Annual Report of Benthos, Reef Fish and Invertebrate Surveys for Reef Slope and Reef Flat Areas in Rodrigues 2005

E. R. Hardman, F.E. I. Blais, M. S. Desiré, J.S.J Raffin, S. Perrine, R. Raffaut, and M. Chinien-Chetty

Shoals Rodrigues, Pointe Monier, Rodrigues

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Acknowledgements

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Abstract

Surveys of reef composition and fish and invertebrate populations were undertaken using the Global Coral Reef Monitoring Network methodology during October/November 2005, to continue a monitoring programme that began in 1999. Nine sites around the fringing reef were included: Rivière Banane, Passe Armand, Grand Bassin and Ile aux Fous (reef flat and reef slope stations), Passe Cabris, Trou Blanc and Passe L'Ancre (reef flat stations only) and Passe Demi and North Ile aux Sables (reef slope only). The surveys show that coral cover is high on the reef slopes at Rivière Banane, Grand Bassin, Passe Demi and Ile aux Fous (>40%), but is low at North Ile aux Sables and Passe Armand (<30%). In contrast, coral cover was low on all reef flat sites (<25%) and dead coral cover was high at Passe Armand, Trou Blanc and Ile aux Fous with a high percentage cover of rubble at Passe L'Ancre, suggesting that these sites being subjected to human and natural impacts. Despite these impacts, live coral cover has remained stable at the sites between March 2002 and October 2005. The fish community at all sites tended to be dominated by Damselfish. Emperors, Grouper, and Snapper were rare or absent and no Triggerfish or Trevally were observed at any site during the surveys. This lack of large piscivorous predators suggests that the fish population may be unbalanced due to overfishing. There have also been declines in the number of Damselfish, Surgeonfish, Butterflyfish and Wrasse since March 2002 particularly on the reef slopes a further indication of overfishing. Invertebrates were low on the reef slope sites and most sites were dominated by the urchin, *Echinometra mathaei*; this species also dominated the reef flat sites. At all sites, molluscs and crustaceans were either rare or absent; in particular *Tridacna* clams were in low abundance and large gastropods such as *Pleuroploca trapezium* were not observed. This may be an indication that local consumption is resulting in over-harvesting.

1 Introduction

Rodrigues is surrounded by a fringing reef, which forms an almost continuous band measuring approximately 90km in length. The reef encloses a shallow lagoon, which, at 240km^2, is twice the area of the island itself. The maximum tidal range is approximately 1.5m, and since the average water depth in the lagoon is less than 2m, many areas are exposed at low spring tides. The water depth immediately beyond the reef slopes is usually within the range of 10m to 30m. The island has three major channels, one dredged channel for the main harbour at Port Mathurin in the north, and natural channels in the south near Port Sud Est and in the East at St Francois. Several small passes are also found at intervals around the reef.

The reefs of the island consist mainly of scleractinian corals, with *Acropora* spp. dominant on both the reef flat and reef slope. 140 species of coral were recorded in Rodrigues during the first Marine Biodiversity Workshop held in September 2001, of which 25 were *Acropora* spp. (*Shoals of Capricorn Programme,* 2002). The coral cover on the reef slopes around Rodrigues is relatively healthy, while reef flat areas are more heavily impacted, both by fishing (particularly trampling by octopus fishers (Clark, 2001)) and by bleaching events (Hardman *et al.*, 2004).

In order to evaluate temporal changes in the health of the coral reef and the populations of fish and invertebrates that it supports, monitoring activities have been carried out since 1999. The data is also made available to the Global Coral Reef Monitoring Network (GCRMN), being submitted via the regional network administered by the Indian Ocean Commission. This report details findings of the GCRMN monitoring activities that took place in 2005, and contains some comparisons with data from 2004 and 2003 (Lynch *et al.*, 2004a; Lynch *et al.*, 2004b).

2 Materials and Methods

Surveys were carried out at six reef slope and seven reef flat stations around the island by *Shoals Rodrigues* staff in October/November 2005. Of these, the stations at Rivière Banane, Grand Bassin, Passe Demi and Passe Cabris were within the 4 proposed marine reserves, whilst the remaining stations were outside of the proposed reserves. The site locations are listed in Table 1 and shown in Figure 1.

Table 1. The location of the monitoring sites at which surveys were carried out

Site Name	Reef flat GPS Position	Reef slope GPS Position
Rivière Banane	19° 40.224’ S; 63° 28.224’ E	19° 40.154’ S; 63° 28.484’ E
Passe Armand	19° 40.272’ S; 63° 24.982’ E	19° 40.084’ S; 63° 24.677’ E
Grand Bassin	19° 39.408’ S; 63° 21.447’ E	19° 39.381’ S; 63° 21.366’ E
Trou Blanc	19° 45.401’ S; 63° 28.443’ E	
Passe L’Ancre	19 º 48.825’ S; 63º 25.613’ E	
Passe Demi		19° 42.515’ S; 63° 17.562’ E
N Ile aux Sables		19º 40.770’ S; 63º 17.984’ E
Passe Cabris	19º 39.587’ S; 63º 26.406’ E	
Ile aux Fous	19º 39.313’ S; 63º 23.593’ E	19º 39.218’E; 63º 23.977’ E

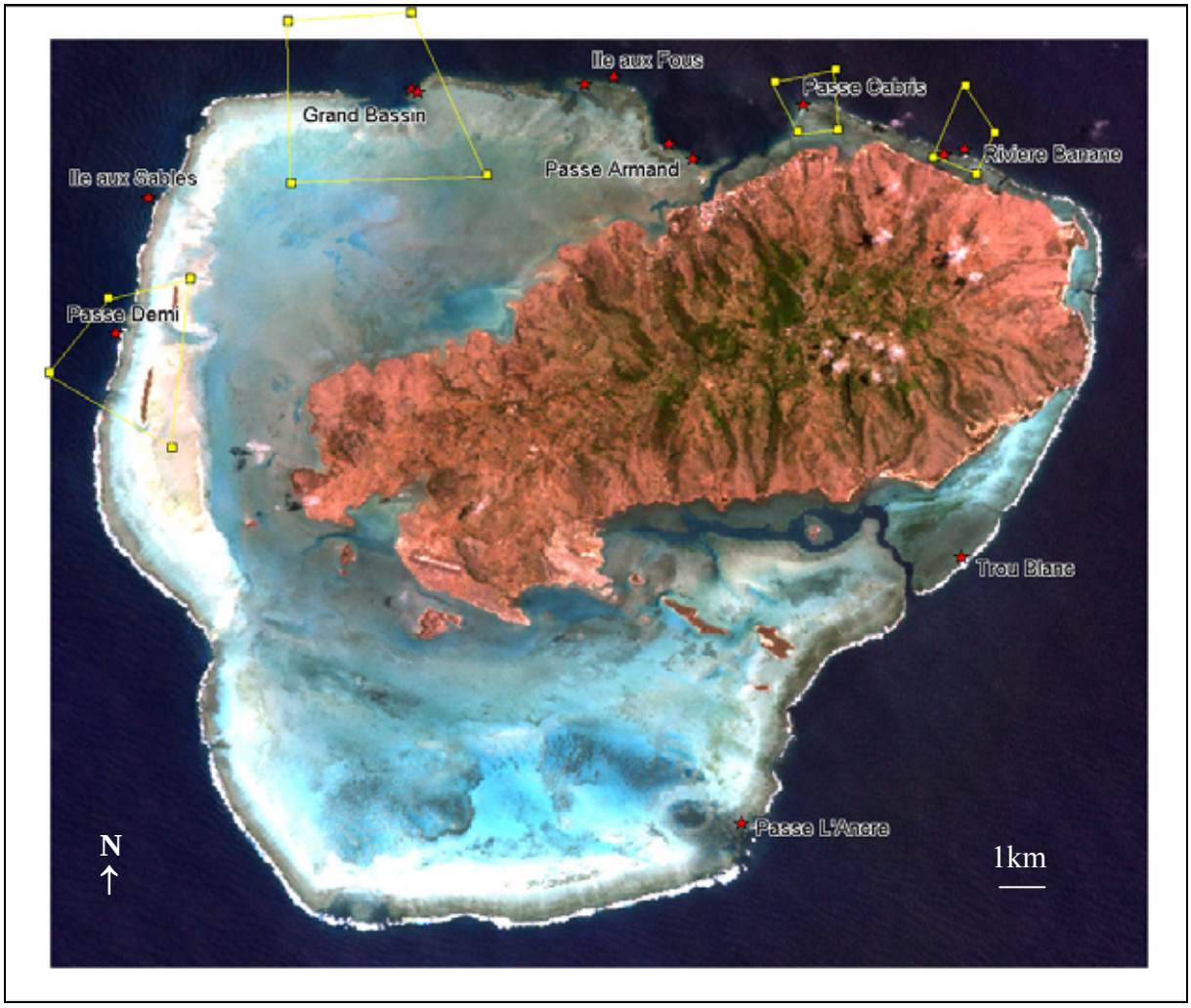

Figure 1. The location of reef monitoring sites around Rodrigues and the position of the 4 proposed marine reserves.

The depth on the reef flat was approximately 1m, while surveys on the reef slope took place at between 6m and 12m depth. Reef flat monitoring was carried out by snorkelling, with SCUBA used for reef slope surveys. The location of the site was recorded on a GPS and transects marked by metal bars and buoys. The methodology used was that of the Indian Ocean Commission regional reef monitoring network as described in their manual (Conand *et al*., 1997), for which three transects were laid at each station. To facilitate replication of the surveys, the transects were permanently marked at 0m, 5m, 10m, 15m and 20m, using 1m lengths of concrete re-enforcing bar hammered into the reef.

Counts of all fish encountered were carried out for a belt of 50 x 5m along each transect, by 2 observers while coverage of benthic species and abiotic features was determined by line intercept along the first 20m of each transect. Surveys of invertebrates were carried out by determining abundance of species over a belt 20 x 5m wide for each transect.

3 Results

3.1 Benthos

Live hard coral cover on the reef slope was >50% at Grand Bassin and Rivière Banane, 42% at Passe Demi and Ile aux Fous, 28% at North Ile aux Sables and 11% at Passe Armand (Figure 2). The sites at Passe Armand and North of Ile aux Sables were dominated by coralline algae (>50%) with a high percentage of the soft coral *Sinularia* sp. at North Ile aux Sables (20%). All sites had a low percentage of recently dead coral (<5%), however there was a high percentage of rubble at Passe Armand (20%). The percentage cover of the red macro-algae *Asparagopsis taxiformis* was high at Grand Bassin (18%) and Ile aux Fous (20%). Cluster analysis groups Passe Demi and Ile aux Fous together at 82% similarity, Rivière Banane and Grand Bassin together at 76% and Passe Armand and Ile aux Sables together at 74% (Figure 3).

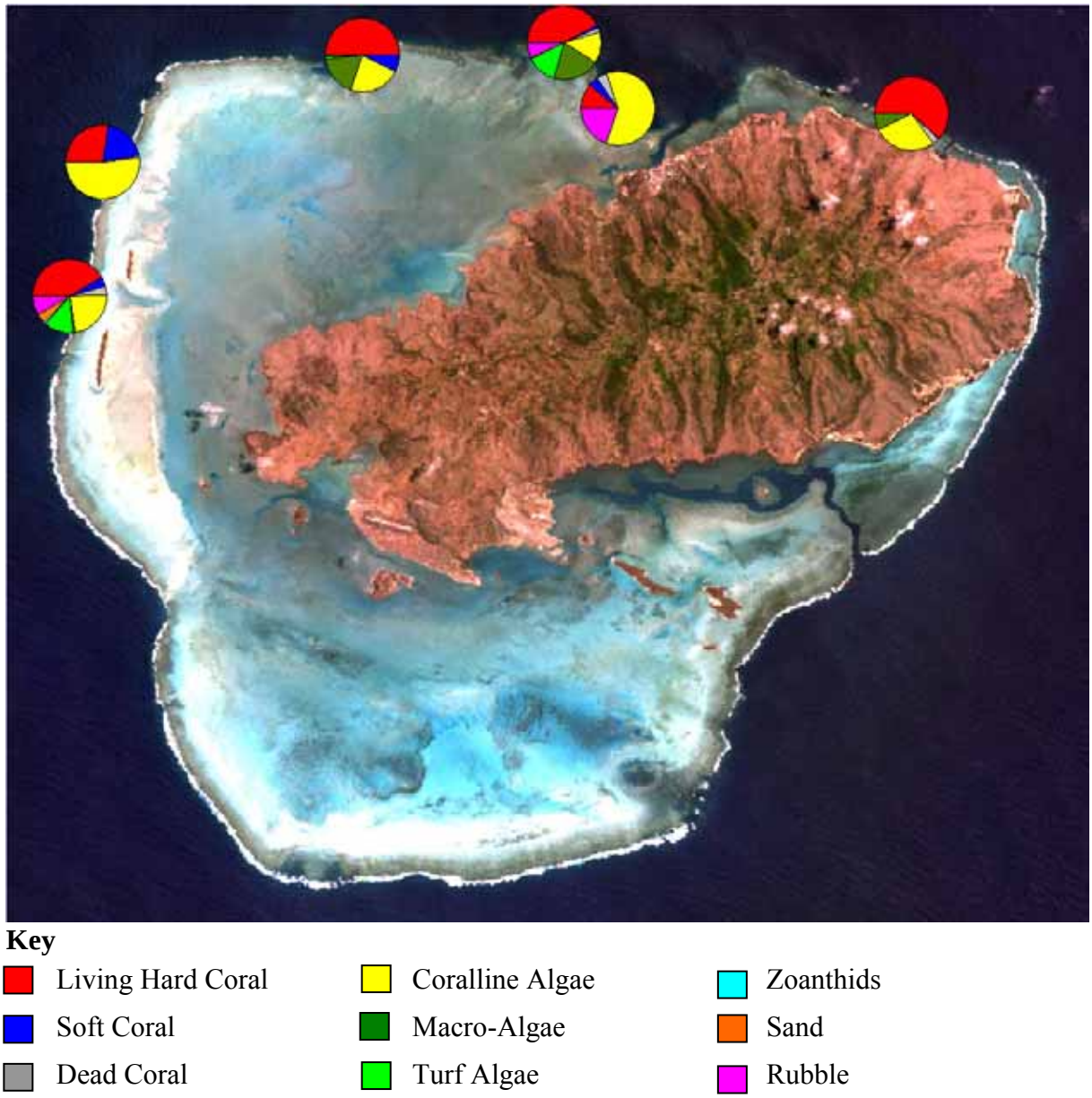

Figure 2. The percentage cover of the different benthic habitats at the 6 reef slope sites.

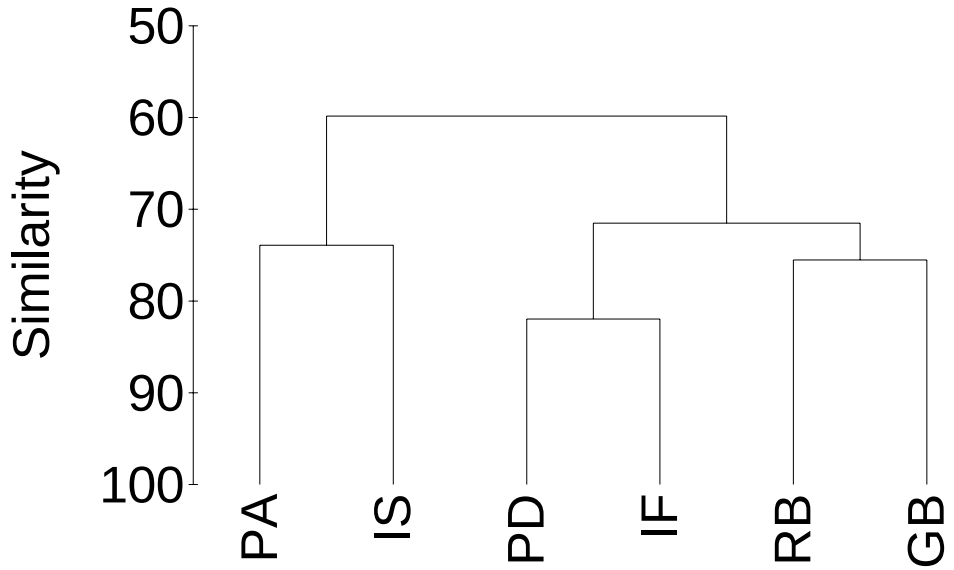

Figure 3. Cluster analysis (√-transformed) of the benthic cover at the 6 reef slope sites (GB = Grand Bassin, IF = Ile aux Fous, IS = North Ile aux Sables, PA = Passe Armand, PD = Passe Demi, RB = Rivière Banane).

