



## **Annual Report of Benthos, Reef Fish and Invertebrate Surveys for Lagoon Areas in Rodrigues 2007**

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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 and molluscs were only found in very low densities, indicating over-harvesting of these organisms. Damselfish dominated the coral habitats whereas Algae/Seagrass areas had a much lower abundance of fish. The species diversity amongst carnivorous fish was low; Emperors, Snappers and Triggerfish were rare and Trevally were entirely absent, suggesting that overfishing is occurring within the lagoon. Few changes were observed in the benthic habitats, however there was a decline in seagrass and the appearance of anoxic patches of mud at Algae/Seagrass site M. The results also show a decline in the abundance of holothurians at sites D, J and M due to the sea cucumber fishery which started in April 2006. All sites showed a decline in the number of individuals, species and genera of fish, with this being particularly true at the northern sites: Coral Block site J and Algae/Seagrass sites I, L and M. In particular, families such as Acanthuridae, Labridae, Mullidae and Scaridae, which are usually common, were only occasionally observed. This is a further indication 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 240km<sup>2</sup>, 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 - 2006, 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.*, 2006a; Hardman *et al.*, 2006b), 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.

This report forms part of the continuing assessment of the lagoon habitats in Rodrigues and presents the results obtained during the 2007 surveys.

## 2 Materials and Methods

Three different habitat types were selected for monitoring. These were areas of lagoon coral on a consolidated limestone platform (1 site), 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.

<b>Lagoon Coral</b>							
<b>Area</b>	<b>Station number</b>	<b>Latitude</b>	<b>Longitude</b>				
<b>A</b>	1	19° 45.270	63° 28.058				
	2	19° 45.446	63° 28 129				
	3	19° 45.270	63° 28 380				
<b>Coral Blocks on Sand</b>				<b>Algae / Seagrass</b>			
<b>Area</b>	<b>Station number</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Area</b>	<b>Station number</b>	<b>Latitude</b>	<b>Longitude</b>
<b>E</b>	1	19° 48.785	63° 24.972	<b>I</b>	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
<b>G</b>	1	19° 49.000	63° 21.000	<b>L</b>	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
<b>J</b>	1	19° 40.456	63° 20.232	<b>M</b>	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 during 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

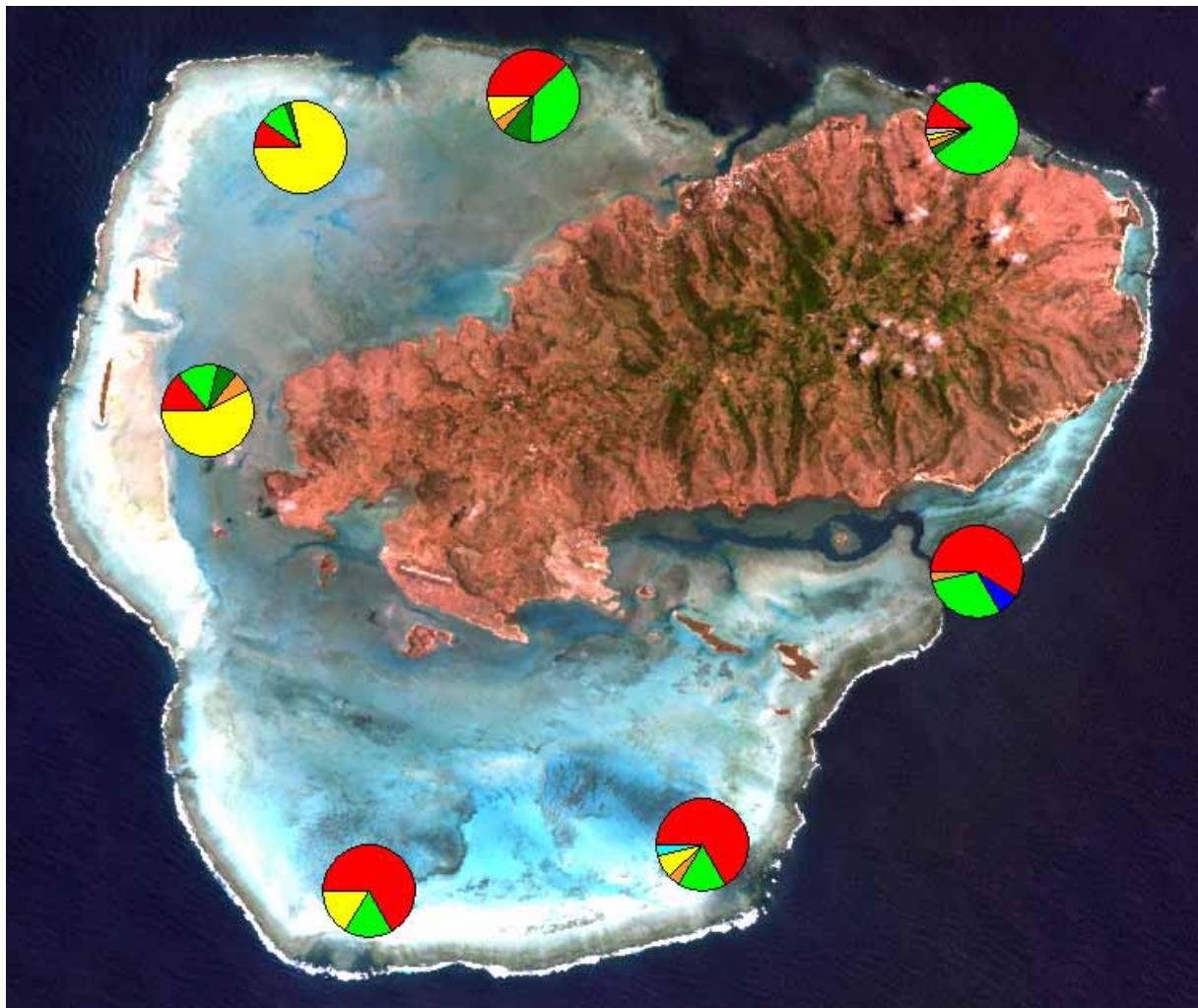
#### 3.1 Benthos

At the Lagoon Coral site A the mean percentage cover of hard coral was 51-75% (Figure 2). Coral cover was diverse, consisting of 31-50% *Acropora* spp., especially branching and digitate species, with mushroom (*Fungia* spp.) colonies also common (11-30%). Mean soft coral cover was 1-10%. No dead coral was observed and the mean percentage of rubble was <1%, however mean turf algal cover was 31-50%.

