

Annual Report of Benthos, Reef Fish and Invertebrate Surveys for Lagoon Areas in Rodrigues 2006

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Shoals Rodrigues, Pointe Monier, Rodrigues

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Summary

This report forms part of the continuing assessment of the lagoon habitats in Rodrigues, which was started in 2003. Surveys were undertaken in three different habitat types: Lagoon Coral (2 sites), Coral Blocks (3 sites) and Algae/Seagrass (3 sites). At each site three 500m transects were surveyed and benthos, invertebrate and fish populations were assessed using a semi-quantitative scale. The results were similar to those found in the previous three years' surveys, highlighting healthy coral colonies in the southern lagoon with >50% hard coral cover. In contrast, coral cover was low at the northern Coral Block site. Cluster Analysis clearly separates the southern sites from the northern survey sites, with the southern sites being dominated by hard coral and the northern sites being dominated by sand, rubble and vegetation. The lack of hard coral in the northern lagoon may be as a result of the high turbidity, which tends to affect this region. Invertebrate populations were echinoderm dominated, with holothurians being particularly abundant. Molluscs were only found in very low densities, indicating over-harvesting of these organisms. Damselfish dominated the coral habitats with juvenile Parrotfish also abundant in the south. Algae/Seagrass areas had a much lower abundance of fish, however tended to show more diversity in fish populations with Wrasse, Goatfish and Damselfish common. The species diversity amongst carnivorous fish was low; Emperors and Triggerfish were rare and Trevally and Snappers were entirely absent, suggesting that overfishing is occurring within the lagoon. Some changes in the Coral habitats was observed with increases in turf algae at southern Coral sites D and E and an increase in rubble at Site G; seagrass had disappeared from northern Coral Block site J. The results also suggest a large increase in the holothurian, *H. atra* at Coral sites in the south and north and an increase in the sea urchin *Echinometra mathaei* at Couzoupa (Site A). The total number of fish recorded increased at all sites between 2005 and 2006, however this was due to an increase in Damselfish. The number of fish families observed declined between 2005 and 2006 with no species of Trevally (Carangidae), Sea Bream (Sparidae) or Snapper (Lutjanidae) observed during the 2006 surveys, indicating that overfishing is occurring within the lagoon.

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1 Introduction

Shoals Rodrigues has been monitoring reef slope and reef flat areas around Rodrigues since 1999. Equally important, however, are the lagoon habitats. Rodrigues is surrounded by a shallow lagoon of over 240km², extending up to 13km width in the south. Lagoon habitats, such as coral patch reefs and seagrass beds are however under threat from a number of natural and anthropogenic impacts. Due to weather conditions, the majority of fishing effort is concentrated within the lagoon resulting in overfishing (Lynch *et al.*, 2004a) and physical damage from trampling and anchors (Clark, 2001); the lagoon is also affected by sedimentation (Lynch *et al.*, 2003) and increased water temperatures resulting in coral bleaching (Hardman *et al.*, 2004; Lynch *et al.* 2004b)

The Rodrigues lagoon is a little studied ecosystem and the fisheries that occur within it are of major importance to the island's population. A monitoring programme has therefore been established to provide a better understanding of the composition of the lagoon habitats and the animal populations they support, and how these change in response to human and natural impacts. The results of the first three years of study conducted in 2003 - 2005, indicate that there are still relatively vigorous coral communities within the lagoon, particularly in the south around Passe l'Ancre and Couzoupa (Lynch *et al.*, 2004c; Lynch *et al.*, 2005; Hardman *et al.*, 2006), however coral cover was much reduced in the north-western lagoon. The plant communities found within the Rodrigues lagoon tended to be dominated by algae, although seagrass was abundant near Baie Malgache and Ile aux Fous. Invertebrate populations were echinoderm dominated, with holothurians being particularly abundant, and urchins also common. Damselfish, Parrotfish and Surgeonfish dominated the coral habitats and the species diversity amongst carnivorous fish was low, with Trevally, Snappers and Triggerfish being either rare or entirely absent. The fine sediment habitats supported very limited animal life. Surveys in 2005 indicated a decline in fish abundance at all sites between 2004 and 2005.

This report forms part of the continuing assessment of the lagoon habitats in Rodrigues and presents the results obtained during the 2006 surveys.

2 Materials and Methods

Three different habitat types were selected for monitoring. These were areas of lagoon coral on a consolidated limestone platform (2 sites), isolated coral blocks within a generally sandy area (3 sites) and beds of algae and/or seagrass (3 sites). Three stations were surveyed within each site. The location of the stations is shown in Figure 1, with the habitat type and GPS position of each station given in Table 1.

Table 1. The habitat type and area code for each site, with the GPS position of individual stations.

Lagoon Coral							
Area	Station number	Latitude	Longitude				
A	1	19° 45.270	63° 28.058				
	2	19° 45.446	63° 28 129				
	3	19° 45.270	63° 28 380				
D	1	19° 48.772	63° 25.634				
	2	19° 48.772	63° 25.624				
	3	19° 49.031	63° 25.674				
Coral Blocks on Sand				Algae / Seagrass			
Area	Station number	Latitude	Longitude	Area	Station number	Latitude	Longitude
E	1	19° 48.785	63° 24.972	I	1	19° 43.436	63° 19.269
	2	19° 48.633	63° 24.920		2	19° 43.565	63° 19.157
	3	19° 48.806	63° 25.138		3	19° 43.278	63° 19.319
G	1	19° 49.000	63° 21.000	L	1	19° 39.849	63° 23.061
	2	19° 49.160	63° 21.037		2	19° 39.896	63° 22.960
	3	19° 49.243	63° 21.234		3	19° 39.966	63° 22.816
J	1	19° 40.456	63° 20.232	M	1	19° 40.248	63° 28 129
	2	19° 40.493	63° 20.234		2	19° 40.271	63° 28.079
	3	19° 40.561	63° 20.222		3	19° 40.100	63° 27.569