The coral cover on all reef slope sites was dominated by branching and tabular *Acropora* spp., in particular *A. austera* and *A. abrotanoides* (Figure 4). *A. nobilis* and *A. cytherea* were also common at Rivière Banane, Passe Armand, Grand Bassin and Ile aux Fous and *A. seriata* was common at Passe Demi. Branching and tabular corals made up 51% of the coral cover at Passe Armand and encrusting corals (*Montipora* spp.) and the massive corals, *Favites* spp. and *Platygyra daedalea* were also common (21% and 27% respectively). At Grand Bassin and Rivière Banane, the corals were dominated by branching and tabular *Acropora* spp (85% and 82% respectively) with other growth forms forming only a low percentage cover. Coral cover at Passe Demi was dominated by branching and tabular *Acropora* spp (57%), however the massive corals, *P. daedalea*, *Favites* spp., *Symphyllia recta* and *Lobophyllia corymbosa* were also common (33%). At Ile aux Fous, branching and tabular *Acropora* spp. also constituted 57% of coral cover and the massive corals *P. daedalea*, *Leptoria phrygia, L. corymbosa* and *S. recta* were also common (36%). Similarly, at North Ile aux Sables branching and tabular *Acropora* spp. made-up 59% of coral cover with the massive corals, *L. phrygia, P. daedalea* and *Favites* spp and the sub-massive coral *Pavona duerdeni* also being common (24% and 16% cover respectively).

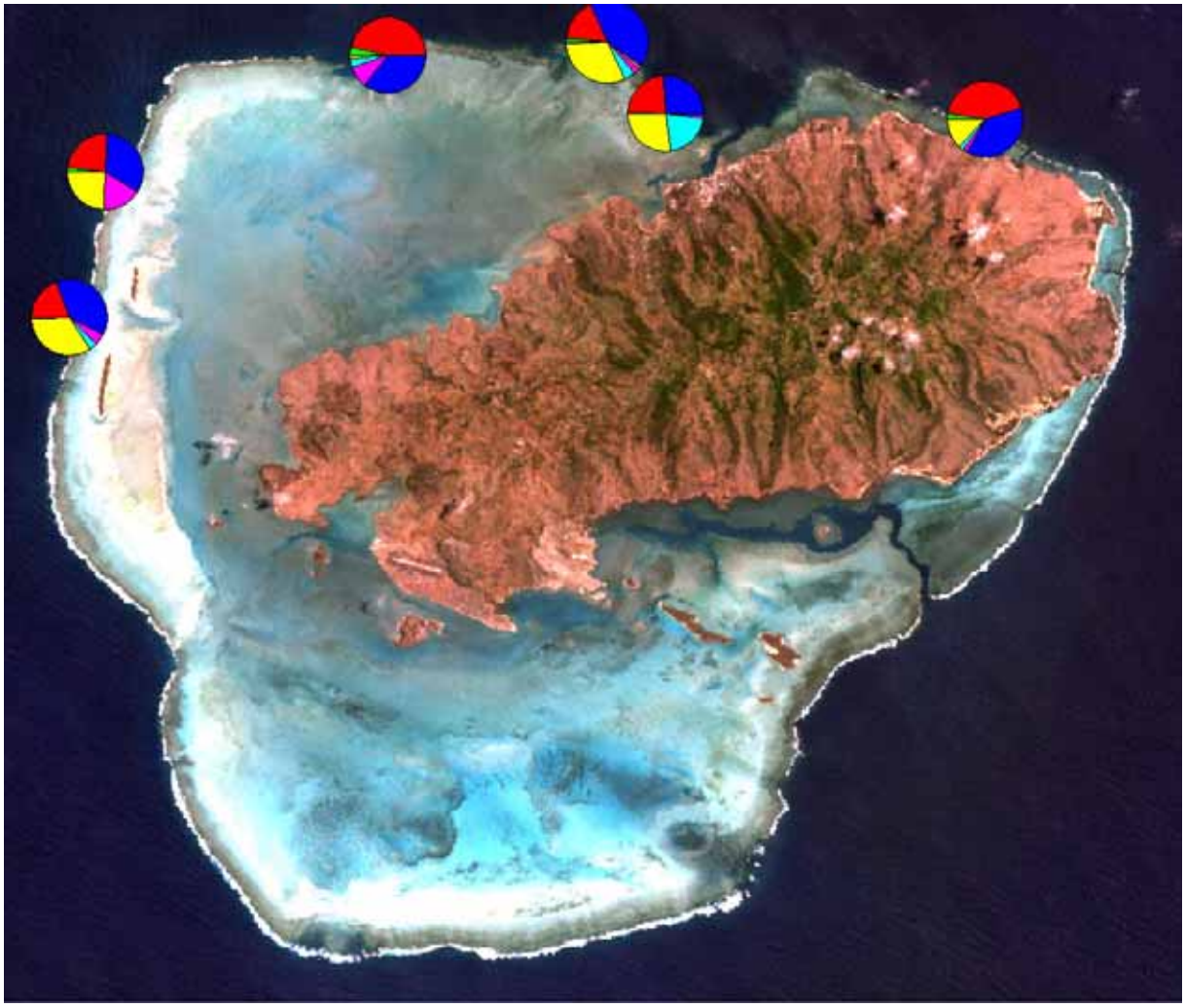

Figure 4. The proportion of coral cover consisting of each of the 9 growth form categories.

On the reef flat, coral cover was 9-11% at Rivière Banane, Passe Armand, Grand Bassin, Trou Blanc and Passe Cabris, 16% at Ile aux Fous and 25% at Passe L'Ancre (Figure 5). The sites at Rivière Banane, Grand Bassin and Passe Cabris were dominated by coralline algae (≥79%) and the site at Trou Blanc was dominated by the soft coral *Xenia* spp. (49%). Dead coral was high (32-38%) at Passe Armand, Trou Blanc and Ile aux Fous and rubble was high (30%) at Passe L'Ancre. Cluster analysis groups Passe Armand and Ile aux Fous together at 86% similarity and Rivière Banane, Grand Bassin and Passe Cabris together at 82% similarity; the southern sites, Passe L'Ancre and Trou Blanc are more distinct (Figure 6).

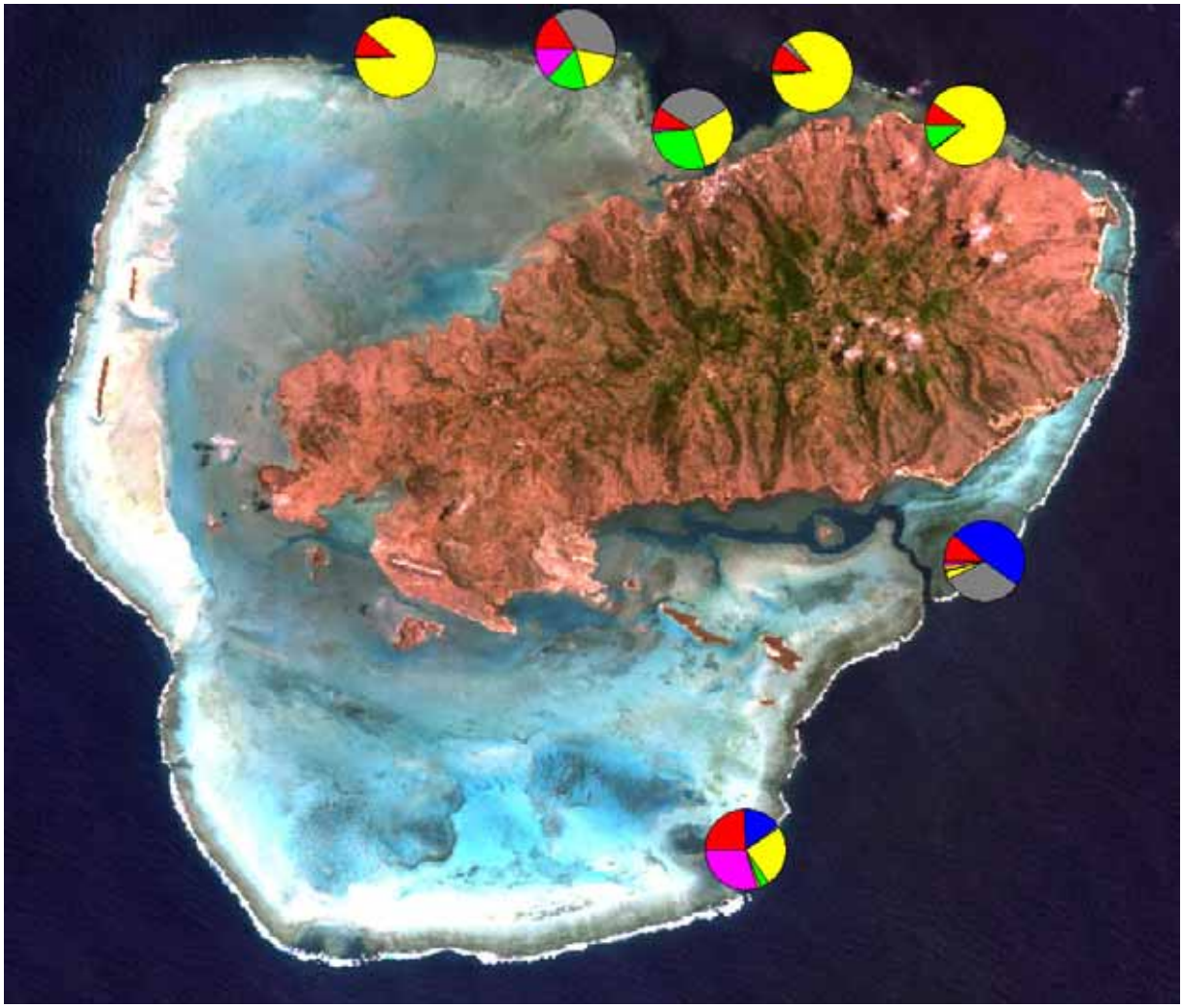

Figure 5. The percentage cover of the different benthic habitats at the 7 reef flat sites.

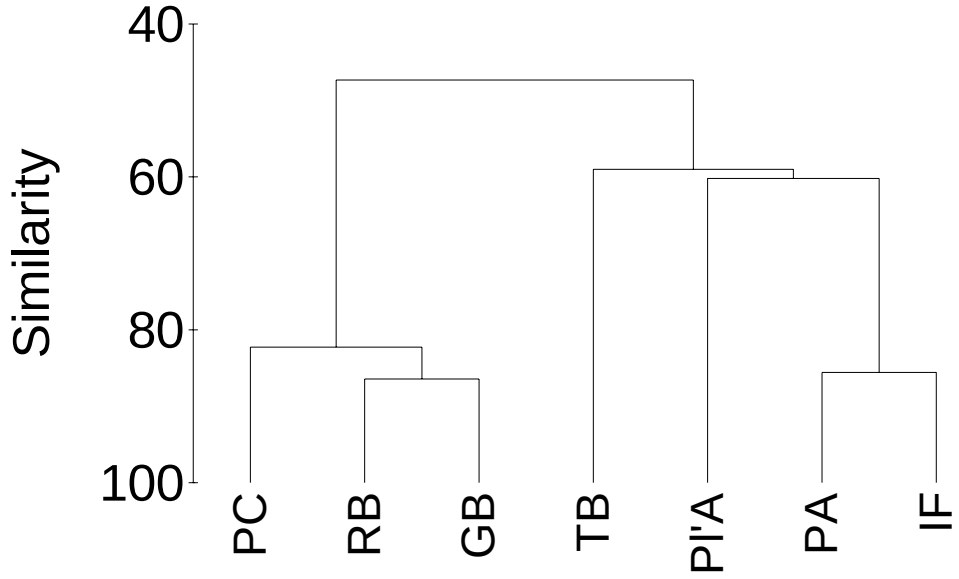

Figure 6. Cluster analysis (√-transformed) of the benthic cover at the 7 reef flat sites (GB = Grand Bassin, IF = Ile aux Fous, PA = Passe Armand, PC = Passe Cabris, Pl'A = Passe L'Ancre, RB = Rivière Banane, TB = Trou Blanc).

The dominant coral growth forms were more variable on the reef flats than on the reef slope with sub-massive and encrusting growth forms more common (Figure 7). At Passe Armand branching, digitate and tabular *Acropora* spp. (*Acropora digitifera, A. muricata* and *A. cytherea*) constituted 43% of the coral cover, with the sub-massive corals *Porites rus* and *Pocillopora* spp. making up 20% and massive corals (*Platygyra daedalea* and *Leptoria phrygia*) and encrusting corals (*Pavona varians* and *Montipora* spp.) also common (16% cover each). At Trou Blanc, branching and tabular *Acropora* spp. (*A. muricata* and *A. cytherea*) were dominant (67%), however the sub-massive coral, *Montipora digitata* was also common (27%). Branching and digitate *Acropora* spp. (*A. digitifera* and *A. nobilis*) dominated the coral cover at Grand Bassin (66%); branching and tabular *Acropora* spp. (*A. muricata* and *A. cytherea*) dominated at Pass L'Ancre (86%) and at Rivière Banane the coral consisted of 72% *Acropora* spp (*A. digitifera, A. abrotanoides, A. cytherea* and *A. nobilis*). At Ile aux Fous, the coral consisted of 99% non-*Acropora* species and was dominated by the sub-massive corals (*Porites rus* and *Pocillopora* spp.), with encrusting corals (*Montipora* spp. and *Cyphastrea* sp.) and mushroom corals (*Fungia* spp.) also common (17% each). The sub-massive corals, *P. rus* and *Pocillopora* spp. also dominated at Passe Cabris (60%) with branching *Acropora* (*A. austera*) making-up only 25% of the coral cover.

Figure 7. The proportion of coral cover consisting of each of the 9 growth form categories.

3.2 Fish

On the reef slopes, the highest number of individuals was recorded at Rivière Banane (mean of 181 individuals) and the lowest number at North Ile aux Sables (38 individuals) (Table 2). The highest number of species were observed at Grand Bassin and Ile aux Fous (24 species) and the highest numbers of families at Grand Bassin and Passe Armand (9 families). The lowest numbers of species and families were recorded at North Ile aux Sables (12 species and 6 families). Species Diversity calculated using the Shannon-Weiner Diversity Index was highest at Passe Armand (H' = 2.593) and lowest at Rivière Banane (H' = 0.997). Pielou's Index of Evenness was highest at North Ile aux Sables (J = 0.868) and lowest at Rivière Banana (J = 0.339). Based on fish genera, Cluster Analysis groups Passe Armand, Ile aux Fous and Grand Bassin together at 68% similarity and Passe Demi, North Ile aux Sables and Rivière Banane together at 61% similarity (Figure 8).

Table 2. The mean number of individuals, species, genera and families and species diversity indices for the fish communities at each of the 6 reef slope sites.

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	Ile aux Sables
No. Individuals	181	62	86	85	60	38
No. Species	19	23	24	23	24	12
No. Genera	15	14	14	17	13	11
No. Families	8	9	9	9	8	6
H’	0.997	2.593	2.160	2.362	2.338	2.157
J’	0.339	0.839	0.680	0.753	0.736	0.868

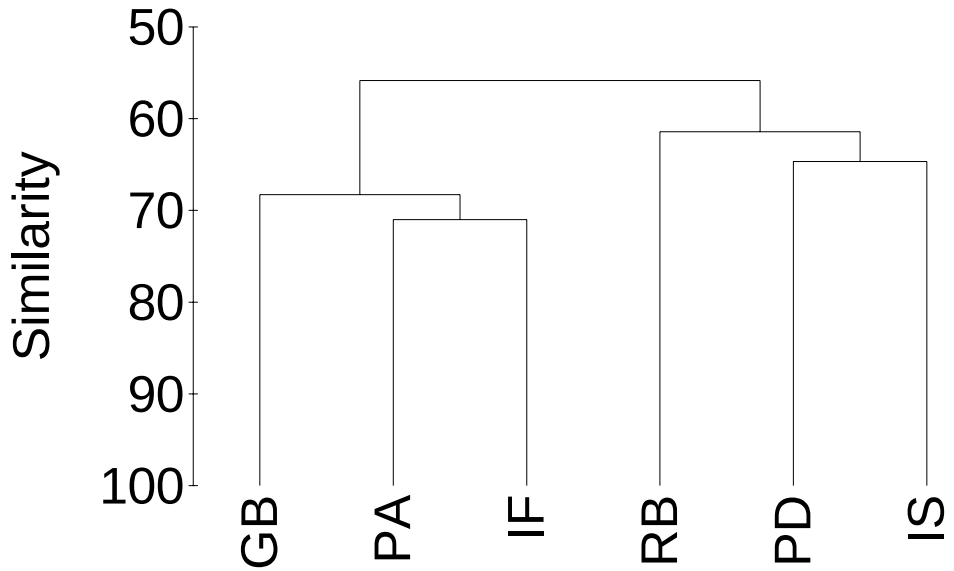

Figure 8. Cluster analysis (√-transformed) of the fish genera observed at the 6 reef slope sites (GB = Grand Bassin, IF = Ile aux Fous, IS = North Ile aux Sables, PA = Passe Armand, PD = Passe Demi, RB = Rivière Banane).