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 11-30% 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 massive and sub-massive corals only. No dead coral was observed at any site and rubble was 1-10% at site E and not present at sites G and J. Algal cover was however 11-30% at all 3 sites.

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 sub-massive coral colony were observed. At Site L, coral cover consisted of 11-30% branching *Acropora* sp., massive corals, sub-massive corals and *Millepora* sp. At Site M, coral cover consisted of 31-50% massive corals and 31-50% sub-massive corals. Mean percentage cover of rubble was <1% at all 3 sites. Mean percentage cover of macro-algae was 1-10% at Site I, 31-50% at Site L and 76-100% at Site M; seagrass was 1-10% at Site L and <1% at Sites I and M. Mean percentage cover of sand was 31-50% at Site I, 1-10% at Site L and <1% at Site M; <1% Mud was also observed at Site M.

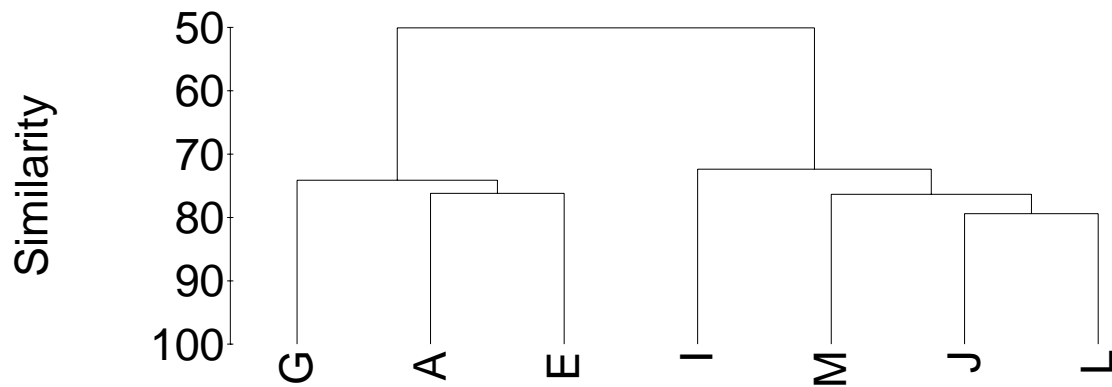
Cluster Analysis groups the southern Lagoon Coral and Coral Block Sites (Sites, A, D, E and G) together at 74% (Figure 3). The northern Coral Block site (Site J) is grouped with the Algae/Seagrass sites at 72% similarity.



**Key**

- |   |  |
|---|--|
| <span style="color: red;">■</span> Hard Coral     | <span style="color: orange;">■</span> Rubble |
| <span style="color: blue;">■</span> Soft Coral    | <span style="color: yellow;">■</span> Sand   |
| <span style="color: green;">■</span> Algae        | <span style="color: grey;">■</span> Mud      |
| <span style="color: darkgreen;">■</span> Seagrass | <span style="color: cyan;">■</span> 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.

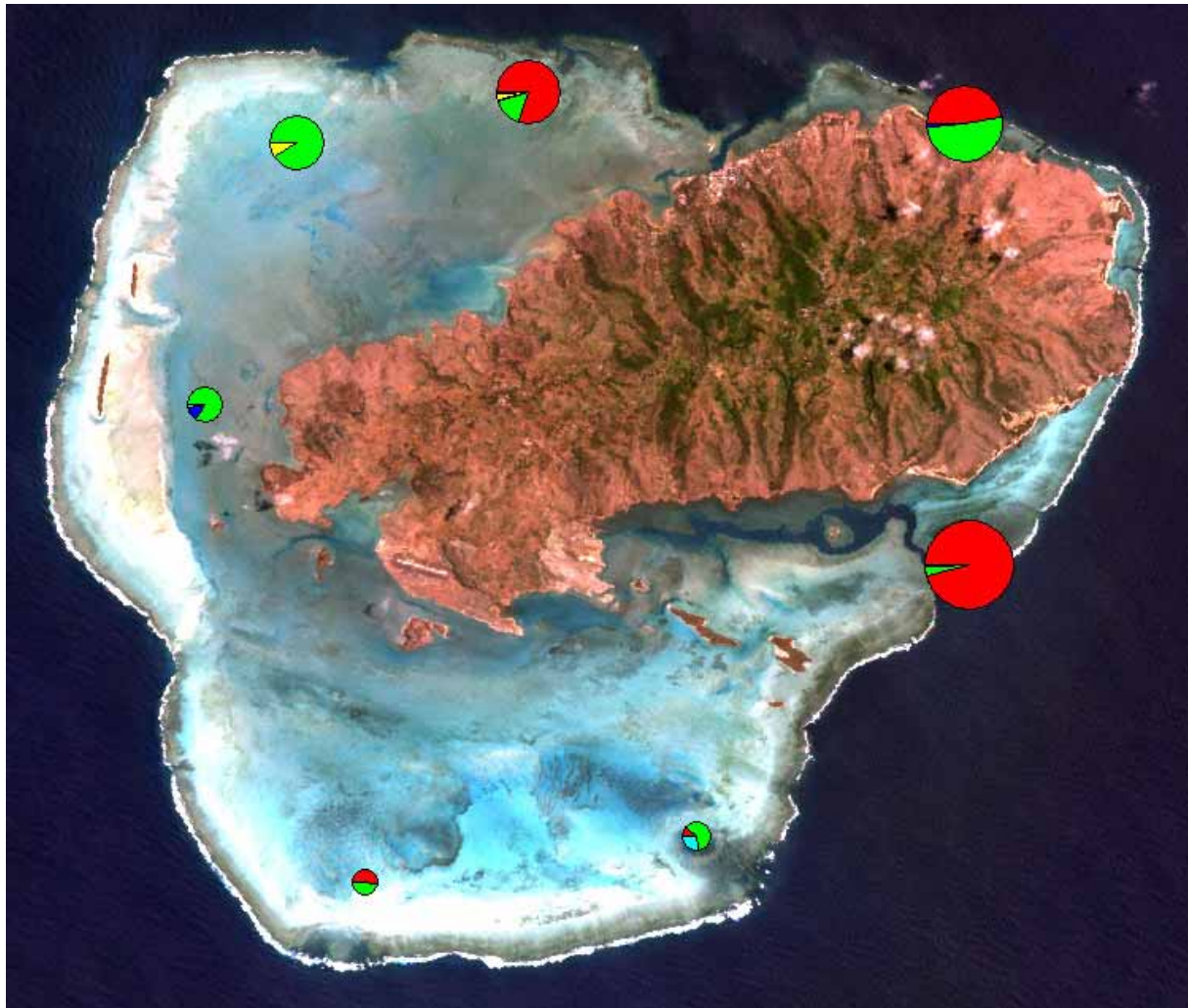
### 3.2 Invertebrates

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 2-5 individuals); the gastropod *Cypraea tigris* was also only observed at Site A (mean of 2-5 individuals) and the gastropod, *Pleuroploca trapezium* was observed at Sites E, J (1 individual at each site) and I (mean of 2-5 individuals). The only crustacean to be observed was the hermit crab, *Dardanus* sp. at Site L.