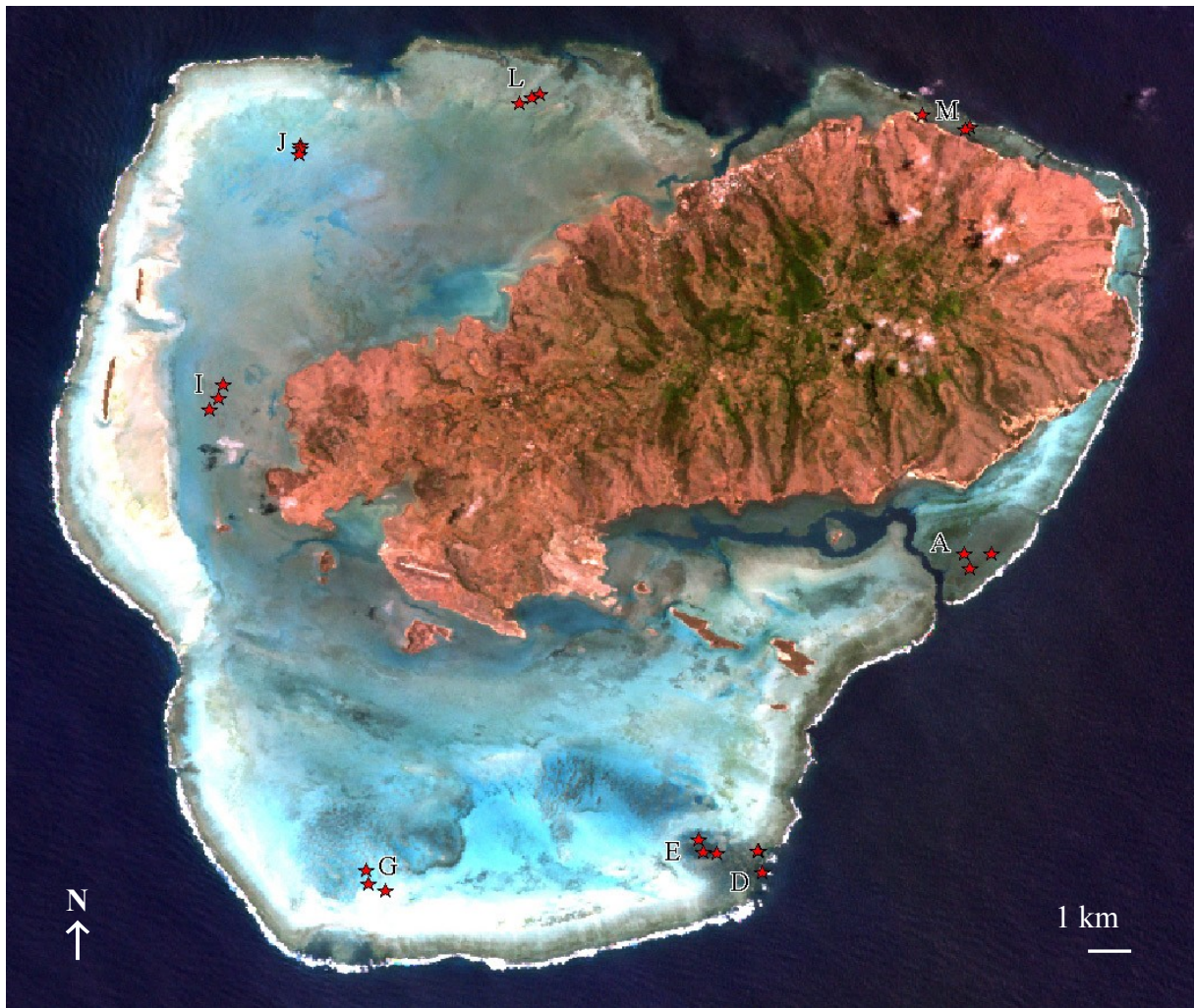


Figure 1. The location of the areas in which the survey stations were located.

A 500m transect was surveyed at each station, with the length of the transect being determined using a GPS. Fish and invertebrates in a 2m wide belt were counted continuously along the transect by separate observers. The benthos was assessed by evaluating a 5m x 5m area at one minute intervals along the transect. The surveys were semi-quantitative, to reflect the lack of absolute precision in the dimensions of the transects. The abundance scales used are given in Table 2. Monitoring took place during winter in May/June.

Table 2. The abundance scales used to categorise the prevalence of benthic features and organisms and the size of fish and invertebrate populations.

Benthos		Fish & Invertebrate Populations	
Category	Percentage cover	Category	Abundance
1	<1	1	1
2	1 – 10	2	2 – 5
3	11 – 30	3	6 – 15
4	31 – 50	4	16 – 50
5	51 – 75	5	51 – 250
6	76 – 100	6	250 – 1000
		7	>1000

3 Results

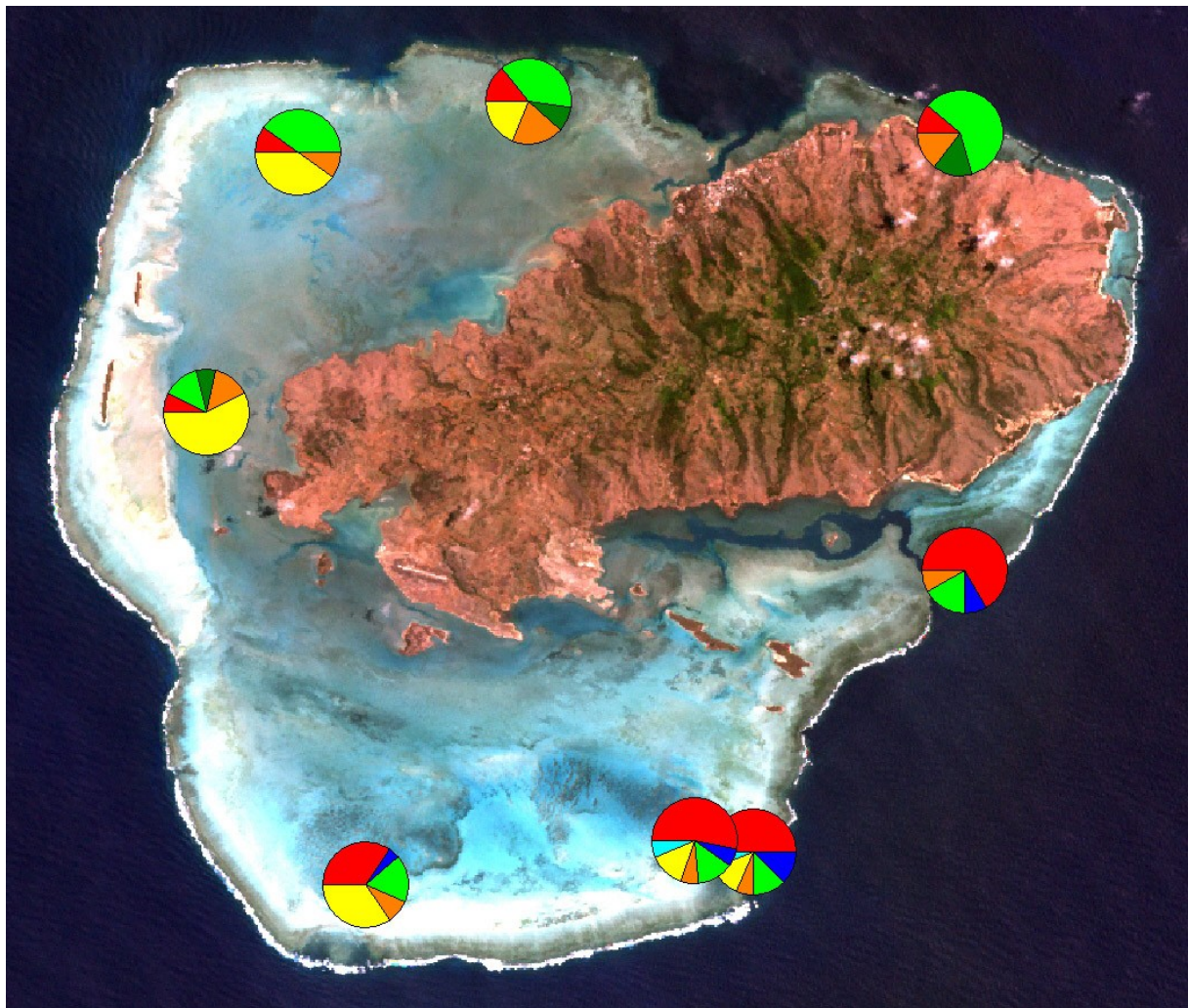
3.1 Benthos

At the Lagoon Coral sites the mean percentage cover of hard coral was 51-75% at both Couzoupa (Site A) and Passe l'Ancre (Site D) (Figure 2). At Site A, coral cover was diverse, consisting of 31-50% *Acropora* spp., especially branching and digitate species, with massive and mushroom (*Fungia* spp.) colonies also common (11-30%). At Site D, coral cover consisted of 51-75% *Acropora* spp. colonies, especially branching and tabular species. No dead coral was observed at either site and mean percentage of rubble at both sites was 1-10%. Mean soft coral cover was 11-30% at Site D and 1-10% at Site A and at Site D zoanthids had 1-10% cover. Mean turf algal cover was 11-30% at both sites.

At the Coral Block Sites, the mean percentage cover of hard coral was 51-75% at Site E, 31-50% at Site G, but only 1-10% at the northern site J. At Sites E and G, coral cover consisted of 51-75% *Acropora* spp. colonies, especially tabular and branching species. At Site J, however no *Acropora* spp. were observed and coral cover consisted of 31-50% massive corals and 31-50% encrusting corals. No dead coral was observed at any site and rubble was 1-10% at all 3 sites. Turf algal cover was 1-10% at Site E and 11-30% at Site G; macro-algae was 1-10% at Site E and 31-50% at Site J. Sand consisted of a mean of 11-30% at Site E and 31-50% at Sites G and J.