Damselfish (Pomacentridae) dominated the reef slopes at all sites except for Grand Bassin and were particularly abundant at Rivière Banane (mean of 164 individuals) (Figure 9); Pomacentridae were dominated by *Chromis* spp. at Rivière Banane and North Ile aux Sables, *Pomacentrus* spp. at Passe Armand and Grand Bassin and *Plectroglyphidodon* spp. at Grand Bassin and Ile aux Fous. The fish community at Grand Bassin was dominated by Parrotfish (Scaridae) with a mean of 48 individuals. Surgeonfish (Acanthuridae) were also common at Passe Armand, Grand Bassin and Ile aux Fous and the Fusilier, *Pterocaesio tile* was common at Passe Demi (mean of 17 individuals). The mean number of Butterflyfish (Chaetodontidae) ranged from a mean of 1 to 5 individuals. Emperors (Lethrinidae) were rare or absent and were only represented by 1 species (*Gnathodentex aurolineatus*); similarly, Groupers (Serranidae) were also rare or absent and were only represented by 2 species (*Cephalopholis*

argus at Passe Demi only and *Epinephelus spilotoceps* at the remaining sites). No Triggerfish (Balistidae), Trevally (Carangidae) or Snapper (Lutjanidae) were recorded at any site.

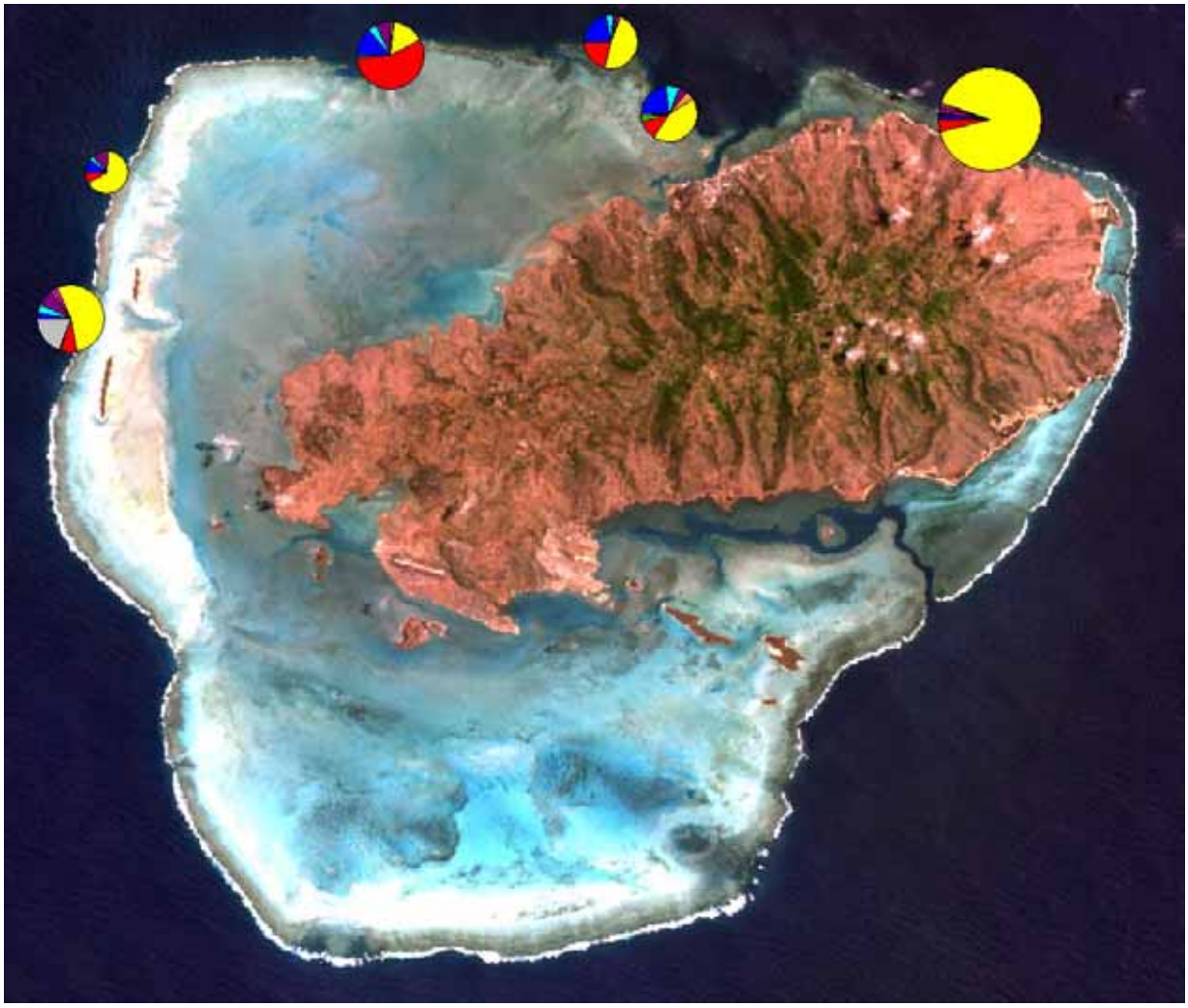

Figure 9. The distribution of fish families at the 6 reef slope survey sites.

On the reef flat, the highest number of individuals was recorded at Ile aux Fous (mean of 368 individuals), followed by Passe Armand (mean of 324 individuals) and the lowest number at Rivière Banane (mean of 53 individuals) (Table 3). The highest number of species were observed at Passe Armand (28 species) and the highest numbers of both genera and families at Trou Blanc (18 genera and 10 families). The lowest number of species and genera were recorded at Rivière Banane (14 species and 11 genera) and the lowest numbers of families at Passe L'Ancre (6). Species Diversity calculated using the Shannon-Weiner Diversity Index

was highest at Grand Bassin (H' = 2.077) and lowest at Passe L'Ancre (H' = 1.475). Pielou's Index of Evenness was highest at Grand Bassin (J = 0.749) and lowest at Passe L'Ancre (J = 0.501). Based on fish genera, Cluster Analysis groups Trou Blanc, Ile aux Fous and Passe L'Ancre together at 54% similarity, Passe Armand and Passe Cabris together at 58% similarity and Rivière Banane and Grand Bassin together at 51% similarity. (Figure 10).

Table 3. The mean number of individuals, species, genera and families and species diversity indices for the fish communities at each of the 7 reef flat sites.

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
No. Individuals	53	334	75	310	232	126	368
No. Species	14	28	16	26	19	20	24
No. Genera	11	17	13	18	14	12	15
No. Families	7	7	8	10	6	9	8
H'	1.760	1.874	2.077	1.863	1.475	1.990	1.797
J'	0.667	0.562	0.749	0.572	0.501	0.664	0.566

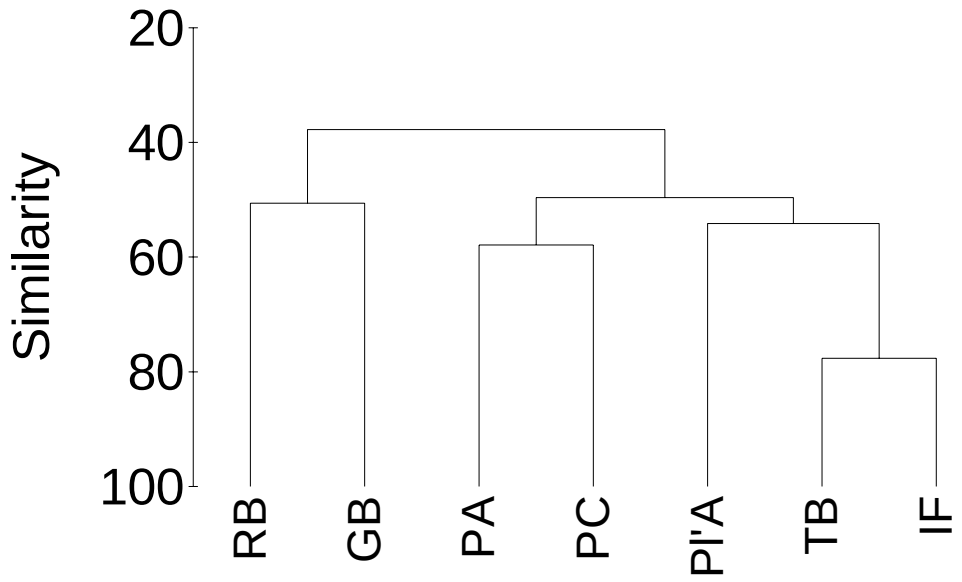

Figure 10. Cluster analysis (√-transformed) of the fish genera observed at the 7 reef flat sites (GB = Grand Bassin, IF = Ile aux Fous, PA = Passe Armand, PC = Passe Cabris, Pl'A = Passe L'Ancre, RB = Rivière Banane, TB = Trou Blanc).

Damselfish (Pomacentridae) dominated the reef flat sites at Passe Armand, Trou Blanc, Passe Cabris and Ile aux Fous (Figure 11). Pomacentridae were dominated by *Chromis viridis* at Passe Armand, *Dascyllus aruanus* at Trou Blanc and Pass L'Ancre, *Stegastes limbatus* at Passe Cabris and *Stegastes nigricans* at Ile aux Fous. The fish communities at Grand Bassin and Passe L'Ancre were dominated by Parrotfish (*Scarus sordidus* and small immature parrotfish). Rivière Banane was dominated by Wrasse (particularly *Thalassoma genivittatum*)

and Wrasse were also common at Grand Bassin. Small and Medium Surgeonfish (Acanthuridae) were common at Passe Armand and Passe Cabris. Emperors (Lethrinidae) were only present at 2 sites, Trou Blanc and Ile aux Fous, and were only represented by 1 species (*Gnathodentex aurolineatus*) and only 1 Snapper (*Lutjanus fulvus*) was observed at Trou Blanc. Groupers were only represented by 2 species (*Cephalopholis argus* at Ile aux Fous only and *Epinephelus spilotoceps* at the remaining sites). No Triggerfish (Balistidae), Trevally (Carangidae) or Fusiliers (Caesionidae) were recorded at any site.

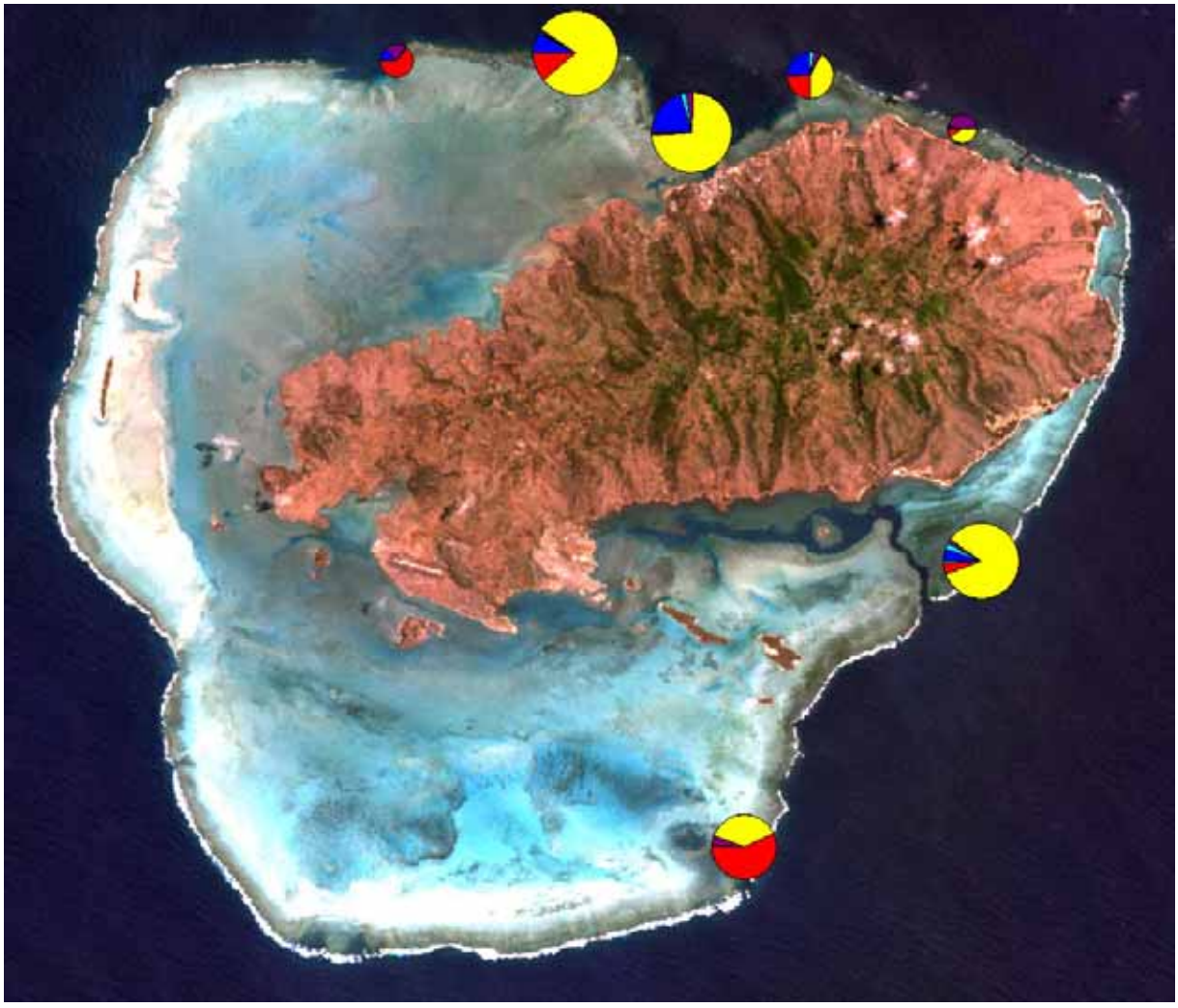

Figure 11. The distribution of fish families at the 7 reef flat survey sites.

3.3 Invertebrates

The abundance of invertebrates tended to be low on the reef slopes and a total of only 16 species were recorded during all 6 surveys. Invertebrates were particularly low at Grand Bassin and only 5 individuals from 5 species were observed (Table 4); invertebrates were also low at Passe Demi where only 8 individuals from 5 species were recorded. The highest number of individuals and species were recorded at North Ile aux Sables (mean of 700 individuals and 8 species). Species Diversity calculated using the Shannon-Weiner Diversity Index was highest at Grand Bassin (H' = 0.942) and lowest at North Ile aux Sables (H' = 0.039). Pielou's Index of Evenness was also highest at Grand Bassin (J = 1.516) and lowest at North Ile aux Sables (J = 0.082). Cluster Analysis suggests that invertebrate communities at the 6 sites are fairly distinct, grouping Passe Armand, Ile aux Fous and North Ile aux Sables together at just 44% and Rivière Banane, Grand Bassin and Passe Demi together at 35% (Figure 12).

Table 4. The mean number of individuals and species and species diversity indices for the invertebrate communities at each of the 6 reef slope sites.

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	Ile aux Sables
No. Individuals	22	141	5	8	68	700
No. Species	8	5	5	5	6	8
H'	0.503	0.373	0.942	0.784	0.217	0.039
J'	1.047	0.599	1.516	1.261	0.389	0.082

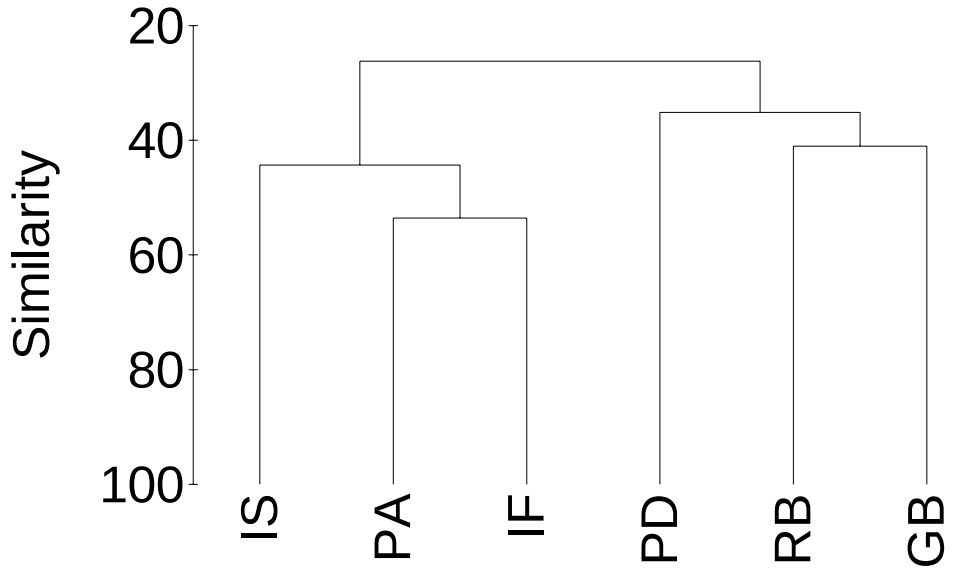

Figure 12. Cluster analysis (√-transformed) of the invertebrate species observed at the 6 reef slope sites (GB = Grand Bassin, IF = Ile aux Fous, PA = Passe Armand, PC = Passe Cabris, Pl'A = Passe L'Ancre, RB = Rivière Banane, TB = Trou Blanc).

All sites except for Grand Bassin were dominated by Sea Urchins (Echinoidea), especially *Echinometra mathaei*, which was particularly abundant at North Ile aux Sables, where a mean of 691 individuals were recorded (Figure 13). The Sea Cucumber (Holothuroidea) *Stichopus chloronatus* was relatively abundant at Passe Armand (mean of 22 individuals), however no holothurians were recorded at any other sites. Gastropods were completely absent from Passe Armand and were found in low numbers at other sites and the Bivalve, *Tridacna maxima* was only observed at Ile aux Fous (1 individual) and Passe Armand (2 individuals). Crustaceans were only represented by hermit crabs (*Dardanus* sp.) which were observed at Rivière Banane, Grand Bassin and North Ile aux Sables.

