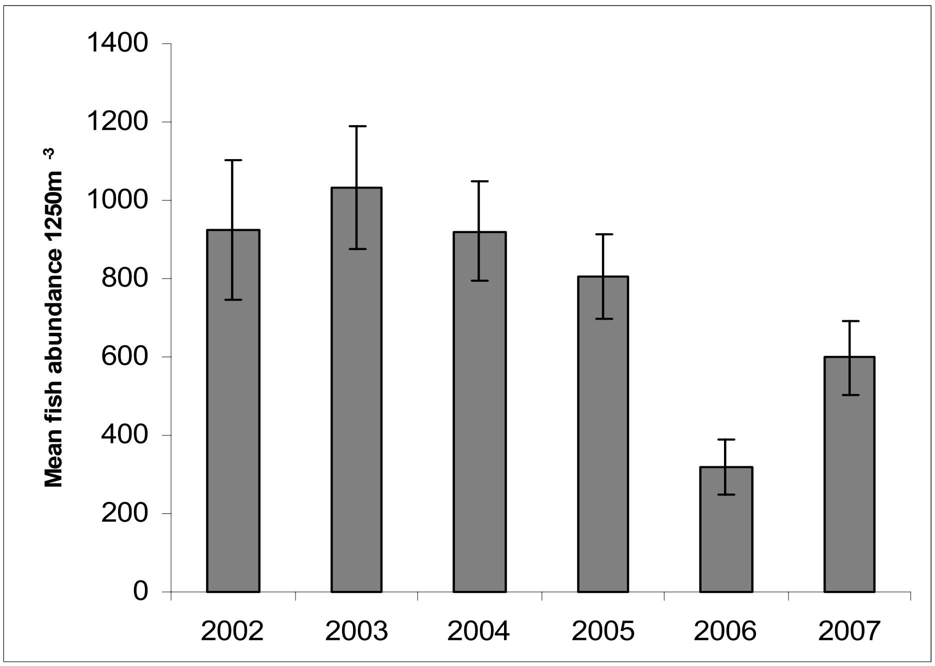

Figure 10. Mean(±SE, n=3) fish abundance per $1250m^3$ within the Wakatobi MNP over the six study years

The mean number of species identified per transect was found to be significantly different across the study years ($F_{5,35}$=13.8;p<0.001). No significant difference was found between the first three years data and that from 2007, but the 2005 richness data was found to be higher than all other years (p<0.01), with the exception of 2004, to which there was no significant difference. The species richness data for 2006 showed a significantly lower value than all other years in the study (p<0.001). The fish species richness was originally recorded at 51.4(±4.5) in 2002, this increased to 71.7(±2.3) in 2005, reduced to 36.2(±3.4) in 2006 and increased to 52.5(±2.2) in 2007. No significant change was recorded in the mean richness of either the Scaridae (Figure 11a), nor the Serranidae (Figure 11b) in the Wakatobi MNP over the six year study period. Over the six year period there was a mean Scarid richness of 2.7(±0.2), and a mean Serranid richness of 1.6(±0.1) per transect. Nor was there a significant difference in the species richness of the Pomacanthid over the same period, with a mean species richness of 2.1(±0.1) per transect. However there was a significant difference in the species richness of the Pomacentridae (Figure 11c) over the six annual surveys ($F_{5,35}$=30.2;p<0.001). There was significantly fewer species recorded in 2006 (p<0.001) and 2007 (p<0.05) than in all other years between which there was no significant difference. The mean number of Pomacentrid species in 2002 was 13.6(±1.3) per transect, this reduced to 3.2(±1.2) per transect, in 2006 and increased to 11.1(±0.9) per transect in 2007. There was also a significant difference in the species richness of the Labridae (Figure 11d) over the study period ($F_{5,35}$=4.9;p=0.002). There was no significant difference in Labrid richness in 2002, 2003, 2004, 2005 and 2007, but the value for 2006 was significantly lower than for 2003, 2004 and 2005 (p<0.01), but was not significantly different from the values for 2002 and 2007. In 2002 a mean Labrid richness of 8.7(±1.2) per transect was recorded, this reduced to 5.1(±1.4) per transect in 2006, but increased again to 8.3(±1.1) per transect in 2007. Finally, there was a significant difference in the species richness of the Acanthuridae over the study period ($F_{5,35}$=5.5;p=0.001). 2002 showed a lower mean species richness than did 2004, 2005, 2006 and 2007. The recorded richness in 2002 was 3.3(±0.4) per transect, which increased to 4.8(±0.3) per transect in 2007.