At the Algae/Seagrass sites, the mean percentage cover of hard coral was 1-10% at Site I and 11-30% at Sites L and M. At Site I only 1 massive and 1 encrusting coral colony were observed. At Site L, coral cover consisted of 31-50% massive corals and 11-30% sub-massive, and encrusting corals and *Millepora* sp., At Site M, coral cover consisted of 76-100% massive corals, with 11-30% encrusting corals. Mean percentage cover of rubble was 11-30% at all 3 sites. Mean percentage cover of macro-algae was 11-30% at Site I, 31-50% at Site L and 51-75% at Site M; seagrass was 1-10% at Sites I and L and 11-30% at Site M. Mean percentage cover of sand was 11-30% at Site L and 51-75% at Site I; no sand was recorded at site M.

Cluster Analysis groups the southern Lagoon Coral and Coral Block Sites (Sites, A, D, E and G) together at 86% (Figure 3). The northern Coral Block site (Site J) is grouped with the Algae/Seagrass sites at 73% similarity.



Key

- | | |
|---|--|
| ■ Hard Coral | ■ Rubble |
| ■ Soft Coral | ■ Sand |
| ■ Algae | ■ Mud |
| ■ Seagrass | ■ Other |

Figure 2. The mean percentage cover of each benthic category at the 8 sites.



Figure 3. Cluster Analysis ($\sqrt{\cdot}$ -transformed) of the benthic habitats at each site.

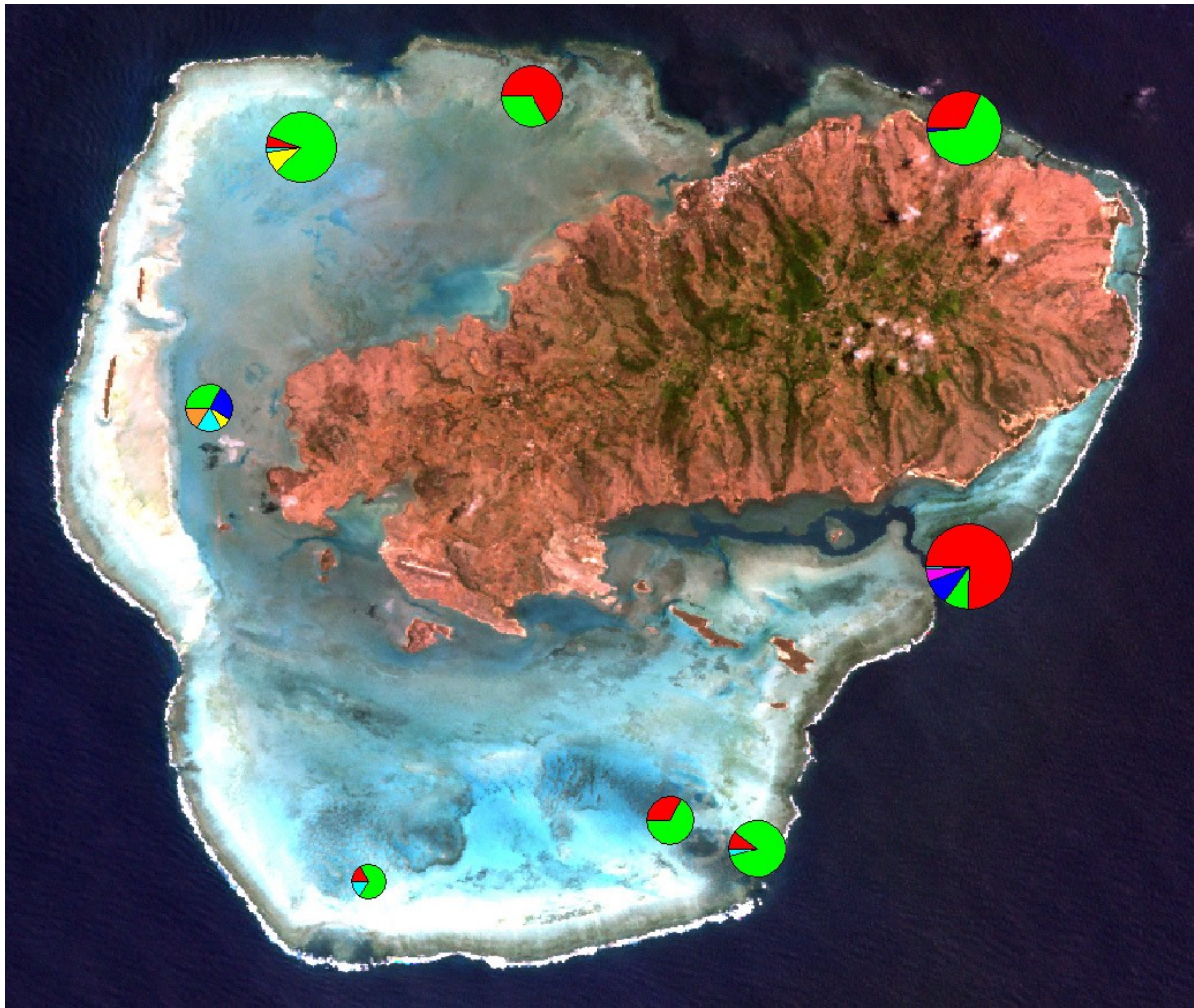
3.2 Invertebrates

All sites were dominated by urchins and/or holothurians and other invertebrate groups were rare (Figure 4). The giant clam, *Tridacna maxima* was only observed at Site A (mean of 6-15 individuals); the gastropod *Cypraea tigris* was observed at Sites A, D and I (1 individual at each) and the gastropod, *Pleuroploca trapezium* was only observed at Site J (mean of 2-5 individuals) and Site I (1 individual). The only crustacean to be observed was the swimming crab, *Thalamita* sp. at Site I.

At the Lagoon Coral sites, the sea urchin, *Echinometra mathaei* was super abundant at Couzoupa (Site A) with a mean of >1,000 individuals; holothurians (*Holothuria atra* and *Synapta maculata*) were also common at this site (16-50 individuals). The holothurian, *H. atra* was abundant at Passe l'Ancre (Site D) (51-250 individuals) and *Bohadschia* sp. was common (16-50 individuals), however urchins were only occasional.

The holothurian, *Holothuria atra* was common at Site E (16-50 individuals) and frequent at Site G (6-15 individuals), however other invertebrates were rare at these sites. At Site J, the holothurians, *H. atra* and *H. leucospilata* were very abundant (250-1,000 individuals each) and the bivalve *Pinna muricata* was frequent (6-15 individuals).

At the Algae/Seagrass sites, invertebrate numbers were low at the western site (Site I) with a mean of 6-15 *Holothuria atra* observed. Site L was dominated by urchins with a mean of 51-250 individuals of *Echinometra mathaei* and holothurians (*H. atra* and *H. leucospilata*) were also frequent (6-15 individuals). At site M, holothurians (*H. atra*, *H. leucospilata* and *Synapta maculata*) and urchins (*E. mathaei*) were all abundant with a mean of 51-250 individuals of each species.



Key

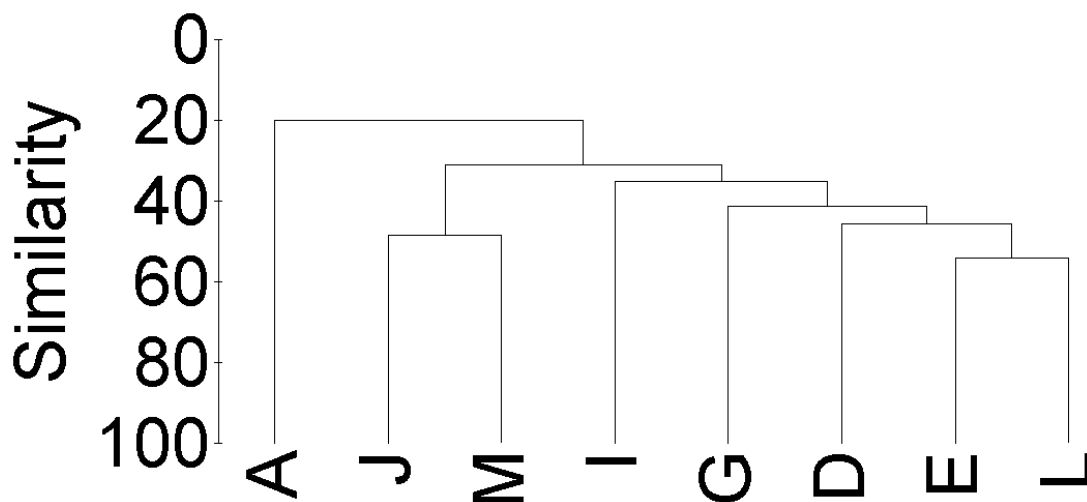
- | | |
|---|--|
| ■ Urchins | ■ Other Bivalves |
| ■ Holothurians | ■ Large Gastropods |
| ■ Other Echinoderms | ■ Octopus |
| ■ <i>Tridacna maxima</i> | ■ Other |

Figure 4. The distribution of invertebrate species at the 8 survey sites.