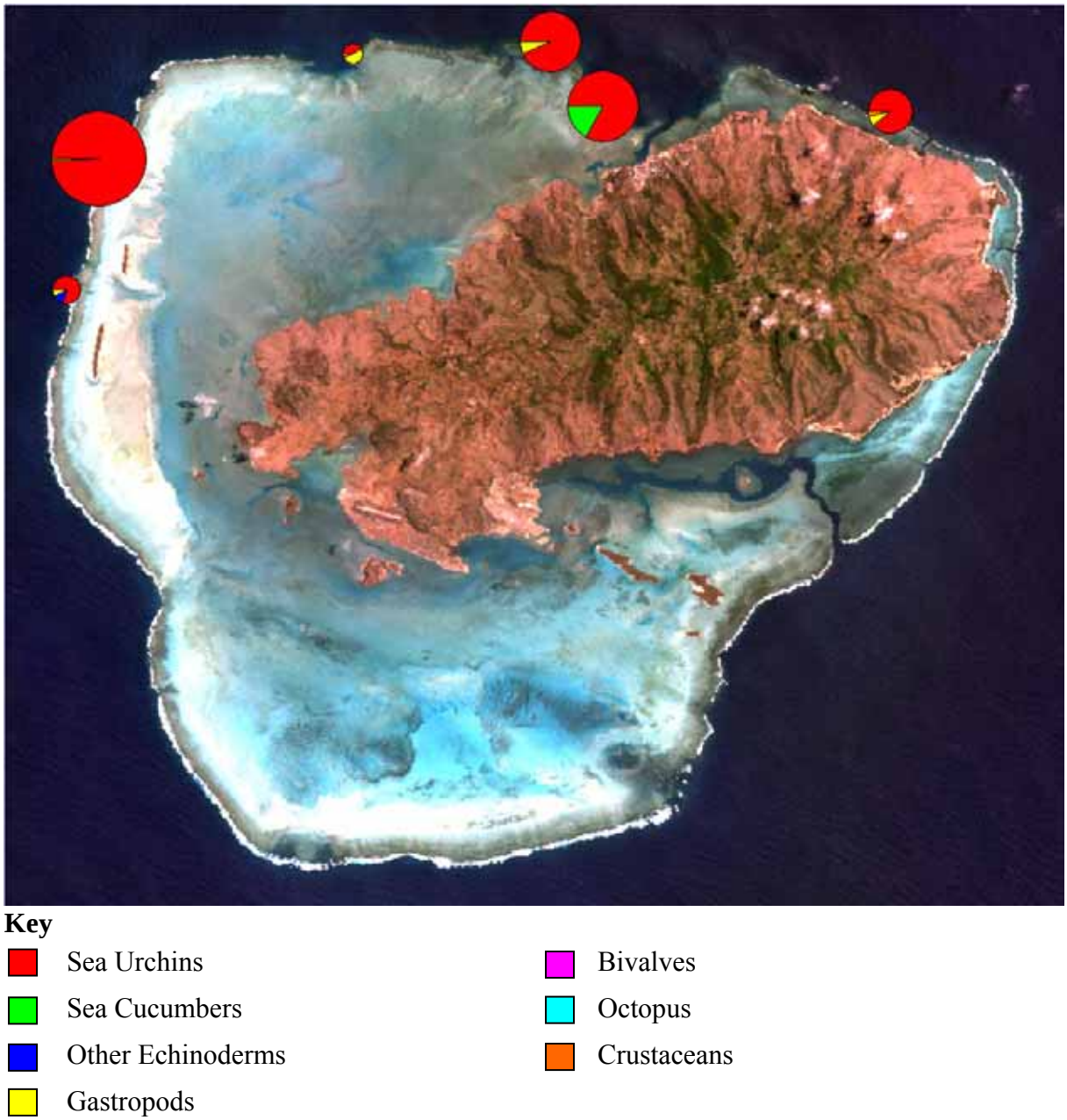

Figure 13. The distribution of invertebrates at the 6 reef slope survey sites.

Twenty two invertebrate species were recorded on the 7 reef flat sites. The highest number of individuals and species was recorded at Passe Armand (mean of 433 individuals and 10 species) (Table 5). Invertebrates were very low at Passe L'Ancre where only 6 individuals from 5 species were observed; invertebrates were also low at Ile aux Fous where a mean of 18 individuals from just 2 species were recorded. Species Diversity calculated using the Shannon-Weiner Diversity Index was highest at Passe L'Ancre (H' = 1.396) and lowest at Trou Blanc (H' = 0.079). Pielou's Index of Evenness was also highest at Passe L'Ancre (J = 0.867) and lowest at Trou Blanc (J = 0.038). Cluster Analysis groups Rivière Banane, Passe Armand and Trou Blanc together at 68% and Grand Bassin and Passe Cabris together at 73%; the invertebrate communities at Ile aux Fous and Passe L'Ancre are very distinct (Figure 14).

Table 5. The mean number of individuals and species and species diversity indices for the invertebrate communities at each of the 7 reef flat sites.

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
No. Individuals	272	433	122	260	6	153	18
No. Species	9	10	10	8	5	8	2
H'	0.302	0.261	0.633	0.079	1.396	0.669	0.217
J'	0.137	0.113	0.275	0.038	0.867	0.322	0.313

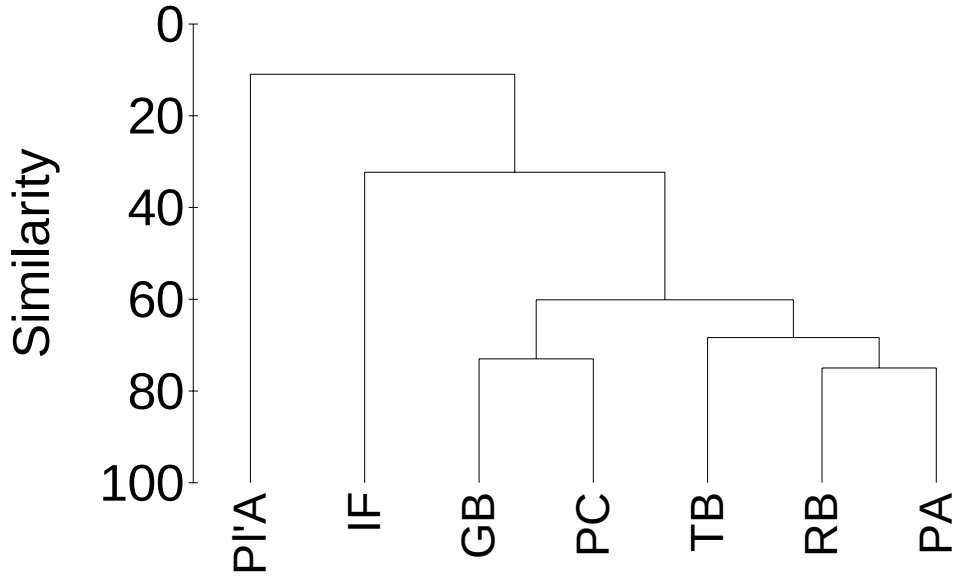

Figure 14. Cluster analysis (√-transformed) of the fish genera observed at the 7 reef flat sites (GB = Grand Bassin, IF = Ile aux Fous, PA = Passe Armand, PC = Passe Cabris, Pl'A = Passe L'Ancre, RB = Rivière Banane, TB = Trou Blanc).

All sites except for Passe L'Ancre were dominated by Sea Urchins (Echinoidea), especially *Echinometra mathaei*, which was particularly abundant at Passe Armand, Trou Blanc and

Rivière Banane (mean of 413, 257 and 257 individuals respectively) (Figure 15). The gastropod, *Trochus maculatus* was relatively abundant at Passe Cabris (mean of 18 individuals), however molluscs were rare at other sites and completely absent from Ile aux Fous. The Bivalve, *Tridacna maxima* was only observed at Passe Armand (2 individuals) and Trou Blanc (3 individuals) and only 1 *Octopus cyanea* was observed at Trou Blanc. Crustaceans were only represented by hermit crabs (*Dardanus* sp.) which were observed at Trou Blanc only.

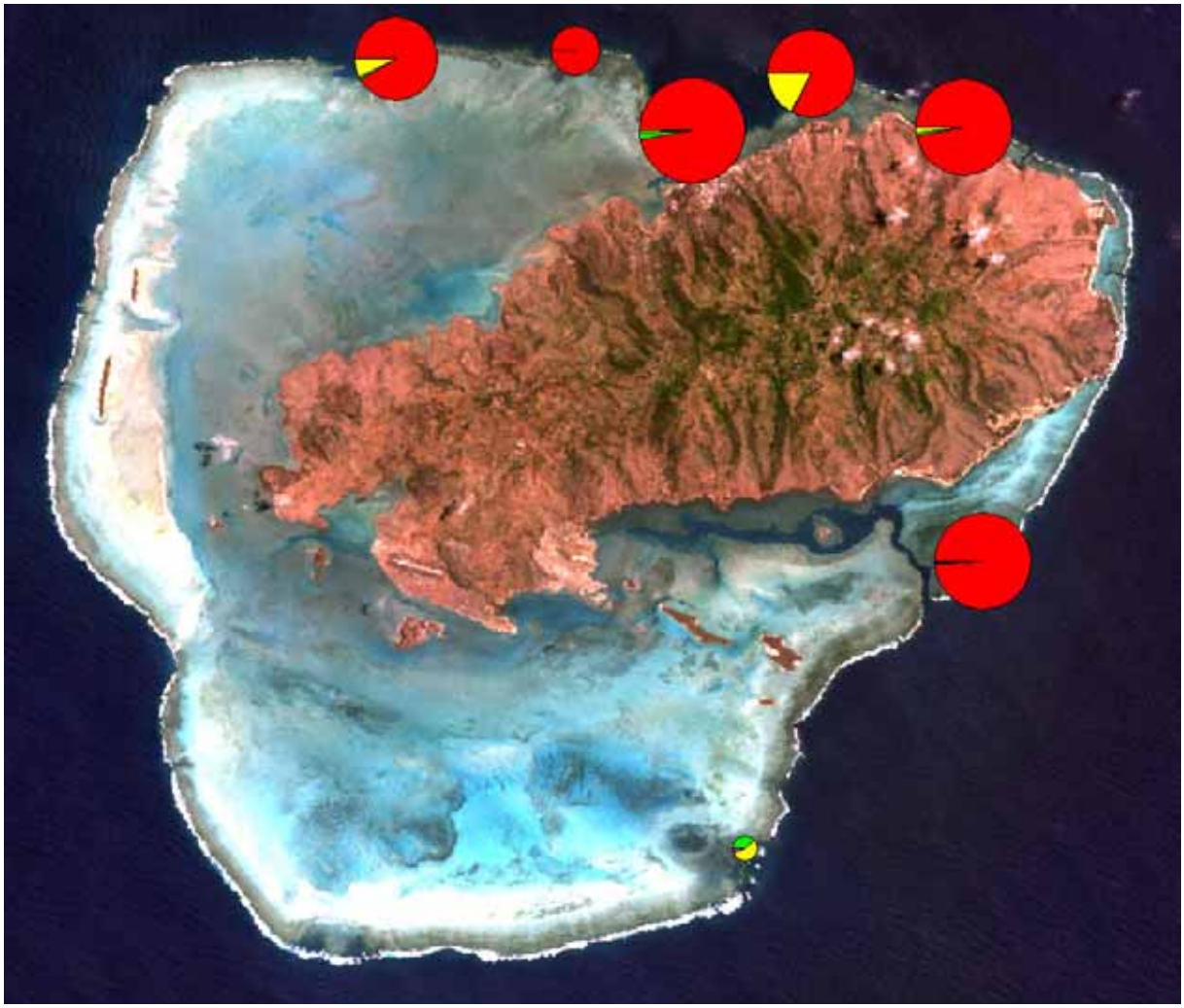

Figure 15. The distribution of invertebrates at the 7 reef flat survey sites.

3.4 Comparison between 2003 and 2004

3.41 Benthos

Multi-dimensional scaling (MDS) indicates that at the 3 reef slope sites where comparisons can be made, the benthic composition at Passe Armand in 2003 and 2004 is different from that at Grand Bassin and Rivière Banane, however at the latter sites there was little change in benthic composition between 2002 and 2004 (Figure 16). Benthic composition in October 2004 at Rivière Banane and Grand Bassin was more distinct due to a high percentage cover of macro-algae at this time (40% and 36% respectively); benthic composition at Rivière Banane and Grand Bassin during October 2005 and Grand Bassin during March 2002 were also distinct due to fairly high macro-algae (7%, 18% and 9% respectively) and coralline algae (28%, 22% and 14% respectively). The benthos at Passe Armand during October 2005 was very distinct from all other sites due to a high percentage cover of rubble (20%) and a very high percentage cover of coralline algae (60%).

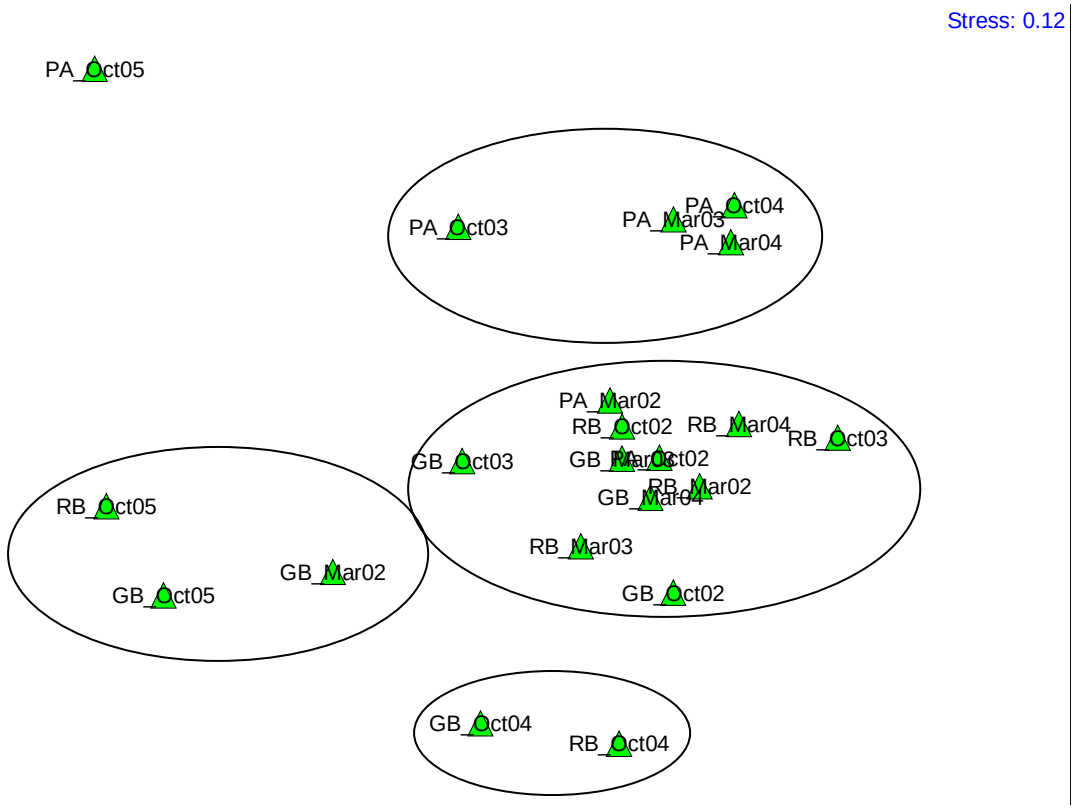

Figure 16. Multi-dimensional scaling plot of benthic composition at the 3 reef slope sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand).

Considering hard coral only, there has been no change in the percentage cover at Rivière Banane, with coral cover remaining fairly high, with a mean of 46.1 ± 4.4% (1-way ANOVA, $F = 2.62$, $df = 6$, $p>0.05$) (Figure 17). Similarly, at Grand Bassin coral cover has remained high with a mean of 54.0 ± 3.1% (1-way ANOVA, $F = 1.67$, $df = 6$, $p>0.05$). At Passe Armand however, there was a significant decline in coral cover between October 2002 and March 2003 from >40% to ≤25% and coral cover remained low in the following years (1-way ANOVA, $F = 5.42$, $df = 6$, $p<0.05$).