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).

At the coral block sites, invertebrates were rare at Sites E and G. At site E, only the holothurian, *H. atra* (mean of 16-50 individuals) was represented by more than one individual; at site G, both *E. mathaei* and *H. atra* were uncommon (mean of 2-5 individuals) and no other invertebrates were observed. At Site J, holothurians (*H. atra* and *H. leucospilata*) were abundant (51-250 individuals) 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 (dominated by *Synapta maculata* with *H. atra*, *H. leucospilata*) were very abundant (250-1,000 individuals) and urchins (*E. mathaei*) were also abundant (mean of 51-250 individuals).



**Key**

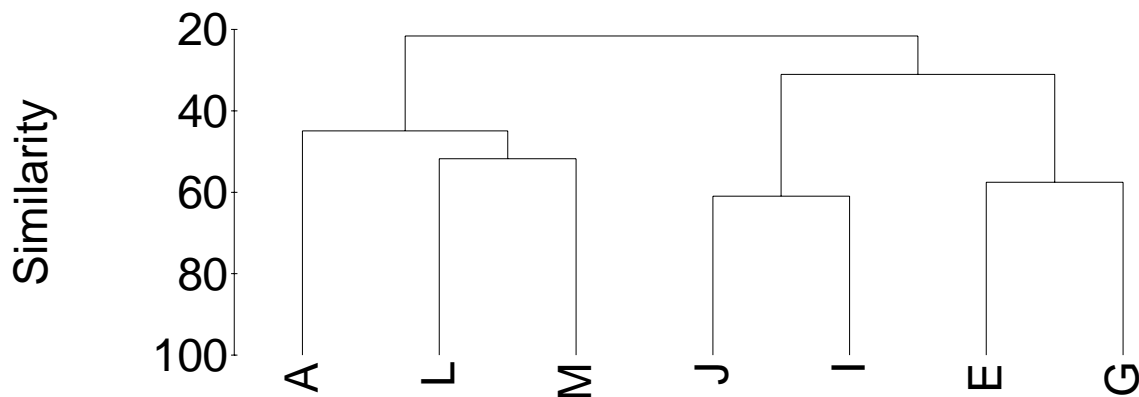
- |   |  |
|---|--|
| <span style="color: red;">■</span> Urchins                    | <span style="color: yellow;">■</span> Other Bivalves |
| <span style="color: green;">■</span> Holothurians             | <span style="color: cyan;">■</span> Large Gastropods |
| <span style="color: blue;">■</span> Other Echinoderms         | <span style="color: orange;">■</span> Other          |
| <span style="color: magenta;">■</span> <i>Tridacna maxima</i> |  |

**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 sites L and M (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 and the least number of individuals were observed at the Coral Block site G (2 species and 6-15 individuals). In terms of invertebrate species, the different sites show little similarity within habitat and there are no clear geographical trends. Coral Block site J and Algae/Seagrass site I cluster together at 61% as holothurians are common at both sites. Coral sites E and G cluster at 58% similarity together due to low numbers of invertebrates and Lagoon Coral Site A and Algae/Seagrass sites L and M cluster together at 45% similarity due to high numbers of the sea urchin, *Echinometra 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
E	6 - 15	5	5
G	6 - 15	2	2
J	51 - 250	6	5
I	16 - 50	6	5
L	51 - 250	10	9
M	251 - 1,000	10	9

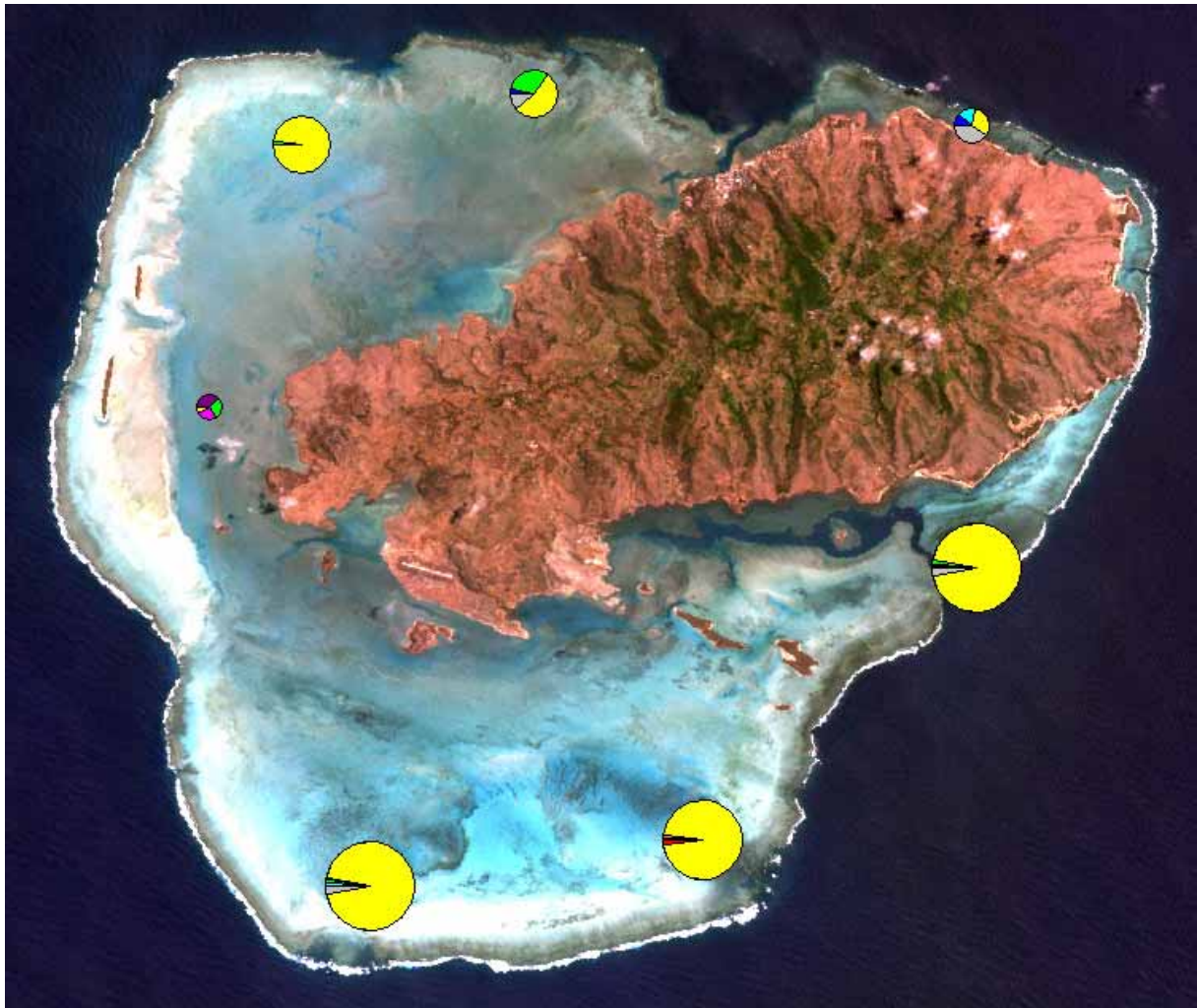
**Figure 5.** Cluster Analysis ( $\sqrt{\text{transformed}}$ ) of the invertebrate species recorded at each site.