The greatest number of invertebrate species was observed at Lagoon Coral site A and the Algae/Seagrass site I (10 species) and the greatest number of individuals at the Lagoon Coral site A due to the presence of large numbers of *Echinometra mathaei* (Table 3). The least number of invertebrate species were observed at the Coral Block site E (4 species) and the least number of individuals at the Coral Block site G (6-15 individuals). In terms of invertebrate species, the different habitats show little similarity in community structure within habitat. Sites I, G, D, E and L all cluster together at 35% similarity due to the dominance of *Holothuria atra* and Sites J and M cluster together at 54% similarity due to high numbers of *H. atra* and *H. leucospilata*; Site A is distinct to the other sites due to the very large numbers of *E. mathaei* (Figure 5).

Table 3. The number of invertebrate individuals, species and genera at each site.

Site	No. individuals	No. species	No. genera
A	>1,000	10	10
D	51-250	8	7
E	16-50	4	4
G	6-15	5	5
J	250-1,000	6	5
I	16-50	10	9
L	51-250	7	6
M	250-1,000	9	8

**Figure 5.** Cluster Analysis ($\sqrt{\cdot}$ -transformed) of the invertebrate species recorded at each site.

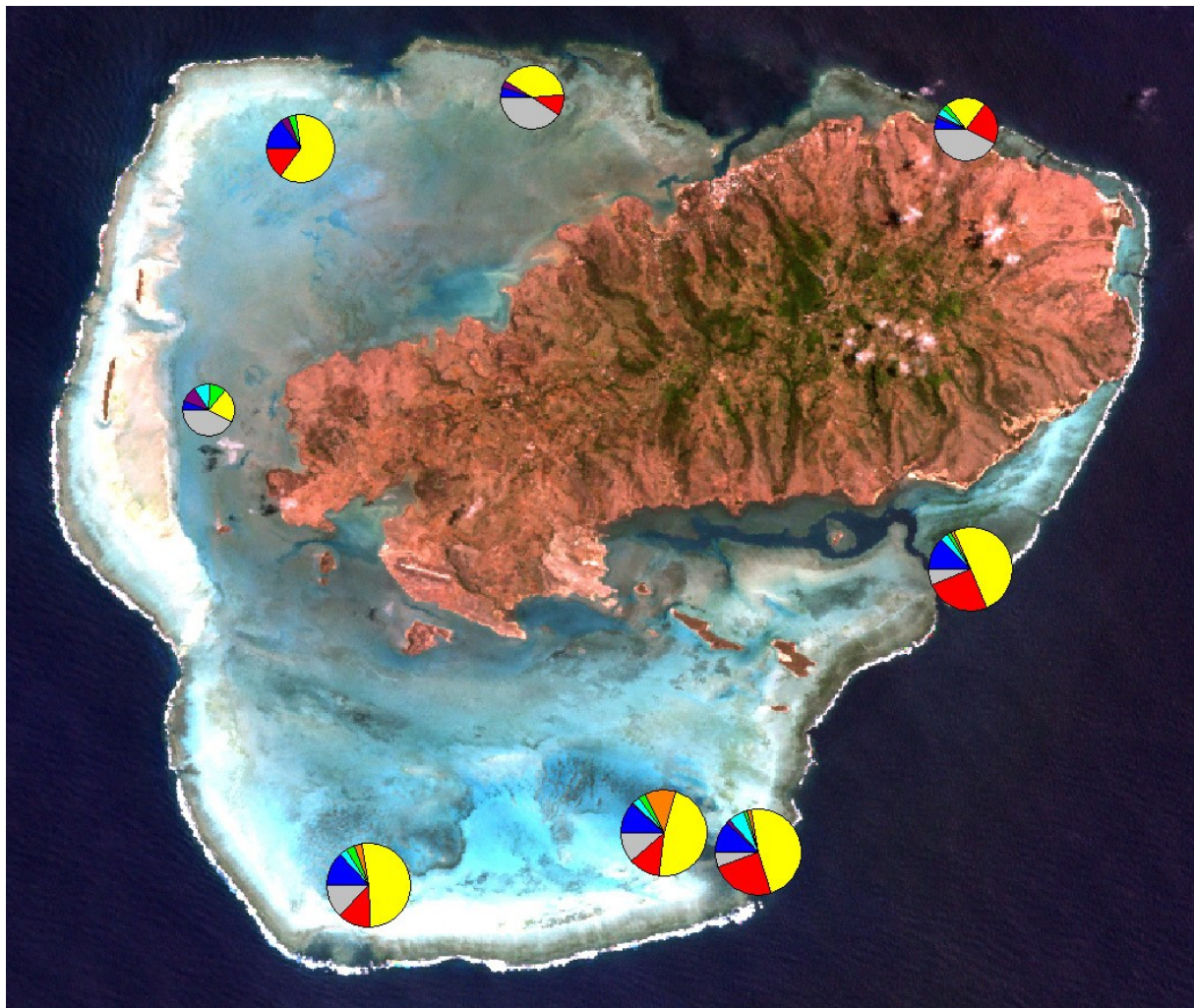
3.3 Fish

The fish populations at both Lagoon Coral sites were dominated by Damselfish (Pomacentridae) with >1,000 individuals, in particular *Chromis viridis*, *Dascyllus aruanus*, *Stegastes limbatus*, *S. lividus* and *S. nigricans* were very abundant; Juvenile Parrotfish were also common at these sites. Snappers (Lutjanidae) and Trevally (Carangidae) were absent from both sites and only 1 Emperor (Lethrinidae) was observed at Site D (Figure 6).

The Coral Block sites were also dominated by Damselfish, however the abundance of fish and species richness was much lower at Site J than at Sites E and G. At Sites E and G, Damselfish were super abundant (>1,000 individuals) and *Chromis viridis*, *Dascyllus aruanus*, *Stegastes limbatus*, *S. lividus* and *S. nigricans* were all very abundant, whereas at Site J only *C. viridis* and *D. aruanus* were abundant. At Site E, Surgeonfish (*Acanthurus* sp. and *A. triostegus*) were abundant (51-250 individuals of each) as was the Goatfish, *Parupeneus barberinus* and the Emperor, *Gnathodentex aureolineatus*; the Goatfish, *Mulloidichthys flavolineatus* was abundant at Site G. Triggerfish (Balistidae) were rare and Snappers (Lutjanidae) and Trevally (Carangidae) were absent from all sites.

In the Algae/Seagrass habitats, Site I had a very low number of fish and was dominated by the Goatfish *Mulloidichthys vanicolensis* (16-50 individuals). Site L was dominated by the Damselfish, *Dascyllus aruanus* and the Wrasse *Thalassoma genivittatum* (51-250 individuals of each species), whereas Site M was dominated by the Wrasse, *T. genivittatum* (51-250 individuals) and juvenile Parrotfish (16-50 individuals). No Trevally (Carangidae), Emperors,

(Lethrinidae) or Snappers (Lutjanidae) were observed at any site and Triggerfish (Balistidae) were rare.