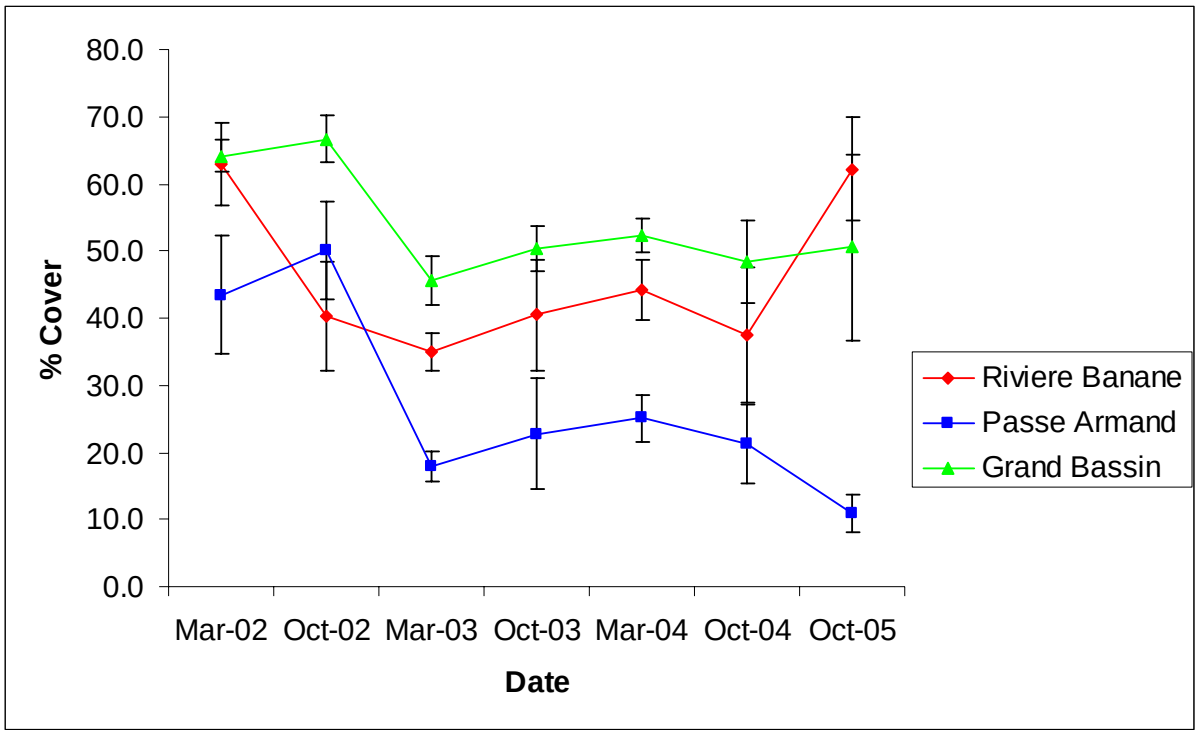

Figure 17. The percentage cover (± SE) of hard coral at 3 reef slope sites between March 2002 and October 2005.

Multi-dimensional scaling shows that at the 4 reef flat sites where comparisons over time can be made there is little difference in the benthic composition at Rivière Banane, Passe Armand and Grand Bassin between March 2002 and October 2004 (Figure 18). Benthic composition at Trou Blanc is however more distinct, due to the high cover of soft coral; there is also a difference in benthic composition over time at this site due to changes in the amount of bare rock recorded. Benthic composition at Grand Bassin in March 2002 and October 2005, Passe Armand in October 2003 and Rivière Banane in October 2005 is also distinct due to a high percentage cover of coralline algae at these sites (26%, 88%, 50% and 79% respectively).

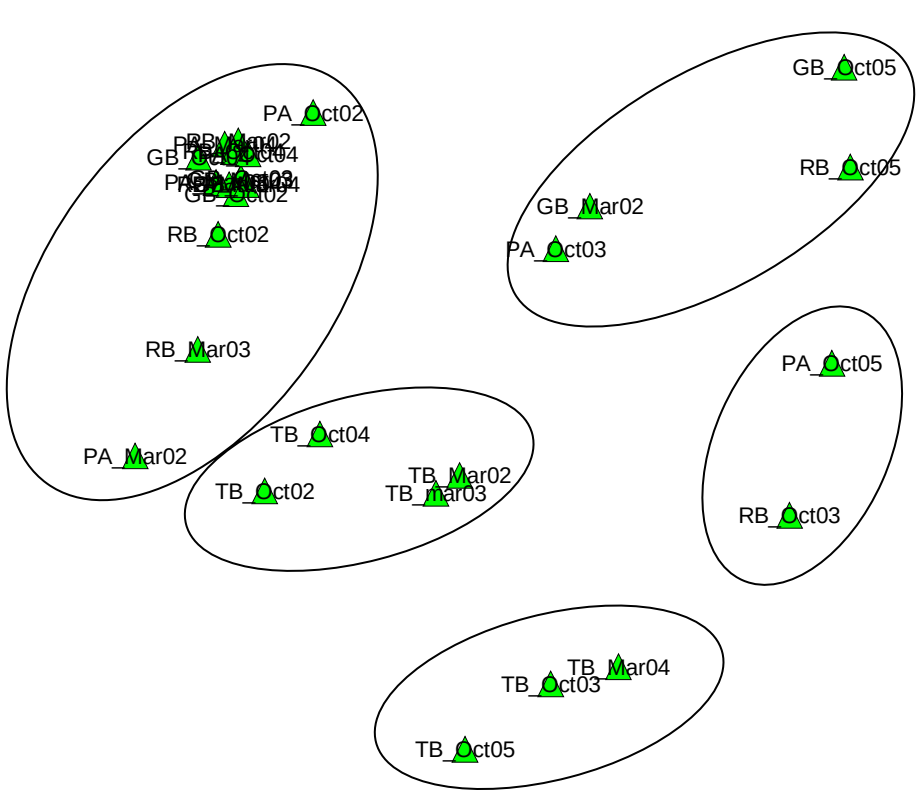

Figure 18. Multi-dimensional scaling plot of benthic composition at the 4 reef flat sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand, TB = Trou Blanc).

Hard coral cover is low on the reef flat sites, however has remained stable between March 2002 and October 2005 at Rivière Banane (mean: 11% cover, 1-way ANOVA, $F = 0.97$, $df = 6$, $p>0.05$), Grand Bassin (mean: 16% cover, 1-way ANOVA, $F = 2.41$, $df = 6$, $p>0.05$) and Trou Blanc (mean: 13% cover, 1-way ANOVA, $F = 2.94$, $df = 6$, $p>0.05$) (Figure 19). The very high coral cover recorded at Passe Armand in October 2002 is likely to be due to a change in transect position and if this data point is removed there has also been no change in coral cover at this site (mean: 13% cover, 1-way ANOVA, $F = 1.91$, $df = 5$, $p>0.05$).

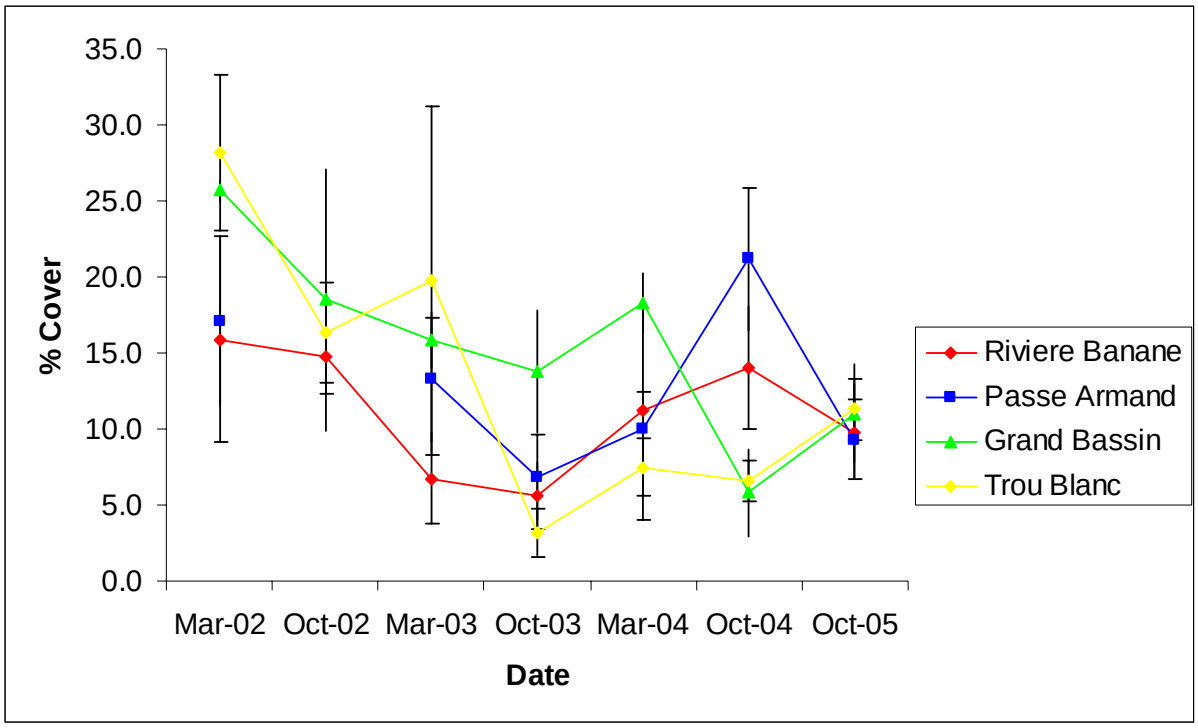

Figure 19. The percentage cover (±SE) of hard coral at 3 reef slope sites between March 2002 and October 2005.

3.42 Fish

Multi-dimensional scaling (MDS) shows that on the reef slope sites there has been little change in fish community composition over time, with communities at Rivière Banane grouping together and those from Grand Bassin and Passe Armand grouping together (Figure 20). Communities at all 3 sites during March 2003 were distinct due to high numbers of the Fusilier, *Pterocaesio tile*, particularly at Passe Armand (mean of 767 individuals).

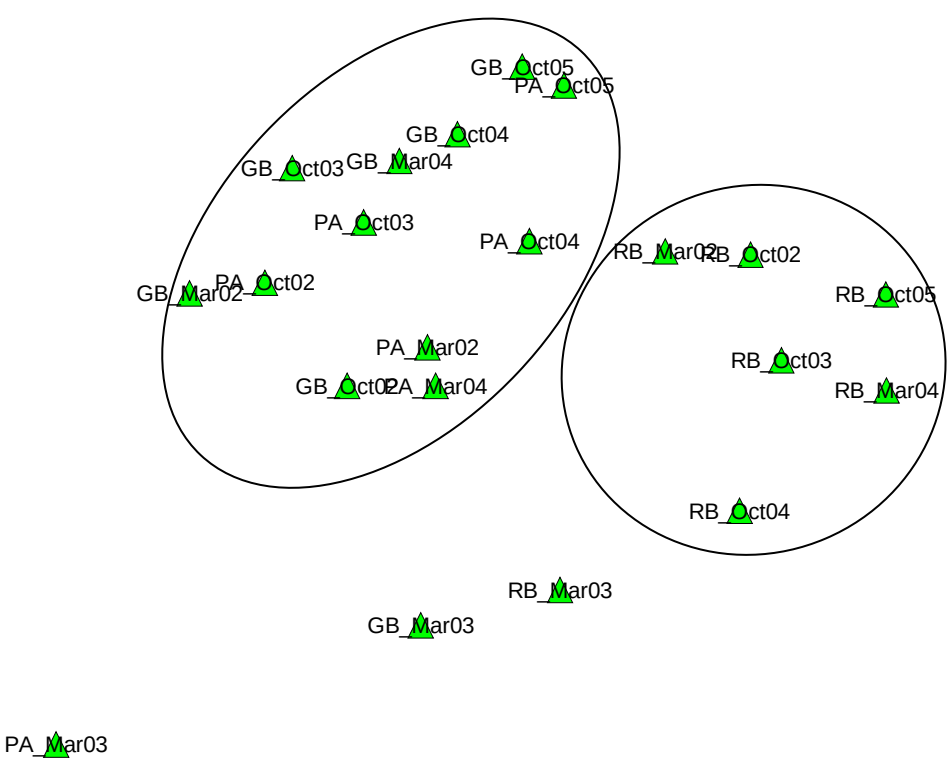

Figure 20. Multi-dimensional scaling plot of fish community composition at the 3 reef slope sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand).

Considering the 5 most commonly occurring families of fish, there was a significant decline in the abundance of Damselfish on the reef slope at Grand Bassin after March 2003 (1-way ANOVA √-transformation, $F = 6.59$, $df = 6$, $p<0.05$) and at Passe Armand after March 2002 (1-way ANOVA, $F = 7.83$, $df = 6$, $p<0.05$) (Figure 21). There was no obvious pattern in Damselfish abundance at Rivière Banane with numbers remaining high (mean of >70 individuals) throughout the surveys. Similarly, there was no change in the numbers of Surgeonfish on the reef slope at Rivière Banane, with numbers remaining low over time (mean of ≤ 12 individuals). At Passe Armand however, there was a general decline in Surgeonfish numbers with a significantly greater abundance in March and October 2002 than in October 2005 (Kruskall-Wallis, $H = 13.82$, $df = 6$, $p<0.05$). There was also a general decline in numbers at Grand Bassin after March 2002 (1-way ANOVA √-transformation, $F = 9.28$, $df = 6$, $p<0.001$). The numbers of Butterflyfish remained low on the reef slope at Rivière Banane between March 2002 and October 2005 (mean of ≤ 7 individuals). There was however a significant decline in the number of Butterflyfish on the reef slopes at both Passe Armand and Grand Bassin after October 2002 (1-way ANOVA, Passe Armand: $F = 7.60$, $df = 6$, $p = 0.001$; Grand Bassin, $F = 8.04$, $df = 6$, $p = 0.001$). There was a similar pattern in abundance of Wrasse at all 3 sites with an increase in numbers between March 2002 and October 2002 and then a decrease in the following months (1-way ANOVA, Rivière Banane: $F = 8.48$, $df = 6$, $p= 0.001$; Grand Bassin: $F = 2.92$, $df = 6$, $p<0.05$; Kruskall-Wallis, Passe Armand: $H = 17.45$, $df = 6$, $p<0.05$). There was no obvious temporal pattern in the abundance of Parrotfish at any of the 3 sites.

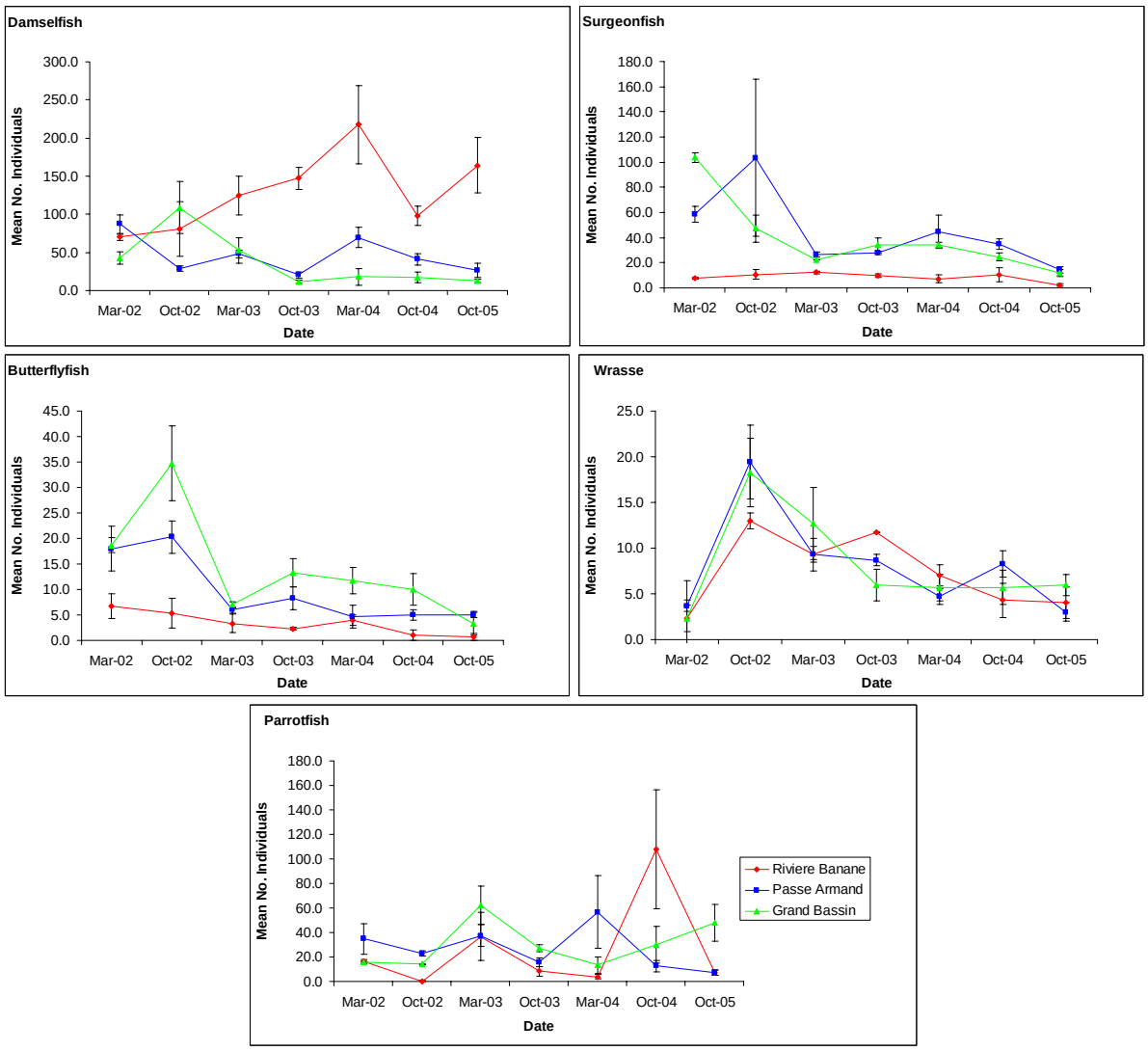

Figure 21. The change in abundance of Damselfish, Surgeonfish, Butterflyfish, Wrasse and Parrotfish (±SE) at Rivière Banane, Passe Armand and Grand Bassin between March 2002 and October 2005.