### 3.3 Fish

The fish populations at the Lagoon Coral site A was dominated by Damselfish (Pomacentridae) with >1,000 individuals, in particular *Dascyllus aruanus*, *Stegastes limbatus*, and *S. nigricans* were very abundant. Snappers (Lutjanidae), Emperors (Lethrinidae) and Trevally (Carangidae) were not observed at this site (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 Site E Damselfish were very abundant (250-1,000 individuals) and they were super abundant (>1,000 individuals) at Site G and *Chromis viridis*, *Stegastes limbatus* and *S. lividus* were all very abundant, whereas at Site J only *D. aruanus* was abundant. The Emperor, *Gnathodentex aureolineatus* was observed at Sites E and G (mean of 16-50 individuals), however Snappers (Lutjanidae) and Trevally (Carangidae) were absent from all sites and Triggerfish (Balistidae) were rare.

In the Algae/Seagrass habitats, all sites had a very low number of fish. At Site I, only the Triggerfish, *Rhinecanthus aculeatus* and grouper, *Epinephelus spilotoceps* were observed in numbers greater than 1 (mean of 2-5 individuals of each species). Site L was dominated by the Damselfish, *Dascyllus aruanus* and the grouper *E. spilotoceps* (16-50 individuals of each species), whereas at Site M only the surgeonfish, *Acanthurus triostegus*, the Wrasse, *Cheilinus chlorurus* and the Damselfish, *Chrysiptera glauca* were observed in numbers greater than 1 (mean of 2-5 individuals of each species). No Trevally (Carangidae), or Emperors (Lethrinidae) were observed at any site, whilst Snappers (Lutjanidae) and Triggerfish (Balistidae) were only observed at Site I.



**Key**

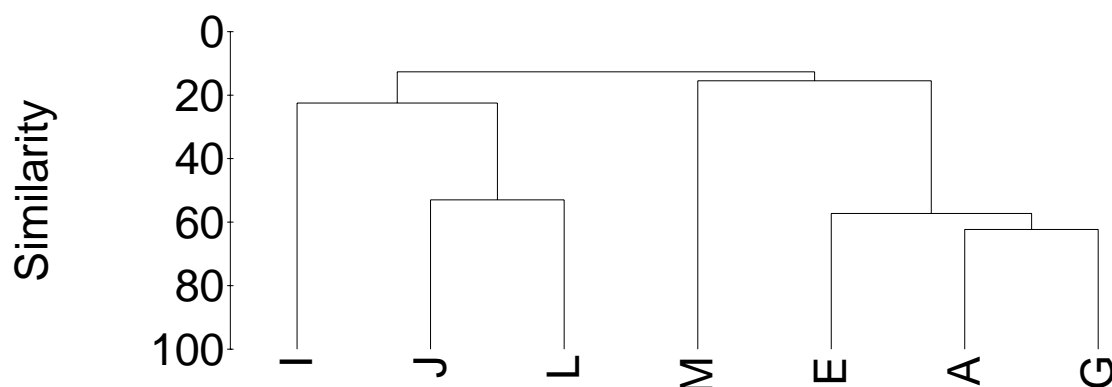
- |  |   |
|--|---|
| <span style="color: blue;">■</span> Acanthuridae   | <span style="color: magenta;">■</span> Lutjanidae   |
| <span style="color: purple;">■</span> Balistidae   | <span style="color: yellow;">■</span> Pomacentridae |
| <span style="color: cyan;">■</span> Chaetodontidae | <span style="color: red;">■</span> Scaridae         |
| <span style="color: green;">■</span> Epinephelini  | <span style="color: grey;">■</span> Other           |
| <span style="color: orange;">■</span> Lethrinidae  |   |

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

Lagoon Coral site A and Coral Block site G had the greatest species richness in terms of number of fish species and number of genera, with 20 species of 13 genera observed at Site A and 19 species of 14 genera observed at Site G (Table 4). The Algae/Seagrass site I had the lowest number of individuals (8) and Coral Block site J had the lowest number of fish species and genera (3 species in 3 genera). Cluster Analysis groups the southern coral sites, A, E and G together at 57% and the Algae/Seagrass sites L and J together at 53%; sites I and M are distinct due to the low numbers of fish observed at these sites (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 the grouper *Epinephelus spilotoceps*.