Key

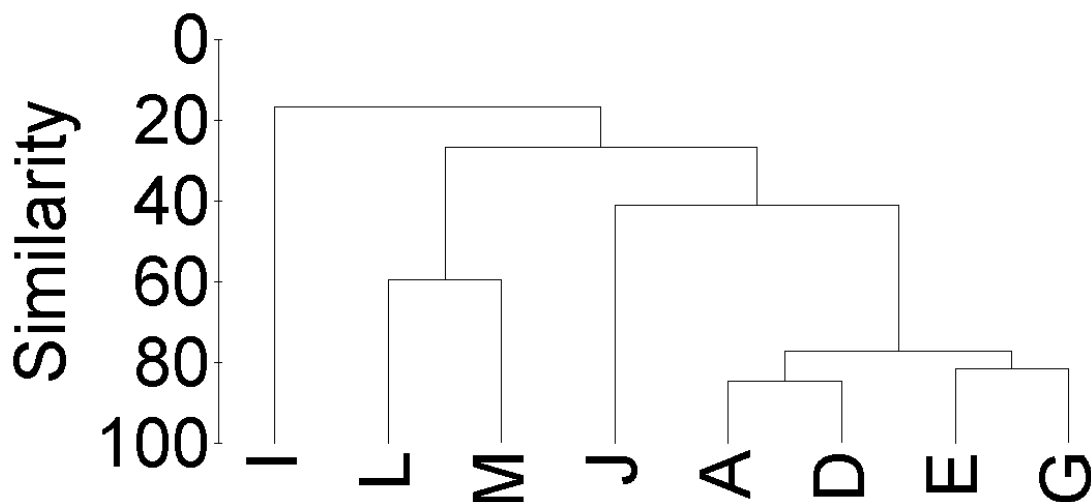
- | | |
|--|---|
| ■ Acanthuridae | ■ Lutjanidae |
| ■ Balistidae | ■ Pomacentridae |
| ■ Chaetodontidae | ■ Scaridae |
| ■ Epinephelini | ■ Other |
| ■ Lethrinidae | |

Figure 6. The distribution of fish families at the 8 survey sites

Coral Block site E and Lagoon Coral site D had the greatest species richness in terms of number of fish species and number of genera, with 27 species of 18 genera observed at Site D and 28 species of 18 genera observed at Site E (Table 4). The Algae/Seagrass sites I and M had the lowest number of individuals and Coral Block site J had the lowest number of fish species and genera (8 species in 7 genera). Cluster Analysis groups the southern coral sites, A, D, E and G together at 77% and the Algae/Seagrass sites L and M together at 59%; site I is distinct due to the low numbers of fish observed at this site (Figure 7). Simper Analysis indicates that Lagoon Coral and Coral Block sites are characterised by high numbers of Damselfish in the genera *Stegastes*, *Dascyllus* and *Chromis*, whereas Algae/Seagrass sites tend to be dominated by Wrasse.

Table 4. The number of fish individuals, species and genera at each site.

Site	No. individuals	No. species	No. genera
A	>1,000	20	13
D	>1,000	27	18
E	>1,000	28	18
G	>1,000	21	13
J	250-1,000	8	7
I	51-250	10	9
L	250-1,000	12	11
M	51-250	18	13

**Figure 7.** Cluster Analysis ($\sqrt{\text{transformed}}$) of the fish genera recorded at each site.

3.4 Comparisons with previous years

The results suggest that there have been very few changes in benthic composition at the survey sites, with Multi-Dimensional Scaling (MDS) plots clustering the habitats from the different years together (Figure 8). Some variations can however be seen at the Lagoon Coral and Coral Block sites D, E, G and J in 2006. At the northern Coral Block site J, there was a decline in seagrass abundance from 1-10% in 2005 to 0% in 2006. There was also a decline in seagrass at Algae/Seagrass site L from 31-50% in 2005 to 1-10% in 2006. At the southern Coral Block site G, there was a decline in coral cover from 51-76% in 2004 to 31-50% in 2006 and an increase in rubble from 0% in 2004 to 1-10% in 2006, whereas at Coral Block site E there was an increase in soft coral cover from 0% in 2005 to 1-10% in 2006 and an increase in turf algae from 0% in 2005 to 11-30% in 2006. Similarly, at Lagoon Coral site D, there was an increase in turf algae from 0% in 2005 to 11-30% in 2006.

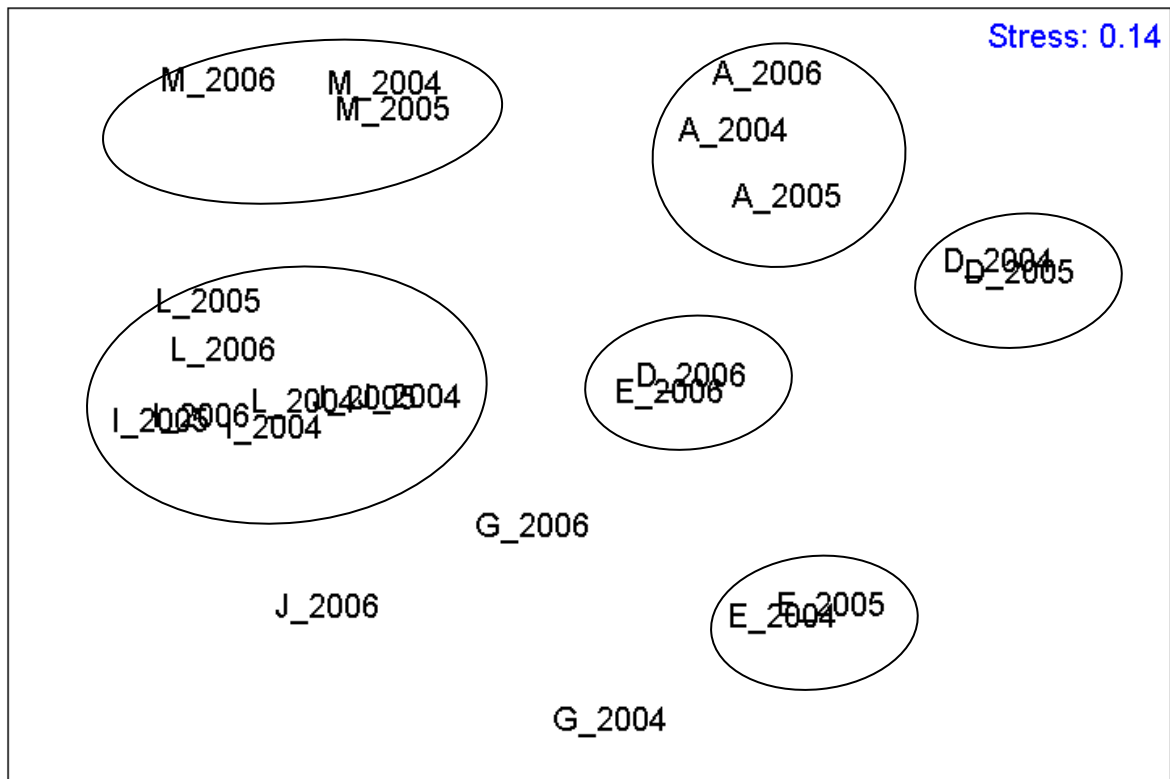


Figure 8. Multi-dimensional scaling plot of benthic habitats at the 8 survey sites during 2004-2006.

Invertebrate community structure also shows little change over time, however Multi-dimensional scaling indicates that communities at Lagoon Coral and Coral Block Sites A, D, E and J during 2006 were distinct from those in years 2004 and 2005 (Figure 9). At Lagoon Coral site A, this is due to an increase in the sea urchin, *Echinometra mathaei* from 250-1,000 individuals in 2005 to >1,000 individuals in 2006. At Lagoon Coral site D and Coral Block sites E and J, the difference is due to an increase in holothurians: at Site D, *Holothuria atra* increased from 2-5 individuals in 2005 to 51-250 individuals in 2006; at Site E *H. atra* also increased from 2-5 individuals in 2005 to 16-50 individuals in 2006 and at Site J, *H. atra* and *H. leucospilata* increased from 51-250 individuals in 2005 to 250-1,000 individuals in 2006.