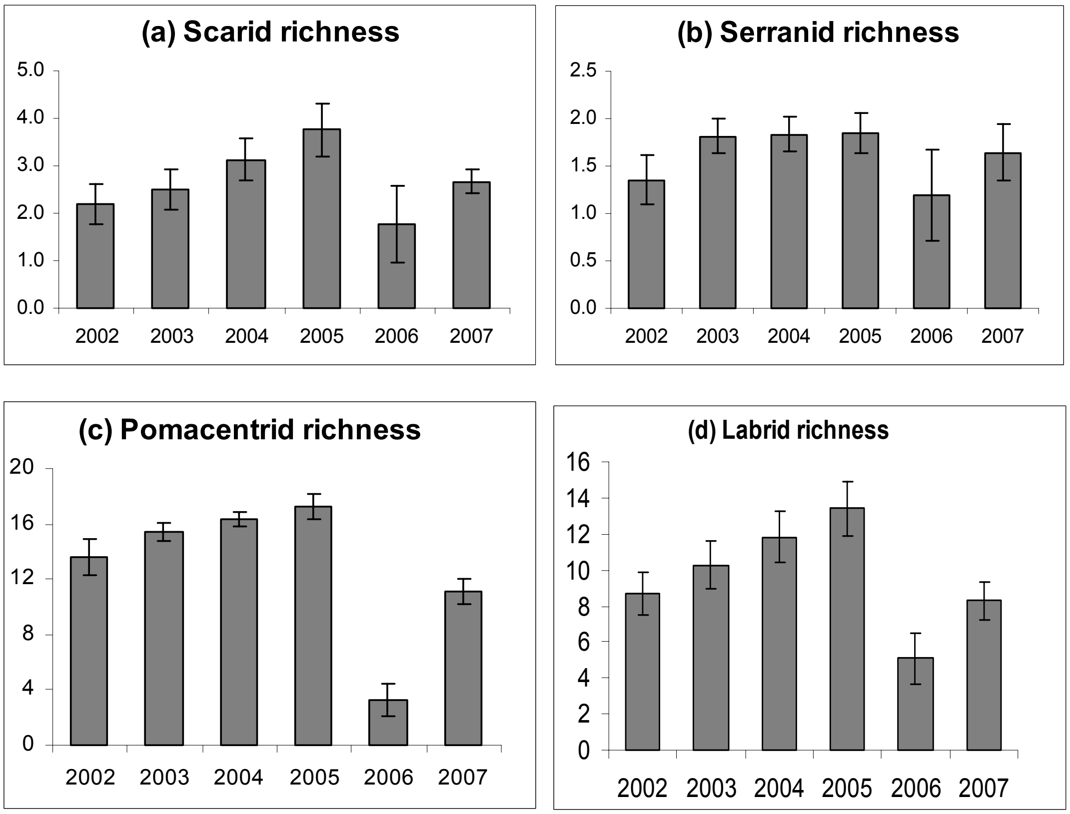

Figure 11. Mean (±SE, n =3.) values for four fish Family richness attributes within the Wakatobi MNP over the five study years. (a) Scarid richness, (b) Serranid/ Epinephelid richness, (c)Pomacentrid richness, (d) Labrid richness

Large interval monitoring for the Southern Kaledupa region

Over the longer five year interval between surveys (Figure 12), a two-way ANOVA showed that the hard coral cover at all three west Kaledupa study sites declined significantly ($F_{1,35}$=223.7;p<0.001). Although there was no significant difference in hard coral cover between the three sites, there was a significant interaction between the two years of the study and site ($F_{2,35}$=27.1;p<0.001). The Sombano site showed a 70% decline in hard coral cover, the Montigola site declined by over 52% and the Taou site declined by 12%. For soft coral cover there was a significant difference between the three sites ($F_{1,35}$=38.5;p<0.001) with the Taou (p<0.001) and Montigola (p<0.001) sites showing significantly more soft coral the than the Sombano site. There was a significant increase in soft coral cover over the five year period ($F_{1,35}$=16.2;p<0.001), but only at the