Multi-dimensional scaling (MDS) shows that on the reef flat sites there has been little change in fish community composition over time, with communities at Rivière Banane, Passe Armand and Grand Bassin grouping together and those from Trou Blanc being more distinct (Figure 22). Communities at Passe Armand, Rivière Banane and Grand Bassin were separate in March 2002 due to low numbers of Wrasse; Passe Armand in October 2005 groups more closely with Trou Blanc due to very high numbers of Damselfish in this year (mean of 242 individuals).

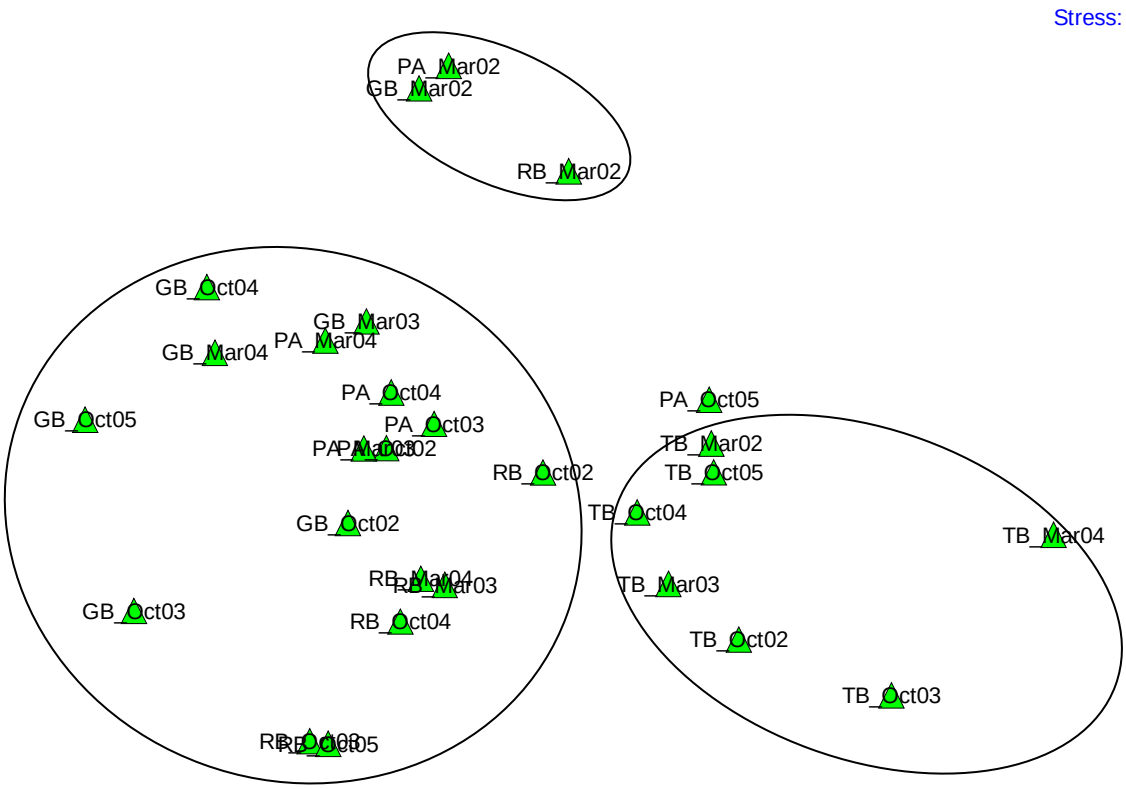

Figure 22. Multi-dimensional scaling plot of fish community composition at the 4 reef flat sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand, TB = Trou Blanc).

Considering the 5 most commonly occurring fish families, there was no change in the abundance of Damselfish on the reef flat at Passe Armand over time and Rivière Banane and Trou Blanc showed no obvious temporal patterns in Damselfish abundance (Figure 23). At Grand Bassin, there was however, a significant decline in the abundance of Damselfish after March 2003 when numbers fell from a mean of 35 individuals to just 1 individual in October 2005 (Kruskall-Wallis, $H = 17.04$, $df = 6$, $p<0.05$). There was no change in the abundance of Surgeonfish at Rivière Banane. At Passe Armand numbers were significantly higher in March 2002 and October 2005 than in the remaining months and at Trou Blanc numbers were significantly lower in October 2003 and March 2004, when they fell to 0 individuals (1-way ANOVA, $F = 6.40$, $df = 6$, $p<0.05$). At Grand Bassin, there was a decline in the number of Surgeonfish with a significantly lower abundance in October 2005 compared to March 2002 (Kruskall-Wallis, $H = 16.91$, $df = 6$, $p<0.05$). There was no change in the numbers of Butterflyfish over time at Rivière Banane, Passe Armand or Grand Bassin with numbers remaining low (mean of <9 individuals). At Trou Blanc, there was a significant decline in numbers between March 2002 and October 2003 from a mean of 15 individuals to 0 (Kruskall-Wallis, $H = 18.18$, $df = 6$, $p<0.05$), however numbers then started to increase again, to a mean of 8 individuals in October 2005. There was a similar pattern in the abundance of Wrasse at Rivière Banane, Passe Armand and Grand Bassin with significantly lower numbers in March 2002, followed by an increase in the subsequent months (1-way ANOVA, Rivière Banane: $F = 5.27$, $df = 6$, $p<0.05$; Passe Armand: $F = 8.75$, $df = 6$, $p = 0.000$; Grand Bassin: $F = 49.52$, $df = 6$, $p = 0.000$). At Trou Blanc, there were significantly lower numbers of Wrasse in March 2003-March 2004 compared to the remaining months (1-way ANOVA, $F = 16.47$, $df = 6$, $p = 0.000$). There was no change in the abundance of Parrotfish at any site over time.

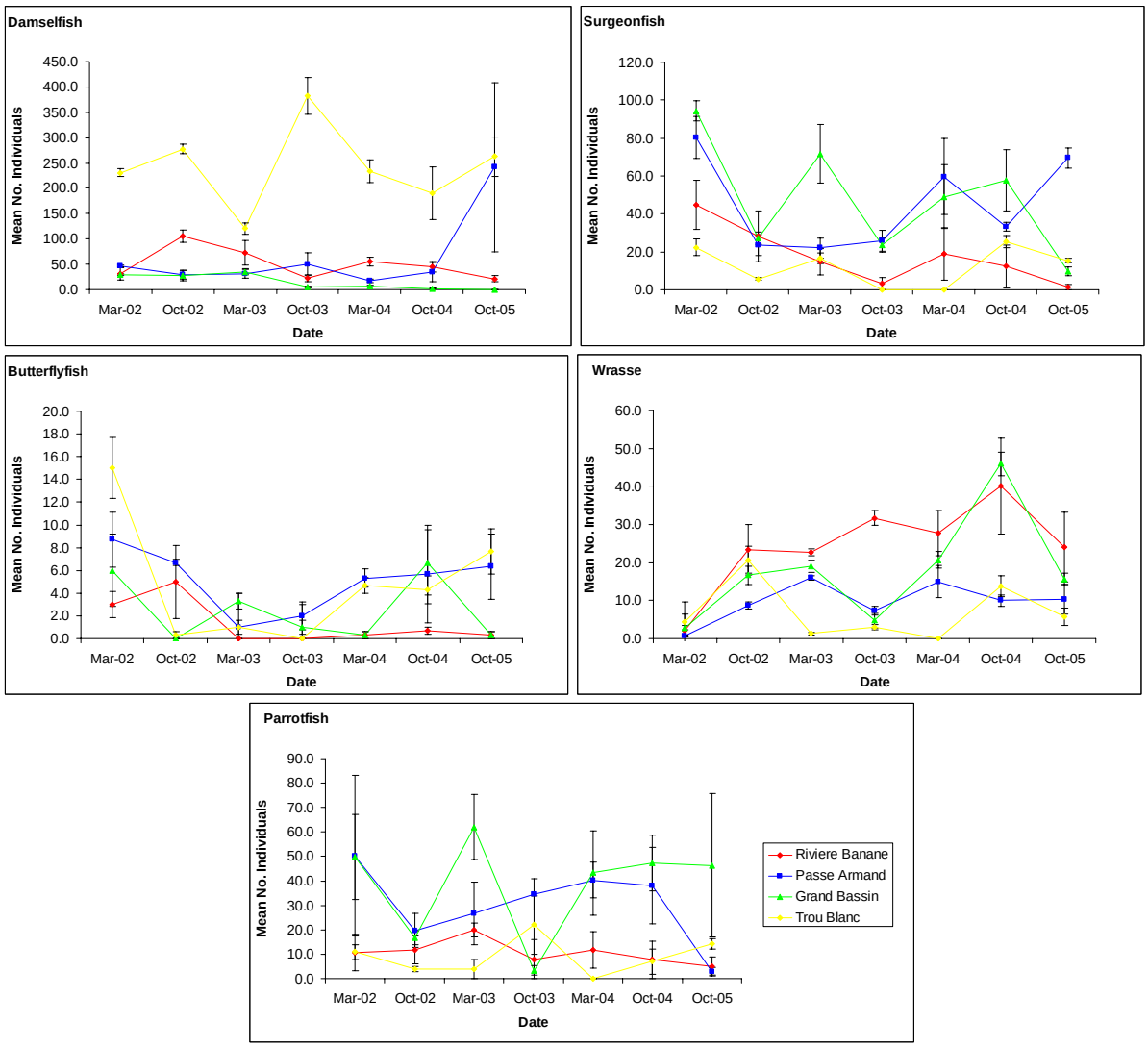

Figure 23. The change in abundance of Damselfish, Surgeonfish, Butterflyfish, Wrasse and Parrotfish (±SE) at Rivière Banane, Passe Armand, Grand Bassin and Trou Blanc between March 2002 and October 2005.

3.43 Invertebrates

Multi-dimensional scaling (MDS) shows that on the reef slope sites there have been little change in invertebrate community composition over time at Passe Armand and Rivière Banane (Figure 24). At Grand Bassin, however, there is a separation between the communities present in March 2002, October 2002 and October 2004 and those present in March 2003, 2004 and October 2005 due to no *Diadema* sp. being present in the latter surveys. The community present during October 2003 groups more closely with the community at Rivière Banane due to high numbers of *Echinometra mathaei* being present at that time (mean of 39 individuals).

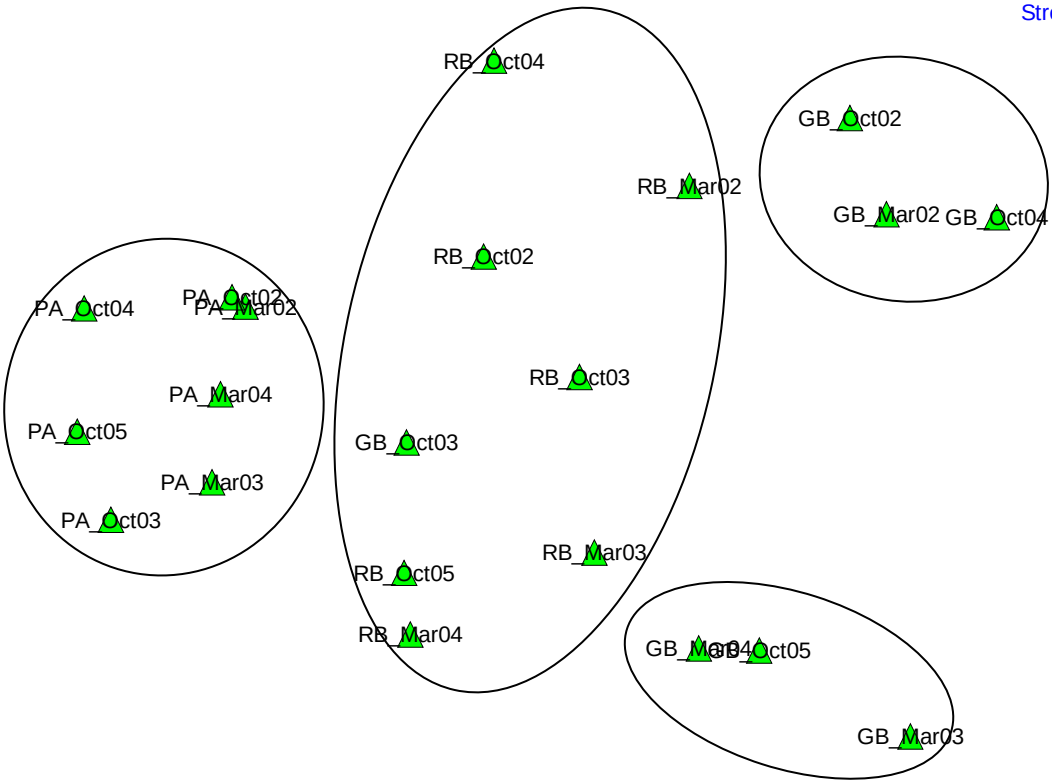

Figure 24. Multi-dimensional scaling plot of invertebrate community composition at the 3 reef slope sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand).

On the reef slope there has been a significant increase in *Echinometra mathaei* at Rivière Banane between March 2002 and October 2005, however the numbers still remain low (mean of 15 individuals) (Kruskall-Wallis, H = 13.94, df = 6, $p<0.05$) (Figure 25). At both Passe Armand and Grand Bassin there were significantly more *E. mathaei* in October 2003 than in the remaining months (Passe Armand: 1-way ANOVA, F = 13.65, df = 6, p = 0.000; Grand Bassin: Kruskall-Wallis, H = 15.19, df = 6, $p<0.05$); this was particularly true at Passe Armand where the numbers increased to a mean of 236 individuals.

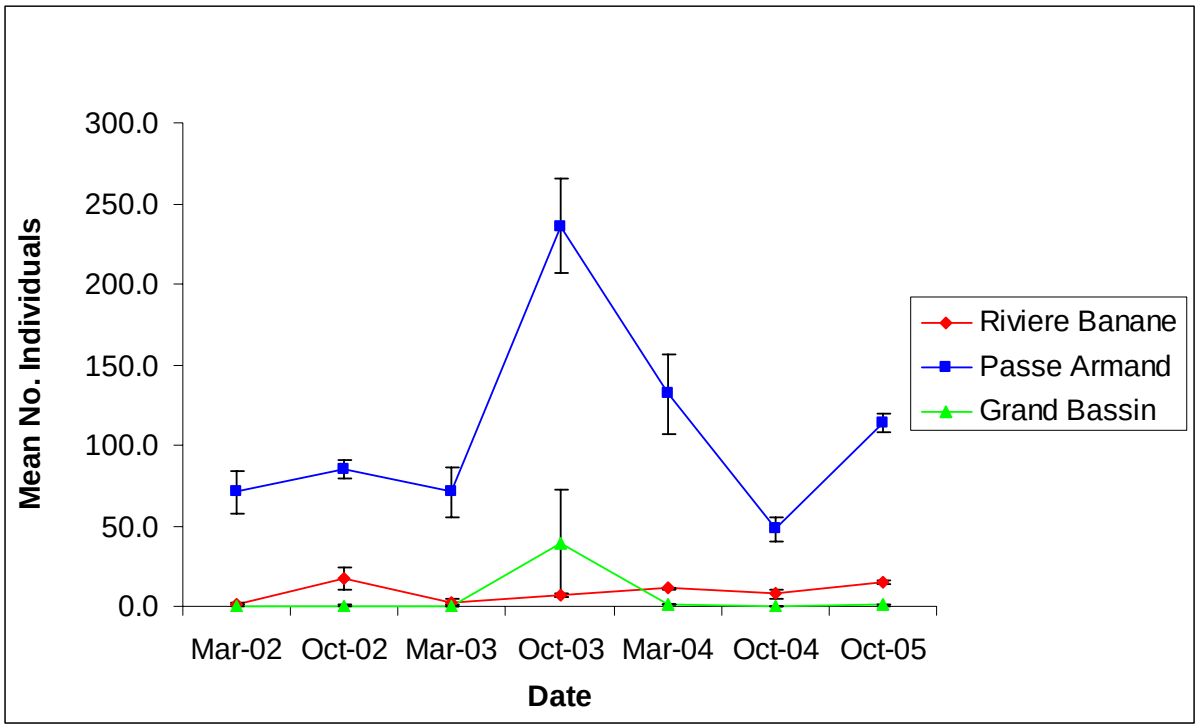

Figure 25. The change in abundance of *Echinometra mathaei* (±SE) at Rivière Banane, Passe Armand and Grand Bassin between March 2002 and October 2005.

On the reef flat, Multi-dimensional scaling shows that there are no obvious temporal or spatial patterns in invertebrate community composition (Figure 26). The communities at Passe Armand in October 2002 and October 2003 are more distinct due to high numbers of *Diadema* sp. in October 2002 (mean of 51 individuals) and very high numbers of *Stichopus chloronatus* in October 2003 (mean of 273 individuals).