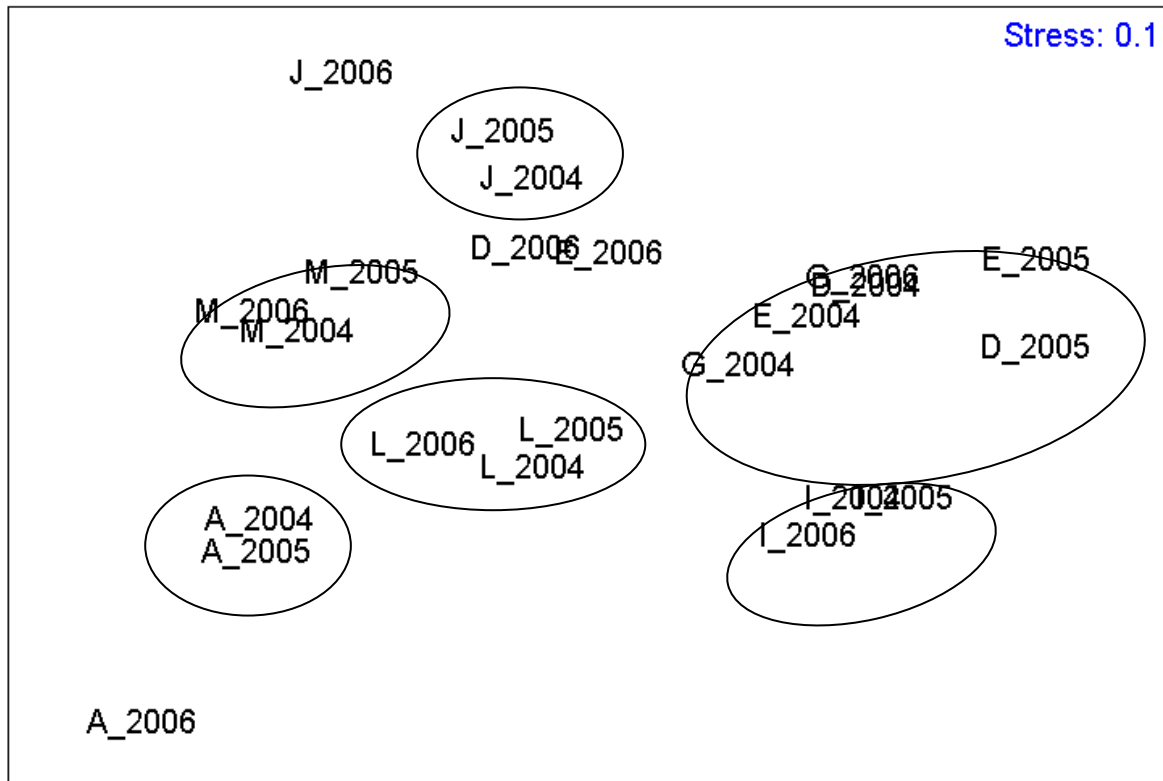


Figure 9. Multi-dimensional scaling plot of invertebrate species at the 8 survey sites during 2004-2006.

There was an increase in the total number of fish at all of the 8 sites between 2005 and 2006, however at all sites this was due to an increase in the number of Damselfish. In general, the total number of fish families encountered during the surveys has declined over time, from 20 families in 2004 to 14 in 2006 and this is due to the loss of families such as Carangidae (Trevally), Sparidae (Sea Breams) and Lutjanidae (Snappers). Multi-dimensional scaling however shows that there has been little change in fish community structure over time, except at Algae/Seagrass sites L and I in 2006 and M in 2005 (Figure 10). At Site M, this was due to lower numbers of Labridae (Wrasse) and Pomacentridae (Damselfish) observed during 2005 than in 2004 and 2006. At Site L, the difference was due to no Serranidae (Groupers) being recorded in 2006 and an increase in Labridae (Wrasse) and Scaridae (Parrotfish) in 2006 and at Site I, it was due to no Gobiidae (Gobies) being observed in 2006 and an increase in Mullidae (Goatfish) between 2004 and 2005 and 2006.

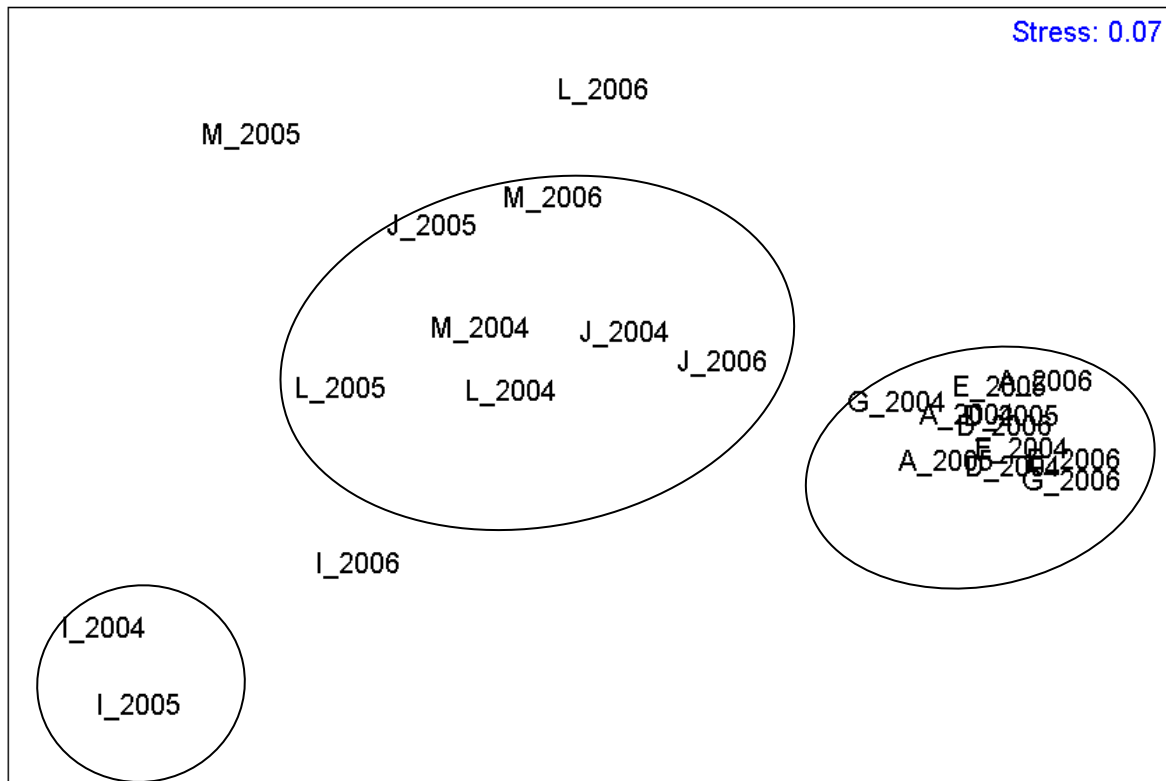


Figure 10. Multi-dimensional scaling plot of fish families at the 8 survey sites during 2004-2006.

4 Discussion

The results are similar to those observed in the 2004 and 2005 surveys (Lynch *et al.*, 2005; Hardman *et al.*, 2006) highlighting fairly healthy coral colonies in the southern lagoon, around Couzoupa (Site A), Quatre Vingt Brisants (Site G) and Passe l'Ancre (Sites D and E). Coral cover was >50% and was dominated by branching and tabular *Acropora* spp colonies. In contrast, coral cover was low at the northern Coral Block site J. The plant communities tended to be dominated by macro-algae, however seagrass was present at Sites I, L and M.

As in previous years, invertebrate populations were echinoderm dominated, with holothurians being particularly abundant, dominating the invertebrate populations of 6 of the 8 sites. The bio-eroding sea urchin *Echinometra mathaei* was also present in large numbers at Lagoon Coral Site A. Molluscs were found in both coral and plant-dominated habitats, but in very low densities. Shellfish are popular food items locally, with octopus and other fishers regularly collecting gastropods and bivalves and therefore the low numbers of these organisms may indicate over-harvesting.