Montigola and Taou sites. Sombano showed no significant change, meaning no significant interaction between year and site as Montigola showed an increase from 10.2(±2.4)% to 19.8(±2.0)%, while Taou showed an increase in soft coral cover from 11.5(±2.3)% to 16.0(±2.6)%. The coral rubble cover showed significant increases between years ($F_{1,35}$=102.7;p<0.001) with the Sombano site showing a five fold increase to 40.8(±6.4)% , Montigola increased by three times to 12.4(±2.3)% and the rubble cover at Taou almost doubled from 6.8(±2.7)% to 12.7(±1.9)%. Significant differences were identified between sites ($F_{1,35}$=28.7;p<0.001) and a significant interaction between site and year was also found ($F_{2,35}$=17.0;p<0.001). Finally for the benthic components, the macro-algal cover showed no significant difference between sites or years.

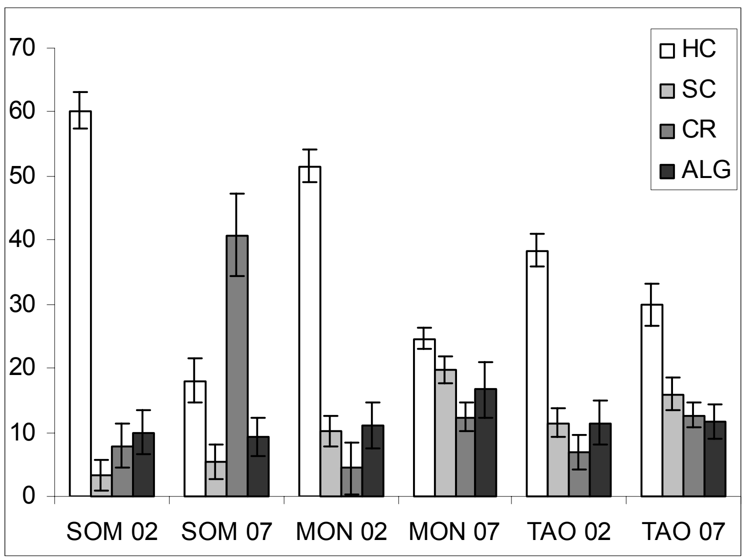

Figure 12 Change in four benthic attributes over the five year study period (mean ±SE, n = 3). [Sites: SOM-Sombano, MON-Montigola, TAO-Taou]
[HC-Hard coral, SC-Soft coral, CR-Coral rubble, ALG-Macro-algae]

Discussion

Benthic site assessment

The hard coral cover data show a significant decline between 2004 and 2005 indicating some sort of impact or disturbance event between these two surveys. The decline in hard coral cover was observed at all sites with the exception of the protected Hoga NTA site.

The fact that this site showed no decline in coral cover suggests an anthropogenic impact affecting the coral cover at the other sites within the park. The total live cover also showed this significant decline between two study years, but here it occurred a year later between 2005 and 2006, suggesting that while the hard coral declined the year before, a further decline in either soft coral, sponges and/ or CCA occurred a year later, on top of the hard coral decline. The cause of these declines is not immediately apparent, there is little tourist activity in the park in the form of recreational boats and divers, nor do the local subsistence fishermen use anchors (per. obs.). Destructive fishing techniques are understood to occur within the park (Pet-Soede & Erdmann, 2003), evidence of dynamite is visible on the reefs in terms of coral rubble, which was shown to increase significantly over the study period at all sites between 2004 and 2005, again suggesting either a storm or some anthropogenic impact. Personal accounts from members of the local community rule out a destructive storm over this period and suggest anthropogenic exploitation as a more likely cause. Distant explosions were often experienced underwater by the Operation Wallacea survey team, and it is possible that these fishermen who employ destructive techniques exploit the reefs around the study area at other times of year when there is no monitoring presence in the region. It is possible however that other factors such as coral disease, coral mining and anchor damage from visiting boats may be an important factor in the decline of the benthic cover.

Another factor suggesting the decline is anthropogenically induced is the behaviour of the macro-algal community, which instead of increasing to exploit the increased substratum availability, has actually decreased significantly over the study period. It can be shown that there is a strong association between hard coral cover with the increase in coral rubble cover, with the damaged coral actually forming the rubble.