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

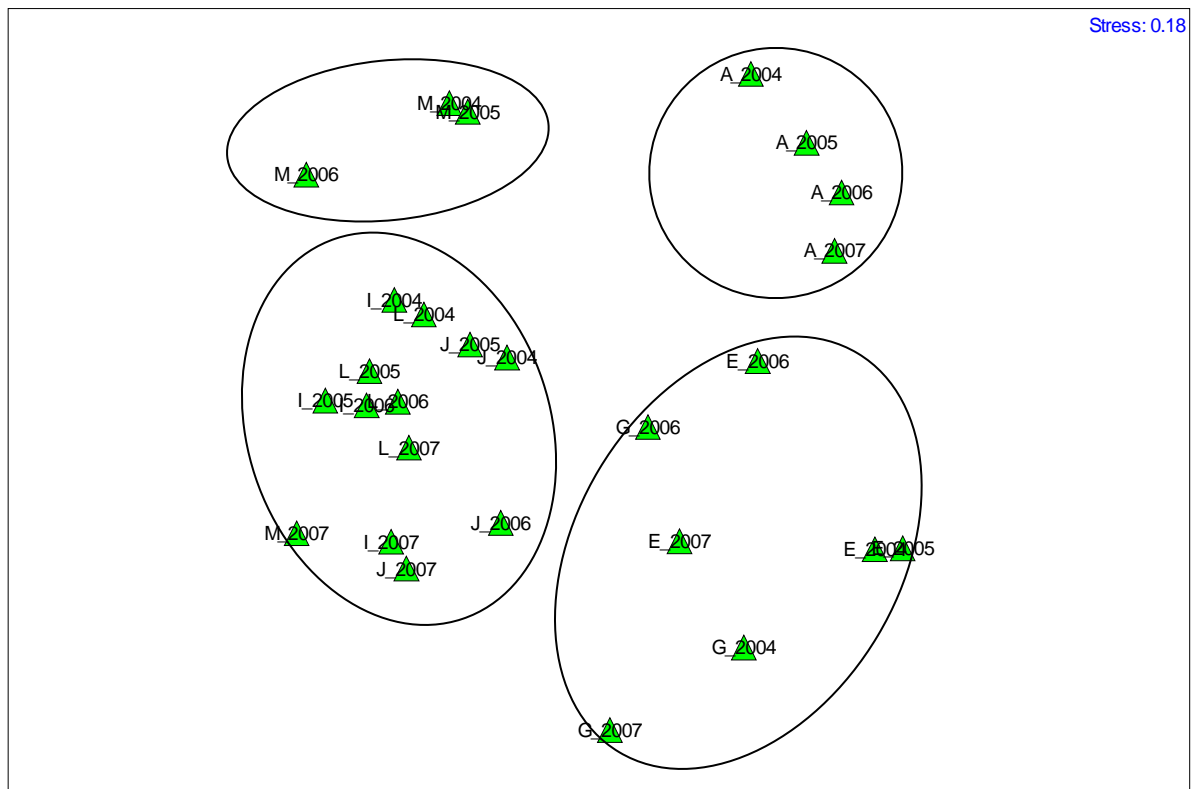
Site	No. individuals	No. species	No. genera
A	>1,000	20	13
E	251 – 1,000	13	11
G	>1,000	19	14
J	51 - 250	3	3
I	6 - 15	5	4
L	16 - 50	8	7
M	16 - 50	12	10



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

### 3.4 Comparisons with previous years

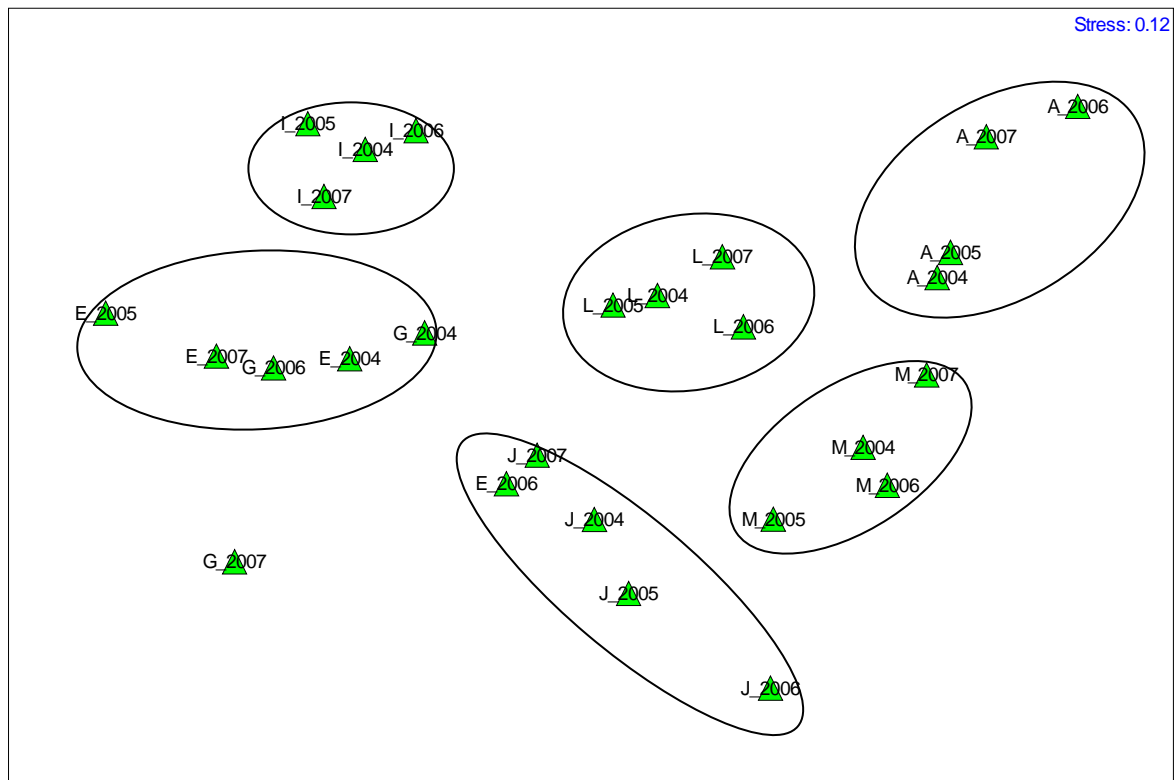
The results suggest that there have been very few changes in benthic composition at the survey sites, with Multi-Dimensional Scaling (MDS) plots clustering the habitats from different years together: Coral Block sites E and G cluster together in all 4 years, as do Algae/Seagrass sites I and L (Figure 8). The only variation is site M, which shifts to cluster together with the other Algae/Seagrass sites in 2007. This change can be explained by an increase in algae from 51-75% in 2006 to 76-100% in 2007, a decline in seagrass from 31-50% to <1% and the appearance of patches of mud amongst the sand.