Damselfish dominated the coral habitats, presumably as a result of their territorial behaviour. Juvenile Parrotfish were also common in southern regions with coral substrates. Algae/Seagrass areas had a much lower abundance of fish and tended to show more diversity in fish populations with Wrasse, Goatfish and Damselfish common. At all sites the species diversity amongst carnivorous fish was low. Emperors were common at one site (Site E), but consisted of only one species: *Gnathodentex aurolineatus*. Triggerfish were rare and Trevally and Snappers were entirely absent, suggesting that overfishing is occurring within the lagoon.

As in the previous years surveys, Cluster Analysis clearly separates the southern sites from the northern survey sites, with the southern sites being dominated by hard coral and the

northern sites being dominated by sand, rubble and vegetation. The lack of hard coral in the northern lagoon may be as a result of the high turbidity, which tends to affect this region. In terms of fish populations the southern sites also cluster together, with the northern lagoon sites having more distinct fish communities. Invertebrate populations show a less obvious distribution pattern.

Comparisons with surveys in 2004 and 2005 suggest that there has been a decline in health of the southern Coral sites D, E and G with an increase in turf algae at sites D and E and an increase in rubble at Site G. Seagrass has disappeared from Site J and decreased from 31-50% in 2005 to 1-10% in 2006 at Site L. The decline in health of the coral sites may be as a result of coral bleaching, which occurred during 2005 or physical impact from fishing activities, which are concentrated in these areas. There were large increases in holothurians (*Holothuria atra*) at the Lagoon Coral and Coral Block sites D, E and J and an increase in *Echinometra mathaei* at Lagoon Coral site A. It is not clear what causes these increases, however it does appear that there are large annual variations in echinoderm numbers within the lagoon, with a large increase in the holothurian *Stichopus chloronatus* also observed between 2002 and 2003 (Lynch *et al.*, 2004b). In contrast to last year's results, there has been a general increase in fish abundance at all sites, however this is due to an increase in the number of Damselfish. The number of fish families observed during the survey has however declined, with no fish from the families Carangidae (Trevally), Sparidae (Sea Bream) or Lutjanidae (Snapper) observed during the 2006 surveys. These fish are carnivorous and targeted by the lagoon fisheries and this is therefore an indication that overfishing is occurring within the lagoon.

5 References

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6 Appendices

Table A1. Benthic cover for the Lagoon Coral and Coral Block sites

	A1	A2	A3	D1	D2	D3	E1	E2	E3	G1	G2	G3	J1	J2	J3
Mud	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branching Acropora	3	3	3	4	4	0	4	2	2	2	2	2	0	0	0
Tabular Acropora	2	2	2	4	3	0	3	2	2	3	3	2	0	0	0
Digitate Acropora	2	2	2	2	2	0	1	1	1	2	2	0	0	0	0
Solitary Coral	3	3	3	3	2	0	1	1	1	0	2	3	0	0	0
Massive Coral	2	2	2	1	2	1	1	1	1	3	2	2	0	1	1
Sub-massive Coral	2	2	3	5	4	0	1	1	1	3	0	2	0	0	1
Foliose Coral	2	2	0	3	3	0	2	2	1	0	2	0	0	0	0
Encrusting Coral	2	2	3	2	0	0	1	1	1	2	3	2	2	0	1
Algae	4	4	5	3	3	5	2	2	2	3	3	3	4	4	4
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubble	2	2	3	4	5	0	1	2	2	2	3	2	3	3	2
Sand	0	0	0	2	3	3	2	4	4	4	3	4	5	5	5
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft Coral	2	2	2	4	3	0	0	1	1	0	2	0	0	0	0
Millepora	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0

Table A2. Benthic cover for the Algae/Seagrass sites.

	I1	I2	I3	L1	L2	L3	M1	M2	M3
Mud	0	0	0	0	0	0	0	0	0
Branching Acropora	0	0	0	0	0	0	0	0	0
Tabular Acropora	0	0	0	0	0	0	0	0	0
Digitate Acropora	0	0	0	0	0	0	0	0	0
Solitary Coral	0	0	0	0	0	0	0	0	0
Massive Coral	1	0	0	1	1	1	2	1	1
Sub-massive Coral	0	0	0	1	1	2	0	1	0
Foliose Coral	1	0	0	0	0	0	0	0	0
Encrusting Coral	1	0	0	1	2	2	2	0	0
Algae	3	5	4	5	4	5	5	5	5

	I1	I2	I3	L1	L2	L3	M1	M2	M3
Rock	0	0	0	0	0	0	0	0	0
Rubble	3	3	3	3	3	2	3	0	3
Sand	5	5	5	3	3	2	0	0	0
Seagrass	0	0	3	2	5	0	0	5	3
Soft Coral	0	0	0	0	0	0	0	0	0
Millepora	0	0	0	1	1	1	0	0	0
Others	0	0	0	0	0	0	0	0	0

Table A3. Numbers of invertebrates recorded at the Lagoon Coral and Coral Block sites.

	A1	A2	A3	D1	D2	D3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Echinothrix diadema</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diadema</i> sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Echinometra mathaei</i>	3538	2218	575	1	1	4	0	11	5	0	1	3	3	2	0
<i>Toxopneustes pileolus</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Holothuria atra</i>	5	26	13	22	138	74	1	39	61	9	3	6	408	384	170
<i>H. leucospilota</i>	0	0	0	0	0	7	0	0	0	0	0	0	408	384	179
<i>Stichopus chloronotus</i>	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0
<i>Synapta maculata</i>	3	23	47	0	0	0	0	2	0	0	0	0	0	0	0
<i>Euapta godeffroyi</i>	0	0	0	1	3	3	0	0	0	0	0	0	0	0	0
<i>Actinopyga mauritania</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bohadschia</i> sp.	0	0	0	0	0	62	0	3	0	1	1	1	3	2	8
Other holothurians	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Linkia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nardoa variolota</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ophiocoma erinaceus</i>	21	20	10	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tridacna maxima</i>	11	8	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pinna muricata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	33
<i>Conus</i> sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Cypraea tigris</i>	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
<i>Pleuroploca trapezium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Strombus</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Thalamita</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4. Numbers of invertebrates recorded at the Algae/Seagrass sites.

	I1	I2	I3	L1	L2	L3	M1	M2	M3
<i>Echinothrix diadema</i>	0	0	0	0	0	0	1	2	1
<i>Diadema sp.</i>	0	0	0	1	0	0	0	0	0
<i>Echinometra mathaei</i>	0	0	0	138	82	29	166	37	43
<i>Toxopneustes pileolus</i>	0	0	0	0	0	0	0	0	0
<i>Holothuria atra</i>	5	4	26	19	16	6	158	208	41
<i>H. leucospilota</i>	1	3	3	19	10	5	47	171	42
<i>Stichopus chloronotus</i>	0	0	0	0	0	0	10	12	3
<i>Synapta maculata</i>	0	3	0	0	0	1	5	97	232
<i>Euapta godeffroyi</i>	0	0	0	0	0	0	0	0	13
<i>Actinopyga mauritania</i>	0	0	0	5	7	0	0	0	0
<i>Bohadschia sp.</i>	0	0	1	3	2	0	0	0	0
Other holothurians	0	0	0	0	0	0	0	0	0
<i>Linkia sp.</i>	5	4	6	0	0	0	0	1	0
<i>Nardoa variolota</i>	0	0	0	0	0	0	0	1	0
<i>Ophiocoma erinaceus</i>	0	0	0	0	0	0	0	0	0
<i>Tridacna maxima</i>	0	0	0	0	0	0	0	0	0
<i>Pinna muricata</i>	0	1	2	0	0	0	0	0	0
<i>Conus sp.</i>	0	0	0	0	0	0	0	0	0
<i>Cypraea tigris</i>	0	0	1	0	0	0	0	0	0
<i>Pleuroploca trapezium</i>	1	3	0	0	0	0	0	0	0
<i>Strombus sp.</i>	0	3	1	0	0	0	0	0	0
<i>Thalamita sp.</i>	0	5	1	0	0	0	0	0	0

Table A5. Numbers of fish recorded at the Lagoon Coral and Coral Block sites.