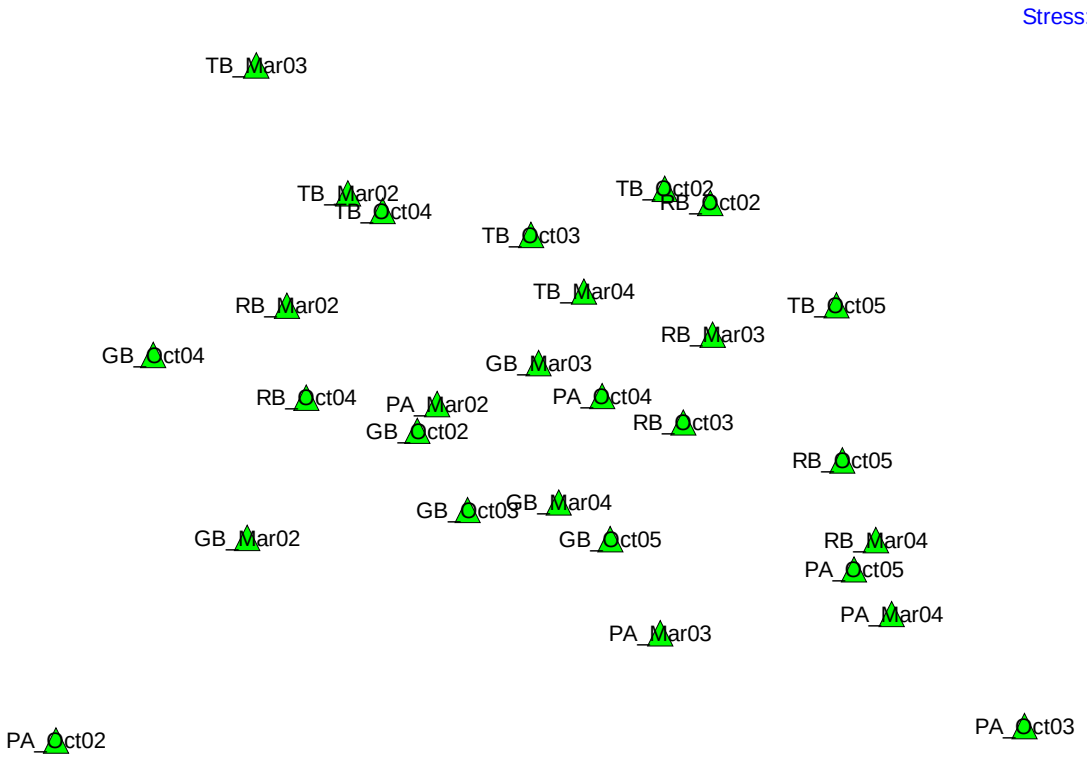

Figure 26. Multi-dimensional scaling plot of invertebrate community composition at the 4 reef flat sites between March 2002 and October 2005 (RB = Rivière Banane, GB = Grand Bassin, PA = Passe Armand, TB = Trou Blanc).

On the reef flat, there was no change in the abundance of *Echinometra mathaei* over time at Grand Bassin, however at Trou Blanc there was a significant increase in numbers between March 2002 and October 2005 (Kruskall-Wallis, H = 14.46, df = 6, $p<0.05$) (Figure 27). There was a similar pattern in the abundance of *E. mathaei* at Rivière Banane and Passe Armand with higher numbers in March 2004 and October 2005 at Rivière Banane and in October 2003, March 2004 and October 2005 at Passe Armand (1-way ANOVA, Rivière Banane: F = 5.92, df = 6, $p<0.05$; Passe Armand, F = 9.28, df = 6, p = 0.000).

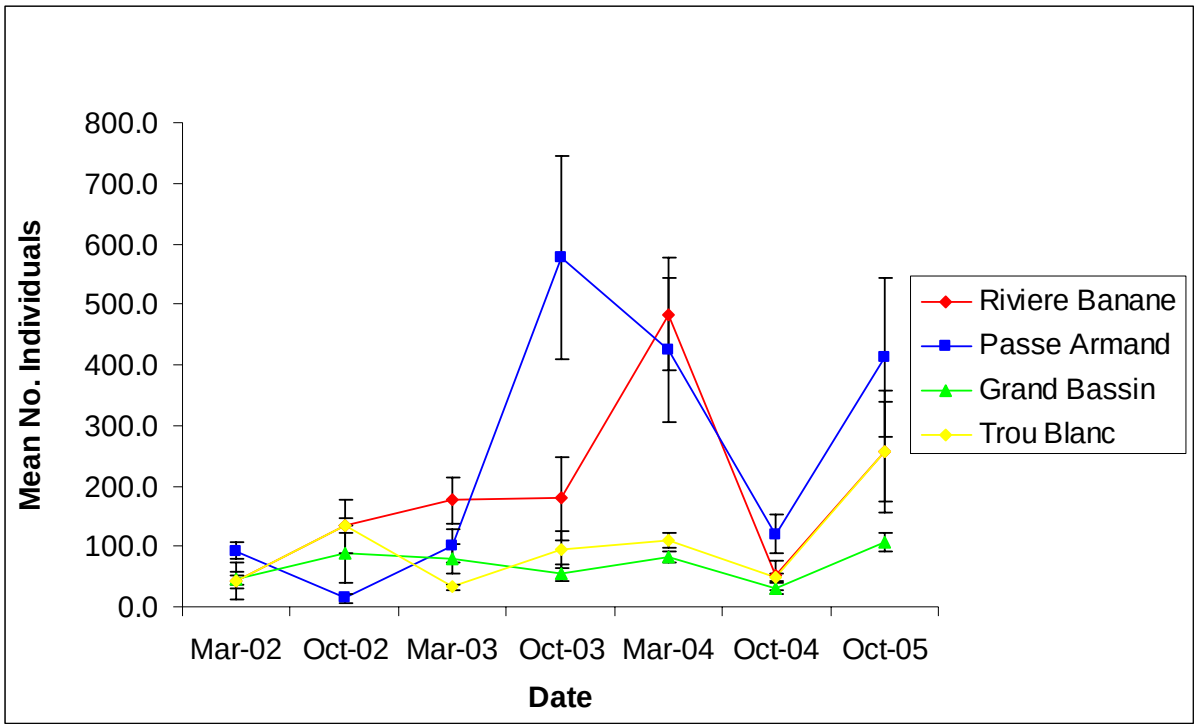

Figure 27. The change in abundance of *Echinometra mathaei* (±SE) at Rivière Banane, Passe Armand, Grand Bassin and Trou Blanc between March 2002 and October 2005.

4 Discussion

Hard coral cover was high on the reef slope at Rivière Banane, Grand Bassin, Passe Demi and Ile aux Fous (>40%), but was low at North Ile aux Sables and Passe Armand, which were dominated by coralline algae. There was however low dead coral cover at all sites, suggesting that the sites are generally healthy. The coral cover was dominated by branching and tabular *Acropora* spp., in particular *A. austera* and *A. abrotanoides*. In contrast, coral cover was low on the reef flat sites (<25%) and dead coral cover was high at Passe Armand, Trou Blanc and Ile aux Fous with a high percentage cover of rubble at Passe L'Ancre, suggesting that these sites being subjected to human and natural impacts. Coral bleaching affected corals during 2002 (Hardman *et al*., 2004) and a further bleaching event occurred in March 2005 resulting in bleaching of 90% of *A. austera* colonies at Passe Armand and Ile aux Fous (Hardman *et al*., 2005). The sites are also likely to be impacted by trampling and boat damage from octopus and seine net fishers. Despite these impacts, live coral cover has remained stable at the reef flat sites between March 2002 and October 2005.

Coral cover on the reef slopes at Rivière Banane and Grand Bassin has also remained stable since March 2002; there was however a decline in coral cover at Passe Armand between October 2002 and March 2003. The 2003 coral bleaching event only affected corals on the shallow reef flat (Hardman *et al*., 2004) and there was no corresponding increase in dead coral or rubble in 2003, suggesting that this change may be simply due to a change in position of the permanent transects. Similarly, the changes in the percentage cover of coralline algae are likely to be due to variations in the way surveyors recorded the benthic categories. Comparisons between the benthic composition in 2002 – 2005 suggests that there was an increase in macro-algae on the reef slopes at Grand Bassin and Rivière Banane in October 2004 and that macro-algae was also high at Grand Bassin and Ile aux Fous in October 2005.

During 2005, this increase was due to the red algae, *Asparagopsis taxiformis* which has been seen on reefs all around Rodrigues between October and December 2005 from 5m down to 20m depth (*pers. obs*.). At some sites the algae is in very high abundance, shading and competing with small coral colonies for space and light. Reasons for increased macro-algal growth could include an increase in fertiliser run-off from agricultural areas or a decline in herbivorous fish due to overfishing.

On the reef slope all sites except Grand Basin were dominated by Damselfish, with very high numbers being recorded at Rivière Banane; the lowest number of fish was observed at North Ile aux Sables. Damselfish were also dominant at the reef flat sites at Passe Armand, Trou Blanc, Passe Cabris and Ile aux Fous. At all sites, Emperors, Grouper, and Snapper were rare or absent and no Triggerfish or Trevally were observed at any site during the surveys. This lack of large piscivorous predators suggests that the fish population may be unbalanced due to overfishing. There have also been declines in the number of Damselfish, Surgeonfish and Butterflyfish over time on the reef slopes at Passe Armand and Grand Bassin and in Wrasse at Rivière Banane, Passe Armand and Grand Bassin. On the reef flats, there were less obvious temporal trends in fish abundance, however Damselfish and Surgeonfish declined at Grand Bassin. The decline in Wrasse and Surgeonfish may be due to overfishing, however Damselfish and Butterflyfish are not targeted by the fisheries and thus the decline in their numbers may be an indication of changes in the benthos, such as a decline in live coral cover or increase in macro-algae. Surveys carried out at 10 lagoon sites also show a general decline in fish abundance between 2004 and 2005, in particular declines in the numbers of Damselfish, Parrotfish, Surgeonfish and Wrasse (Hardman *et al*., 2006).

Invertebrates were low on the reef slope sites, particularly at Grand Bassin and Passe Demi and all sites, except for Grand Bassin were dominated by the urchin, *Echinometra mathaei*. This species also dominated all of the reef flat sites, except for Passe L'Ancre. There were increases in the abundance of *E. mathaei* on the reef slope at Passe Armand and Grand Bassin in October 2003; on the reef flat, there was an increase in numbers during October 2005 at Rivière Banane, Passe Armand and Trou Blanc as well as in March 2004 at Rivière Banane and Passe Armand. The high number of this species may be as a result of intense fishing pressure and the removal of predator fish species. *E. mathaei* is a bio-eroder and so their high density is cause for concern, especially with possible increase in the incidences of coral bleaching resulting in higher coral mortality. At all sites molluscs and crustaceans were either rare or absent; in particular *Tridacna* clams were in low abundance and large gastropods such as *Pleuroploca trapezium* were not observed. This may be an indication that local consumption is resulting in over-harvesting.

Considering the sites within the proposed marine reserves, it can be seen that the reef slopes are healthy with high coral cover (>40%) and a low percentage cover of dead coral. Fish communities are dominated by Damselfish, with Parrotfish dominant at Grand Bassin; invertebrates tend however to be low at all sites. The reef flat sites within the proposed marine reserves however are more degraded with low coral cover (<11%). The abundance of fish was low at Grand Bassin and Rivière Banane and Damselfish and Surgeonfish had declined over time on both the reef flat and slope at Grand Bassin. The invertebrate community at these 2 sites was dominated by very high numbers of the urchin *Echinometra mathaei*. The number of fish was higher at Passe Cabris and the gastropod *Trochus maculatus* was also abundant. The presence of marine reserves in these areas will protect the healthy reef slopes from future impacts and aim to facilitate recovery of the degraded reef flat areas.

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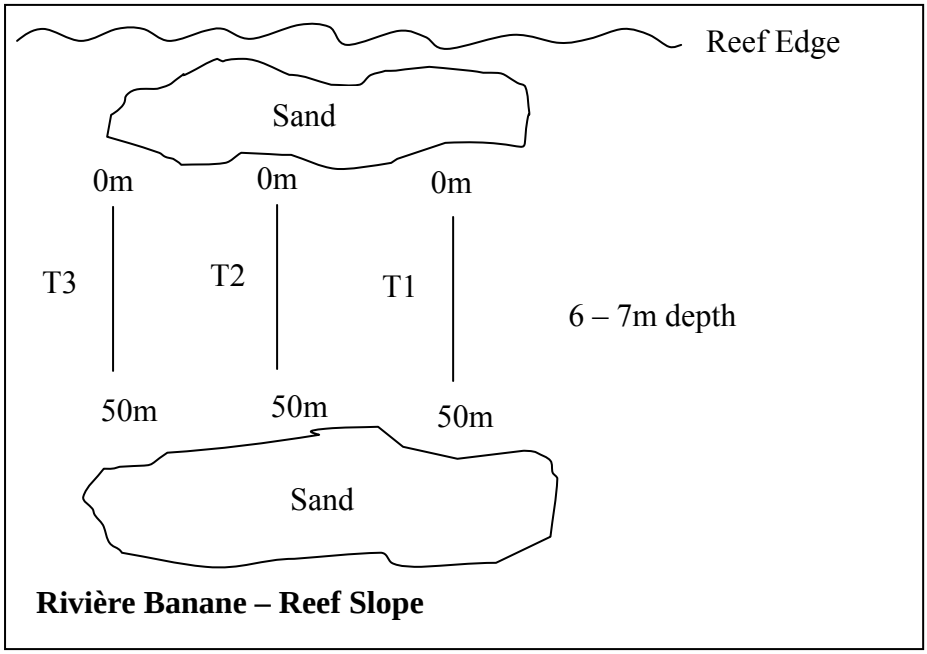
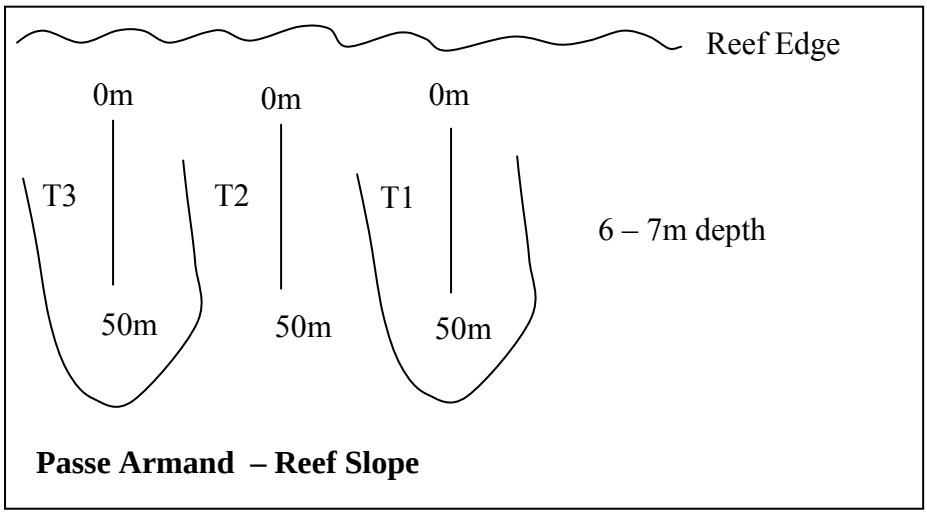
6 Appendices