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

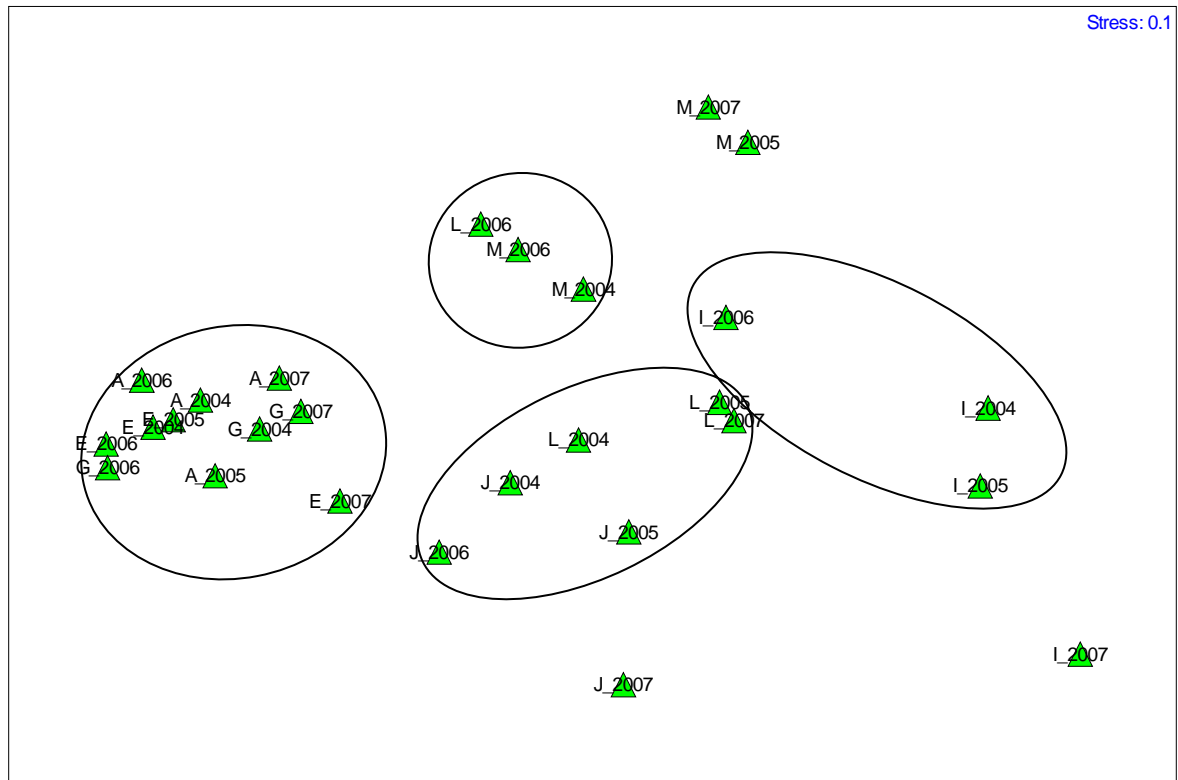
Invertebrate community structure also shows little change over time, with sites remaining echinoderm dominated. Multi-dimensional scaling shows that only Coral Block site G, showed a shift, due to the absence of any molluscs in the 2007 surveys (Figure 9). There were however changes in the abundance of organisms over time. At Coral Block sites D and J and Algae/Seagrass site M, there were declines in the abundance of holothurians between 2006 and 2007. This was particularly true at Site J, where numbers fell from a mean of 251-1,000 in 2006 to 51-250 in 2007 and at Site D where they fell from a mean of 51-250 in 2006 to 6-15 in 2007.





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

There was a decrease in the total number of fish at all of the 7 sites between 2006 and 2007, And this was particularly true at the northern Coral Block site J and the Algae/Seagrass sites. There were also declines in the number of species and genera present. Families which were abundant in 2006 such as Acanthuridae (Surgeonfish), Labridae (Wrasse), Mullidae (Goatfish) and Scaridae (Parrotfish) were not common in 2007 and the only family present in any significant number was the Pomacentridae (Damsel fish). Acanthuridae declined from 51-250 individuals in 2006 to 6-15 individuals at Lagoon Coral site A and <1 individual at Coral Block sites E and G; Labridae declined from 51-250 individuals to 2-5 individuals at Algae/Seagrass sites L and M and Scaridae declined from 51-250 individuals to 0 individuals at Lagoon Coral site A and Coral Block site G and 6-15 individuals at Coral Block site E. Multi-dimensional scaling shows that there has been little change in fish community structure over time with sites remaining dominated by Pomacentridae (Figure 10). Sites J and I are however distinct in 2007 due to low numbers of fish genera being observed and data from 2007 at site M clusters more closely with that in 2005 due to low numbers of Labridae and Pomacentridae being recorded in both years.



**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, 2005 and 2006 surveys (Lynch *et al.*, 2005; Hardman *et al.*, 2006a; Hardman *et al.*, 2006b) highlighting fairly healthy coral colonies in the southern lagoon, around Couzoupa (Site A), Quatre Vingt Brisants (Site G) and Passe l’Ancre (Site 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 and seagrass was rare,

As in previous years, invertebrate populations were echinoderm dominated, and molluscs and crustaceans were found 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.

As in previous years, Damselfish dominated the coral habitats, presumably as a result of their territorial behaviour. Fish diversity was high at the southern Coral sites, A E and G, but tended to be low at the northern sites, with very low numbers of fish observed. The species diversity amongst carnivorous fish was low at all sites. Emperors consisted of only one species: *Gnathodentex aurolineatus* and were only observed in low numbers at 2 sites and Trevally were entirely absent, suggesting that severe overfishing is occurring within the Rodrigues 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 a higher abundance of fish, clearly dominated by Damselfish. Invertebrate populations show a less obvious distribution pattern.