	A1	A2	A3	D1	D2	D3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Acanthurus sp.</i> (20 - 40cm)	0	0	0	0	0	0	0	0	0	5	5	1	0	0	0
<i>Acanthurus sp.</i> (<20cm)	52	78	81	399	96	0	98	109	131	68	97	83	0	50	0
<i>Acanthurus triostegus</i>	0	0	0	0	0	0	100	0	0	2	0	8	0	0	0
<i>Zebrasoma scopas</i>	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0
<i>Naso unicornis</i>	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
<i>Chaetodon trifasciatus</i>	0	4	6	36	14	0	17	3	5	7	13	5	0	0	0

	A1	A2	A3	D1	D2	D3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Chaetodon melannotus</i>	5	0	2	2	3	0	0	0	0	0	0	0	0	0	0
<i>Chaetodon lunula</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetodon auriga</i>	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
<i>Chaetodon trifascialis</i>	0	0	2	9	6	0	0	2	1	0	0	3	0	0	0
<i>Chaetodon xanthocephalus</i>	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
<i>Epinephelus spilotoceps</i>	5	5	5	10	0	6	7	30	9	3	5	10	5	5	5
<i>Thalassoma genivittatum</i>	10	9	8	2	6	11	10	5	0	0	0	0	0	0	0
<i>Thalassoma hardwicke</i>	8	8	19	19	8	0	2	1	0	0	0	0	0	0	0
<i>Cheilinus trilobatus</i>	2	3	1	4	2	0	0	1	0	0	0	0	0	0	0
<i>Chelinus chlorourus</i>	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
<i>Cheilinus fasciatus</i>	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
<i>Halichoeres scapularis</i>	0	0	4	0	20	0	0	2	0	0	0	0	0	0	0
<i>Halichoeres marginatus</i> (juvenile)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gnathodentex aureolineatus</i>	0	0	5	0	13	0	17	192	230	1	0	27	0	0	0
<i>Lethrinus harak</i>	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
<i>Mulloidichthys vanicolensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mulloidichthys flavolineatus</i>	0	0	0	0	0	0	0	0	0	119	220	67	0	0	0
<i>Parupeneus barberinus</i>	0	1	2	5	11	0	0	250	200	5	0	0	0	0	0
<i>Parupeneus trifasciatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parupeneus macronema</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parupeneus ciliatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chromis viridis</i>	60	1500	11	1125	661	0	619	745	1002	905	997	780	0	518	35
<i>Chrysiptera glauca</i>	7	33	98	16	12	0	0	0	0	0	0	0	0	0	0
<i>Dascyllus aruanus</i>	740	590	570	1285	1248	6	900	1005	1513	1620	1040	1080	31	251	27
<i>Stegastes limbatus</i>	720	820	445	547	563	0	325	411	703	790	750	740	0	17	0
<i>Stegastes punctatus</i>	608	600	460	680	227	0	500	103	220	270	190	50	0	0	0
<i>Stegastes nigricans</i>	1750	290	110	315	160	0	20	148	160	220	130	51	0	1	0
<i>Abudefduf sexfasciatus</i>	0	0	0	0	0	0	3	1	1	1	1	4	0	0	0
<i>Abudefduf sparoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dascyllus trimaculatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile parrotfish	75	270	434	301	340	0	66	67	65	92	67	97	0	57	0
<i>Chlorurus sordidus</i>	0	0	0	150	20	0	20	0	0	2	5	2	0	0	0
<i>Scarus ghobban</i>	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0
<i>Scarus scaber</i>	0	0	2	15	0	0	3	1	15	2	0	2	0	0	0

	A1	A2	A3	D1	D2	D3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Siganus sutor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhinecanthus aculeatus</i>	0	0	0	5	4	3	1	1	0	0	0	0	7	4	2
<i>Fistularia commersonii</i>	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0
<i>Siderea grisea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ostracion meleagris</i>	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
<i>Zanclus cornutus</i>	0	0	0	3	0	0	2	0	0	0	0	3	0	0	0

Table A6. Numbers of fish recorded at the Algae/Seagrass sites.

	I1	I2	I3	L1	L2	L3	M1	M2	M3
<i>Acanthurus</i> sp. (20 - 40cm)	0	0	0	0	0	0	0	0	0
<i>Acanthurus</i> sp. (<20cm)	0	0	0	0	0	1	0	2	1
<i>Acanthurus triostegus</i>	3	0	0	1	4	9	6	7	0
<i>Zebrasoma scopas</i>	0	0	0	0	0	0	0	0	0
<i>Naso unicornis</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon trifasciatus</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon melannotus</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon lunula</i>	2	0	0	0	0	0	0	2	0
<i>Chaetodon auriga</i>	2	0	1	0	0	0	0	1	0
<i>Chaetodon trifascialis</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon xanthocephalus</i>	0	0	0	0	0	0	0	0	0
<i>Epinephelus spilotoceps</i>	6	5	5	0	0	0	0	1	0
<i>Thalassoma genivittatum</i>	7	0	0	200	140	122	55	100	72
<i>Thalassoma hardwicke</i>	0	0	0	0	0	0	0	0	0
<i>Cheilinus trilobatus</i>	0	0	0	0	0	0	0	3	0
<i>Chelinus chlorourus</i>	0	0	0	2	0	0	1	3	1
<i>Cheilinus fasciatus</i>	0	0	0	0	0	0	0	0	0
<i>Halichoeres scapularis</i>	0	0	0	1	0	0	1	1	0
<i>Halichoeres marginatus</i> (juvenile)	0	0	0	0	0	0	2	0	1
<i>Gnathodentex aureolineatus</i>	0	0	0	0	0	0	0	0	0
<i>Lethrinus harak</i>	0	0	0	0	0	0	0	0	0
<i>Mulloidichthys vanicolensis</i>	100	0	0	0	0	0	0	0	0
<i>Mulloidichthys flavolineatus</i>	0	0	0	0	0	0	0	0	0
<i>Parupeneus barberinus</i>	0	0	0	0	0	0	0	0	0
<i>Parupeneus trifasciatus</i>	0	0	0	0	0	0	0	1	0

	I1	I2	I3	L1	L2	L3	M1	M2	M3
<i>Parupeneus macronema</i>	0	0	0	0	0	0	0	2	0
<i>Parupeneus ciliatus</i>	36	0	0	0	0	0	0	0	0
<i>Chromis viridis</i>	0	0	0	40	0	0	0	0	0
<i>Chrysiptera glauca</i>	0	0	0	1	0	0	33	25	10
<i>Dascyllus aruanus</i>	0	0	0	35	40	123	0	0	0
<i>Stegastes limbatus</i>	0	0	0	0	0	0	0	0	0
<i>Stegastes punctatus</i>	0	0	0	0	0	0	0	0	0
<i>Stegastes nigricans</i>	0	0	0	0	0	0	0	0	0
<i>Abudefduf sexfasciatus</i>	33	0	0	0	0	0	0	0	0
<i>Abudefduf sparoides</i>	0	0	0	0	0	0	3	0	0
<i>Dascyllus trimaculatus</i>	0	0	0	0	1	0	0	0	1
Juvenile parrotfish	0	0	0	19	2	18	0	49	41
<i>Chlorurus sordidus</i>	0	0	0	0	0	0	0	0	0
<i>Scarus ghobban</i>	0	0	0	0	0	0	0	0	0
<i>Scarus scaber</i>	0	0	0	0	0	0	0	0	0
<i>Siganus sutor</i>	2	0	0	0	0	1	0	1	0
<i>Rhinecanthus aculeatus</i>	5	2	4	1	1	2	0	2	0
<i>Fistularia commersonii</i>	0	0	0	0	0	0	0	0	0
<i>Siderea grisea</i>	0	0	0	1	0	3	0	0	0
<i>Ostracion meleagris</i>	0	0	0	0	0	0	0	0	0
<i>Zanclus cornutus</i>	0	0	0	0	0	0	0	0	0