Fish assemblage site assessment

The significant decline in mean fish abundance was recorded to have occurred a year after the decline in benthic cover, between the 2005 and 2006 surveys. This decline was only found at the sites which originally had higher levels of coral cover as the Sampela site which was already significantly degraded showed no reduction in fish abundance, with values pre-2006 similar to those post-2006 at all other sites. There is more evidence here for the importance of the Hoga NTA as this site did not show a significant reduction in mean fish abundance. This also suggests that the reduction in abundance was anthropogenic in origin, although it also follows that if the decline was related to habitat decline, then the Hoga NTA site was also the only site that did not decline significantly the previous year, and hence continued to support a higher mean fish abundance. As for the fish abundance, the mean fish species richness also showed a sudden, significant decline between 2005 and 2006. This reduced significantly at all sites except Sampela, which again began the study at a significantly lower level than the other five sites. This provides more evidence that the decline in the fish assemblage was linked to the decline in benthic habitat as identified in the Caribbean by Friedlander & Parish (1997) and in the Indo Pacific by Ohman (1998). Syms & Jones (2000) also showed that degradation of benthic habitat had the same effect in lowering both fish abundance and diversity as did fish removal.

The results from the Grouper (Serranidae/ Epinephelidae) species richness data again show support for the effectiveness of the Hoga NTA with this site having significantly more Grouper species than all other sites, even in the 2006 survey where the majority of surveyed attributes were greatly reduced. The Ridge 1 site was the only site to show very significant declines in Chaetodont species richness, where the overall abundance and species richness also declined in line with live benthic cover. This supports the work of Crosby & Reece (1996) who identified these changes as some species migrate to find food, while those that remain have enlarged territories, excluding others and meaning fewer individuals will be encountered. Surprisingly the richness of the Labridae increased over this same period, possibly as a result of decreased resource competition due to the lower abundance and diversity of other family and functional groups.

As with the general trend at the individual sites, the hard coral cover showed a significant decline between the 2004 and 2005 surveys, again suggesting some park wide disturbance. There was no significant difference in soft coral cover suggesting that they were not replacing the lost hard corals. In fact the total live cover including the soft and hard corals showed significant reductions. The significant increases in coral rubble suggest that the hard coral is remaining at the sites in the form of coral rubble, which would inhibit the recruitment of other benthic organisms and may take several decades to centuries to recover (Fox and Caldwell, 2006). The reducing cover of macro algae suggests that herbivorous fish and invertebrates are currently preventing a shift to an algal dominated state (Done, 1992). This is supported by the fish data which shows no significant reduction over the six year period, with the exception of the 2006 data, which shows extreme values for nearly all attributes, both benthic and fish assemblage. It is possible some form of observer error for the 2006 year's survey as the values are so different from both previous and subsequent years that they are ecologically unlikely. For example the 2006 data showed no Pomacentridae present at numerous sites, which is ecologically unlikely as they are one of the most abundant families on Indo-Pacific coral reefs (Allen, 1997). This highlights a possible shortcoming with the likelihood being that the surveyors did not follow the prescribed training procedures and survey schedule. This seems likely as some categories are massively overestimated while other related categories are massively underestimated. This also highlights the issues raised in Chapter 2 with different surveyors producing different results that could lead to inappropriate management action. The species richness data also supports this with fewer species being recorded during this years surveys at all sites. If this 2006 data is deemed to be inaccurate then there was no significant difference in the majority of the fish attributes monitored, again supporting limited decline in the fish community within the park. The fact that the proportion of the fish communities that were both herbivores and corallivores remained constant over the study period suggests no changes in the trophic composition of the fish assemblage.

The data collected at the South and West Kaledupa sites with the five year interval between surveys, showed large significant changes in both coral cover and coral rubble cover, with the former declining significantly and the latter increasing significantly. This follows a similar pattern to the annual monitoring in the park, but the magnitude of the changes of the five year period suggests that monitoring on a much shorter temporal scale is appropriate within the Wakatobi MNP to allow the early identification of change.

Overall this assessment identifies a change in benthic cover within the Wakatobi MNP. The hard coral cover and live cover are declining while coral rubble cover is increasing. However, due to limited changes in the fish assemblage, this is not leading to an increase in algal cover at the impacted sites. It is important to continue the monitoring of both the benthic and fish assemblages for future change. The study also identified that annual survey was appropriate as the longer term surveys with a five year gap identified large changes in some reef attributes. Annual monitoring will allow the early detection of these changes and may give time to allow management actions to be applied.

This re4earch programme collected date to genus level and often species. This data will be analysed further, within sites, to determine which genera / species are most effected and why. This report represents an overview of generalised findings only.

References
Available on request