There were little changes in the benthic habitats between 2006 and 2007, however sea grass declined from a cover of 11-30% to <1% at Site M and the appearance of patches of anoxic mud at this site, suggest a decline in health. The number of holothurians has declined at 3 sites from abundances of 251-1,000 individuals in 2006 to 51-250 individuals in 2007. This is due to the sea cucumber fishery which was started in Rodrigues in April 2006 and has now removed large numbers of sea cucumbers from the Rodrigues lagoon: 86,000 individuals were landed at one site in the south in just 5 months (Mrowicki, 2006). Area M is the only site which still has high numbers of holothurians, however here they are dominated by *Synapta maculata*, which is not collected, whereas numbers of *Holothruia atra* and *H. leucospilota* have declined. The loss of sea cucumbers may also account for the appearance of mud patches at site M, as *Holothuria* spp. are detritus feeders, which oxygenate the sediment. All sites also showed a decline in the number of individuals, species and genera of fish, with this being particularly true at the northern sites: Coral Block site J and Algae/Seagrass sites I, L and M. In particular, families such as Acanthuridae, Labridae, Mullidae and Scaridae, which are usually common, were only occasionally observed. This is a further indication that overfishing is occurring within the lagoon.

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## 6 Appendices

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

	A1	A2	A3	E1	E2	E3	G1	G2	G3	J1	J2	J3
Mud	0	0	0	0	0	0	0	0	0	0	0	0
Branching Acropora	3	3	3	5	4	5	2	1	0	0	0	1
Tabular Acropora	0	1	1	2	2	3	2	1	1	0	0	0
Digitate Acropora	1	1	1	0	0	0	1	1	1	0	0	0
Solitary Coral	1	1	1	1	1	1	0	1	0	0	0	0
Massive Coral	1	0	1	1	2	1	1	1	1	0	1	1
Sub-massive Coral	1	1	1	1	1	1	0	1	0	1	1	1
Foliose Coral	1	0	1	1	1	2	1	1	0	0	0	0
Encrusting Coral	1	1	0	1	1	1	1	1	1	0	0	0
Millepora	0	0	0	0	0	0	0	0	0	0	0	0
Algae	4	4	4	2	2	3	2	2	4	3	3	3
Rubble	1	1	1	1	1	1	0	0	0	0	0	1
Sand	1	0	0	2	2	1	3	3	2	6	5	6
Seagrass	0	0	0	0	0	0	0	0	0	1	1	1
Sponge	0	0	0	0	1	1	0	0	0	0	0	0
Soft Coral	3	2	1	0	0	0	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	2	1	0
Branching Acropora	0	0	0	1	1	1	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	1	1	1
Sub-massive Coral	0	0	0	0	1	1	1	1	0
Foliose Coral	0	0	0	1	1	0	0	0	0
Encrusting Coral	0	0	0	0	0	0	0	0	0
Millepora	0	0	0	0	1	1	0	0	0
Algae	1	2	3	4	3	4	6	6	5

	A1	A2	A3	E1	E2	E3	G1	G2	G3
Rubble	2	1	1	1	2	1	1	1	1
Sand	3	5	3	2	1	2	1	1	2
Seagrass	0	1	1	2	2	1	0	1	2
Sponge	0	0	0	0	0	0	0	0	0
Soft Coral	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	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
<i>Tripneustes gratilla</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Echinometra mathaei</i>	2467	1006	576	2	0	1	1	2	11	0	0	0
<i>Holothuria atra</i>	3	12	24	2	11	5	0	0	12	26	35	120
<i>Holothuria leucospilota</i>	0	0	0	0	0	0	0	0	0	9	3	4
<i>Stichopus chloronotus</i>	1	0	0	0	0	0	0	0	0	0	0	0
<i>Synapta maculata</i>	4	35	62	0	0	0	0	0	0	2	1	2
<i>Actinopyga mauritania</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bohadschia</i> sp.	0	0	0	0	0	0	0	0	0	1	0	1
<i>Linkia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0
Featherstars	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ophiocoma erinaceus</i>	16	6	2	0	0	0	0	0	0	0	0	0
<i>Nardoa variolota</i>	0	1	0	0	0	0	0	0	0	0	0	0
<i>Tridacna maxima</i>	5	0	3	0	0	0	0	0	0	0	0	0
<i>Pinna muricata</i>	2	0	0	0	0	0	0	0	0	1	8	10
Coral Oyster	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pinctada margaritifera</i>	1	0	0	0	0	0	0	0	0	0	0	0
<i>Conus</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cypraea tigris</i>	2	5	0	0	0	0	0	0	0	0	0	0
<i>Cypraea caputserpentis</i>	0	0	0	0	1	0	0	0	0	0	0	0
<i>Pleuroploca trapezium</i>	0	0	0	0	1	0	0	0	0	0	1	0
<i>Duprella</i> sp.	0	0	0	1	1	0	0	0	0	0	0	0
<i>Aplysia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dardanus</i> sp.	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	2	1	1	1	0
<i>Tripneustes gratilla</i>	0	0	0	0	0	0	13	0	0
<i>Echinometra mathaei</i>	0	0	0	118	151	106	238	18	475
<i>Holothuria atra</i>	12	2	17	11	18	7	58	105	37
<i>Holothuria leucospilota</i>	2	0	4	4	15	11	7	26	1
<i>Stichopus chloronotus</i>	0	0	0	0	0	0	1	2	0
<i>Synapta maculata</i>	5	0	0	0	0	1	26	147	376
<i>Actinopyga mauritania</i>	0	0	0	1	0	0	0	0	0
<i>Bohadschia</i> sp.	2	0	0	0	2	0	0	0	0
<i>Linkia</i> sp.	5	1	1	0	0	0	0	0	0
Featherstars	0	0	0	0	0	0	0	0	24
<i>Ophiocoma erinaceus</i>	0	0	0	0	3	0	0	0	0
<i>Nardoa variolota</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	0	0	0	0	0	0	0	0
Coral Oyster	0	0	0	8	2	5	0	0	0
<i>Pinctada margaritifera</i>	0	0	0	0	0	0	0	0	0
<i>Conus</i> sp.	0	0	0	0	0	0	0	2	1
<i>Cypraea tigris</i>	0	0	0	0	0	0	0	0	0
<i>Cypraea caputserpentis</i>	0	0	0	0	0	0	0	0	0
<i>Pleuroploca trapezium</i>	0	0	2	0	0	0	0	0	0
<i>Duprella</i> sp.	0	0	0	0	0	0	0	0	0
<i>Aplysia</i> sp.	0	0	0	0	0	0	0	1	0
<i>Dardanus</i> sp.	0	0	0	3	1	3	0	0	0

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

	A1	A2	A3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Abudefduf sexfasciatus</i>	17	7	11	0	0	0	0	1	2	0	0	0
<i>Acanthurus</i> sp (20-40cm)	0	0	0	0	0	0	0	0	0	0	0	0
<i>Acanthurus triostegus</i>	1	4	3	3	3	2	10	17	3	0	0	0
<i>Anampses caeruleopunctatus</i>	4	3	0	0	0	0	1	0	0	0	0	0

	A1	A2	A3	E1	E2	E3	G1	G2	G3	J1	J2	J3
<i>Chaetodon auriga</i>	0	0	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
<i>Chaetodon melannotus</i>	0	0	0	0	0	0	1	0	0	0	0	0
<i>Chaetodon trifascialis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetodon vagabundus</i>	23	19	25	2	4	3	5	8	27	4	0	0
<i>Chaetodon trifasciatus</i>	24	30	20	2	0	0	6	13	26	0	0	0
<i>Cheilinus chlorourus</i>	10	13	18	2	0	0	0	3	6	0	0	0
<i>Chromis viridis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chrysiptera glauca</i>	1	1	4	0	0	0	0	0	8	0	0	0
<i>Dascyllus aruanus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epinephelus spilotoceps</i>	1	1	1	0	0	0	0	0	0	0	0	0
<i>Gnathodentex aurolineatus</i>	5	4	3	0	2	0	0	1	2	0	0	0
<i>Gomphosus caeruleus</i>	0	0	2	0	0	0	0	0	0	0	0	0
<i>Halichoeres marginatus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Halichoeres nebulosus</i>	0	0	0	7	12	0	0	10	13	0	0	0
<i>Halichoeres scapularis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lutjanus fulvus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lutjanus kasmira</i>	2	0	0	0	0	0	0	0	0	0	0	0
<i>Mulloidichthys flavolineatus</i>	4	3	4	0	0	0	11	17	23	0	0	0
<i>Mulloidichthys vanicolensis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parupeneus barberinus</i>	0	5	20	90	64	127	450	425	420	0	0	0
<i>Rhinecanthus aculeatus</i>	0	3	5	0	0	0	0	3	0	0	0	0
<i>Siderea grisea</i>	370	300	225	63	31	850	0	0	0	50	45	160
<i>Siganus sutor</i>	660	150	400	75	60	156	820	230	470	0	0	0
Juvenile parrotfish	140	330	120	95	82	199	150	140	130	0	0	0
<i>Stegastes limbatus</i>	1152	110	200	0	0	0	10	50	5	0	0	0
<i>Stegastes lividus</i>	0	0	0	0	0	0	0	0	0	5	0	5
<i>Stegastes nigricans</i>	0	0	0	25	7	0	0	0	0	0	0	0
<i>Stethojulis albovittata</i>	0	0	0	0	2	0	0	0	1	0	0	0
<i>Thalassoma hardwicke</i>	0	1	0	0	0	0	0	1	0	0	0	0
<i>Thalassoma genivittatum</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Zanclus cornutus</i>	0	6	1	0	0	1	0	0	4	0	0	0

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

	I1	I2	I3	L1	L2	L3	M1	M2	M3
<i>Abudefduf sexfasciatus</i>	0	0	0	0	0	0	0	0	0
<i>Acanthurus</i> sp (20-40cm)	0	0	0	0	4	0	5	1	0
<i>Acanthurus triostegus</i>	0	0	0	0	0	0	0	0	0
<i>Anampses caeruleopunctatus</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon auriga</i>	0	0	0	0	0	0	0	1	0
<i>Chaetodon lunula</i>	0	0	0	0	0	0	0	0	3
<i>Chaetodon melannotus</i>	0	0	0	0	0	0	0	0	0
<i>Chaetodon trifascialis</i>	0	0	0	0	0	0	0	2	1
<i>Chaetodon vagabundus</i>	5	0	1	13	11	16	0	0	0
<i>Chaetodon trifasciatus</i>	0	0	0	0	0	0	0	0	0
<i>Cheilinus chlorourus</i>	0	0	0	0	0	0	1	0	0
<i>Chromis viridis</i>	0	0	0	2	0	2	0	3	2
<i>Chrysiptera glauca</i>	0	0	0	2	4	0	1	0	0
<i>Dascyllus aruanus</i>	0	0	0	0	1	0	0	0	0
<i>Epinephelus spilotoceps</i>	0	0	0	0	0	0	0	0	0
<i>Gnathodentex aurolineatus</i>	0	0	0	0	0	0	0	0	0
<i>Gomphosus caeruleus</i>	0	0	0	0	0	0	0	0	0
<i>Halichoeres marginatus</i>	0	0	0	0	0	0	0	1	2
<i>Halichoeres nebulosus</i>	0	0	0	0	0	0	0	0	0
<i>Halichoeres scapularis</i>	1	0	0	0	0	0	0	0	0
<i>Lutjanus fulvus</i>	1	0	0	0	0	0	0	0	0
<i>Lutjanus kasmira</i>	0	0	0	0	0	0	0	0	3
<i>Mulloidichthys flavolineatus</i>	0	0	0	0	0	0	0	0	0
<i>Mulloidichthys vanicolensis</i>	0	0	0	0	0	0	0	2	0
<i>Parupeneus barberinus</i>	0	0	0	0	0	0	0	0	0
<i>Rhinecanthus aculeatus</i>	0	0	0	0	0	0	5	7	4
<i>Siderea grisea</i>	0	0	0	8	26	26	0	0	0
<i>Siganus sutor</i>	0	0	0	0	0	0	0	0	0
Juvenile parrotfish	0	0	0	0	0	0	0	0	0
<i>Stegastes limbatus</i>	0	0	0	0	0	0	0	0	0
<i>Stegastes lividus</i>	2	0	0	6	0	0	0	0	0
<i>Stegastes nigricans</i>	0	0	0	0	0	0	0	0	0
<i>Stethojulis albovittata</i>	0	0	0	0	0	0	0	0	0



	I1	I2	I3	L1	L2	L3	M1	M2	M3
<i>Thalassoma hardwicke</i>	6	2	1	0	0	0	0	0	0
<i>Thalassoma genivittatum</i>	0	0	0	0	1	1	0	0	0
<i>Zanclus cornutus</i>	0	0	0	0	0	0	0	2	0