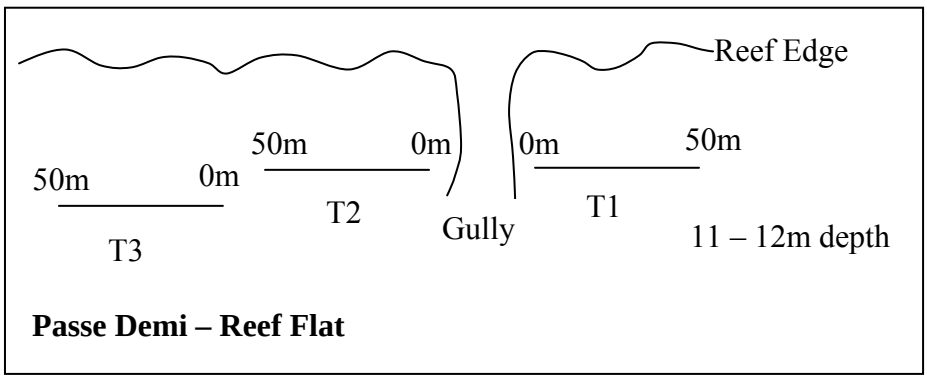
6.1 Transect Locations



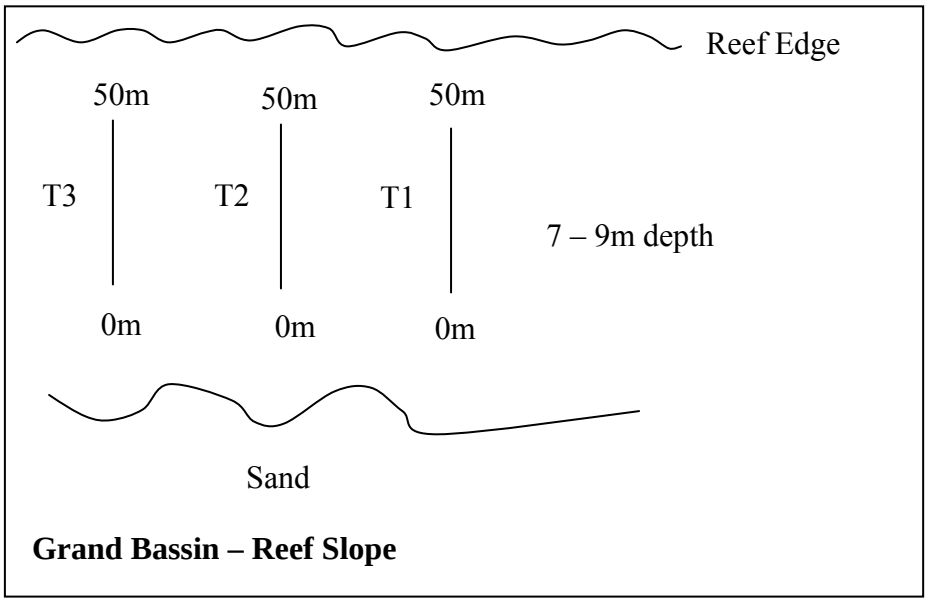
Rivière Banane – Reef Slope



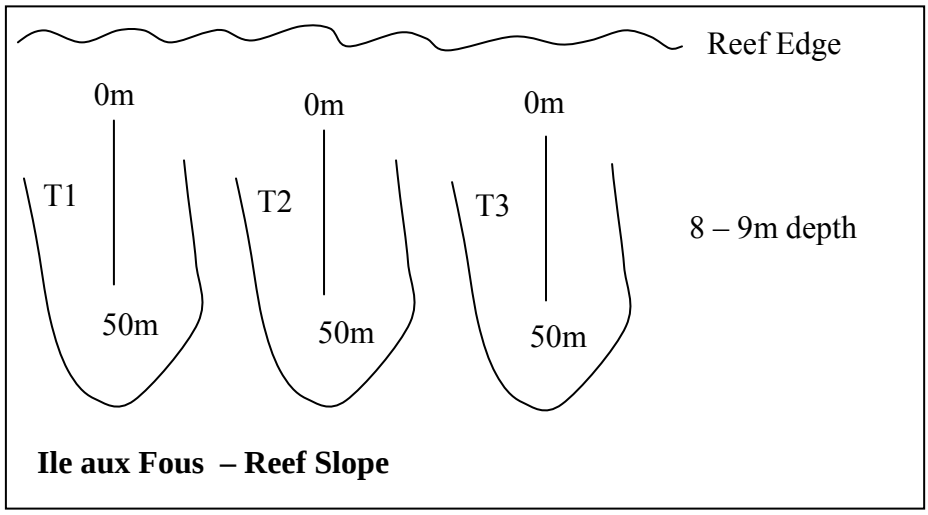
Passe Armand – Reef Slope



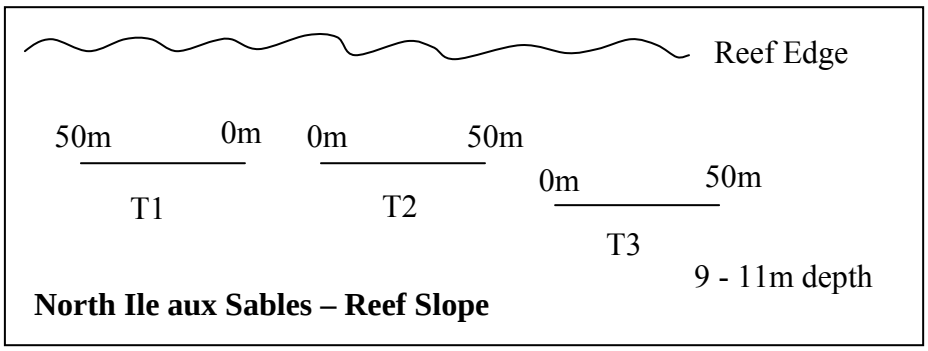
Passe Demi – Reef Flat



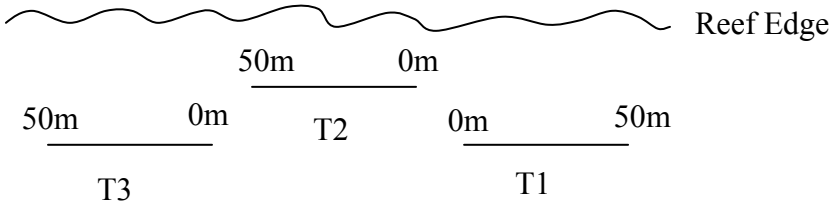
Grand Bassin – Reef Slope



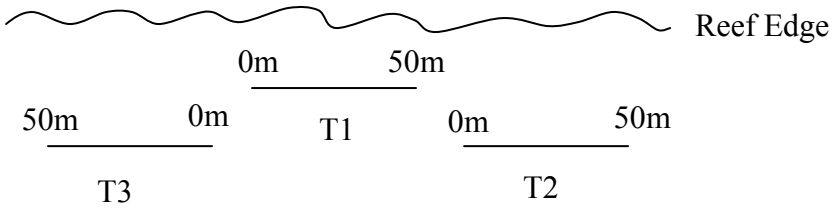
Ile aux Fous – Reef Slope



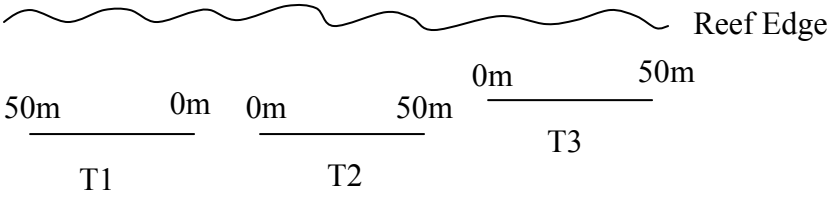
North Ile aux Sables – Reef Slope



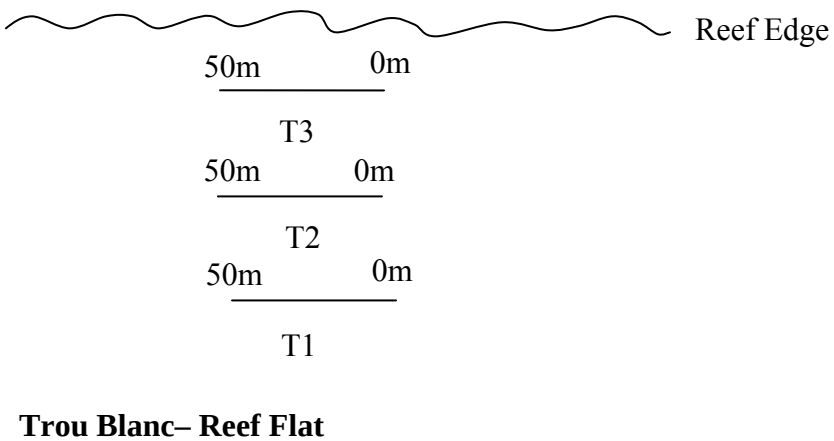
Rivière Banane – Reef Flat



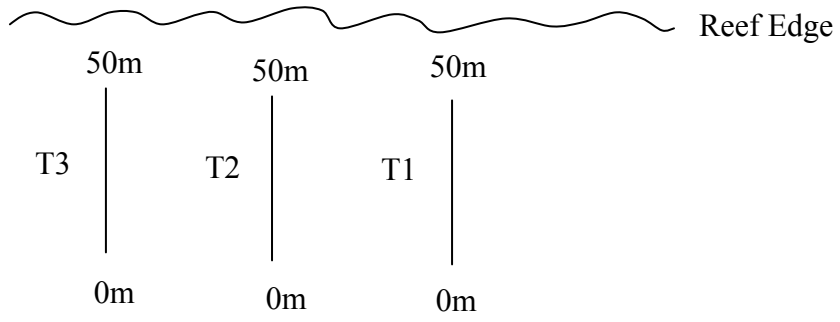
Passe Armand – Reef Flat



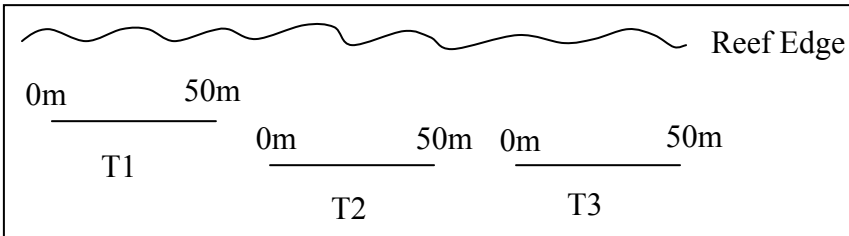
Grand Bassin – Reef Flat



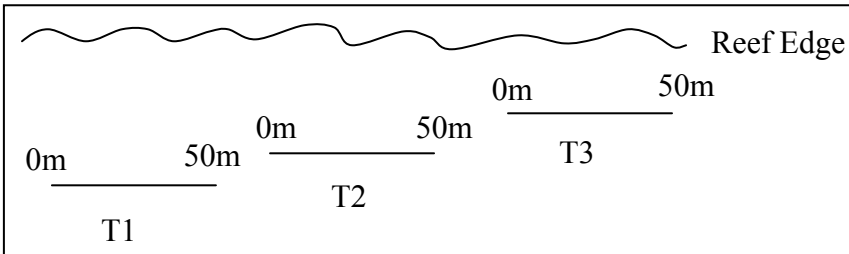
Trou Blanc– Reef Flat



Passe L'Ancre – Reef Flat



Passe Cabris – Reef Flat



Ile aux Fous – Reef Flat

6.2 Data Tables

Table A1. The mean percentage cover of the different benthic habitats at the 6 reef slope sites.

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	North Ile aux Sables
Digitate *Acropora*	1.2	0.1	1.9	0.0	0.6	0.4
Branching *Acropora*	22.9	2.7	27.5	7.1	6.9	7.8
Tablular *Acropora*	26.5	3.7	13.2	14.9	18.6	8.2
Foliose Coral	0.0	0.0	0.1	0.0	0.6	0.0
Sub-massive Coral	1.5	0.2	4.9	1.9	1.1	4.2
Encrusting Coral	1.5	2.0	1.8	1.1	1.7	0.0
Massive Coral	8.6	2.3	1.0	16.7	12.5	7.0
Mushroom Coral	0.0	0.0	0.0	0.0	0.0	0.0
Millepora sp.	0.0	0.0	0.1	0.4	0.4	0.0
Soft Coral	0.1	4.5	6.9	4.2	1.4	20.1
Dead Coral	2.7	4.7	0.0	3.5	2.0	0.7
Zoanthids	0.4	0.0	0.0	0.7	0.3	0.0
Macro-Algae	0.4	0.0	18.0	0.0	0.0	0.0
Turf Algae	6.7	0.0	1.6	12.9	33.5	0.0
Coralline Algae	27.7	59.5	22.2	22.8	13.3	51.3
Rubble	0.0	20.4	0.7	8.8	7.2	0.5
Sand	0.0	0.0	0.0	4.5	0.0	0.0

Table A2. The mean number of fish species present at the 6 reef slope sites.

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	North Ile aux Sables
Small dark surgeons <20cm	2.3	14.3	9.7	1.7	0.0	4.0
Acanthurus triostegus	0.0	0.0	0.0	0.0	13.3	0.0
Naso unicornis	0.0	0.0	0.0	0.3	0.0	0.0
Zebrasoma scopas	0.0	0.0	2.3	0.0	0.0	0.0
Pterocaesio tile	0.0	0.3	0.0	16.7	0.0	0.0
Chaetodon auriga	0.0	0.7	0.7	0.3	0.3	0.0
Chaetodon guttatissimus	0.0	1.3	0.3	0.0	0.0	0.0
Chaetodon melannotus	0.3	0.7	0.0	0.0	0.3	0.0
Chaetodon trifascialis	0.0	0.0	1.3	0.0	0.3	0.0
Chaetodon trifasciatus	0.3	1.7	1.0	0.0	1.3	0.0
Chaetodon unimaculatus	0.0	0.7	0.0	2.7	0.0	1.0
Chaetodon vagabundus	0.0	0.0	0.0	0.7	0.3	0.0
Cheilinus trilobatus	0.0	0.0	1.0	0.0	0.3	0.0
Cheilinus chlororus	0.0	0.0	0.7	0.0	0.3	0.0
Coris aygula	0.3	0.0	0.0	1.0	0.0	0.0
Hemigymnus fasciatus	0.3	1.0	1.3	0.7	0.3	0.0
Anampses caeruleopunctatus	0.0	0.0	0.0	0.0	0.0	1.3
Gomphosus caeruleus	1.0	0.3	0.7	2.0	0.3	1.3
Thalassoma genivittatum	1.3	1.7	2.3	3.3	0.0	2.3
Thalassoma hardwicke	1.0	0.0	0.0	0.0	0.0	0.0
Gnathodentex aurolineatus	1.0	3.3	1.3	1.0	0.7	0.0
Mulloidichthys flavolineatus	0.0	0.0	0.0	1.7	0.0	0.0
Mulloidichthys vanicolensis	1.0	0.0	0.0	0.0	0.7	0.0
Parupeneus barberinus	0.3	0.0	0.3	0.3	0.3	0.0
Parupeneus bifasciatus	0.0	0.0	0.3	0.0	0.0	0.0
Abudefduf sexfasciatus	0.0	4.7	0.0	21.3	7.3	6.0

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	North Ile aux Sables
Abudefduf vaigiensis	0.3	0.0	0.0	0.0	0.0	0.0
Chromis dimidiata	0.0	0.0	0.0	14.3	0.0	0.0
Chromis nigrura	141.0	0.0	0.0	0.0	0.0	9.0
Plectroglyphidodon dickii	11.0	1.7	1.3	1.3	11.0	3.0
Plectroglyphidodon johnstoniatus	0.0	2.0	5.3	2.3	2.0	0.3
Pomacentrus caeruleus	0.0	1.0	0.3	0.0	0.3	0.0
Pomacentrus indicus	12.0	6.0	1.3	3.3	4.0	6.0
Pomacentrus pikei	0.0	0.3	4.0	2.3	2.0	0.0
Pomacentrus rodriguesii	0.0	5.3	0.7	0.0	1.3	0.0
Stegastes peliceri	0.0	5.3	0.0	0.0	0.0	0.0
Scarus scaber	1.0	0.0	0.0	0.3	0.7	0.0
Scarus sordidus	2.7	0.0	14.0	5.7	1.3	3.0
Small immature Parrotfish	3.3	7.0	34.0	1.0	10.7	0.0
Cephalopholis argus	0.0	0.0	0.0	0.3	0.0	0.0
Epinephelus spilotoceps	0.3	2.0	1.0	0.0	0.3	0.3
Zanclus cornutus	0.0	0.7	0.3	0.0	0.0	0.0

Table A3. The mean number of invertebrate species present at the 6 reef slope sites.

	Rivière Banane	Passe Armand	Grand Bassin	Passe Demi	Ile aux Fous	North Ile aux Sables
Echinothrix diadema	4.0	2.7	1.0	0.0	0.0	0.0
Echinometra mathaei	15.3	114.0	0.7	3.3	62.0	691.3
Echinostrephus molaris	0.0	0.0	0.0	2.3	1.3	1.7
Heterocentrotus mammillatus	0.3	0.0	0.0	0.0	0.0	0.3
Holothuria atra	0.0	1.0	0.0	0.0	0.0	0.0
Stichopus chloronatus	0.0	22.3	0.0	0.0	0.0	0.0
Tropiometra carinata	0.0	0.0	0.0	0.0	0.0	0.3
Stephanometra indica	0.0	0.0	0.0	1.0	0.0	0.0
Trochus maculatus	0.0	0.0	0.7	0.3	3.7	3.3
Turbo argyrostomus	0.3	0.0	1.3	0.3	0.0	2.0
Cypraea caputserpentis	0.3	0.0	0.0	0.0	0.0	0.3
Conus sp.	0.3	0.0	0.0	0.0	0.0	0.0
Vasum sp.	0.7	0.0	0.0	0.0	0.3	0.0
Nudibranch	0.0	0.0	0.0	0.0	0.3	0.0
Tridacna maxima	0.0	0.7	0.0	0.0	0.3	0.0
Dardanus sp.	1.0	0.0	0.3	0.0	0.0	0.3

Table A4. The mean percentage cover of the different benthic habitats at the 7 reef flat sites.

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
Digitate *Acropora*	3.5	0.7	3.6	1.2	1.0	0.0	0.0
Branching *Acropora*	0.8	1.3	3.2	4.4	14.8	3.6	0.0
Tablular *Acropora*	3.0	2.0	0.0	2.1	5.4	0.0	0.2
Foliose Coral	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Sub-massive Coral	0.7	2.3	0.2	3.1	3.2	5.0	6.9
Encrusting Coral	1.0	1.5	1.8	0.2	0.0	2.6	2.7
Massive Coral	0.8	1.0	1.0	0.3	0.2	0.0	1.8
Mushroom Coral	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Millepora sp.	0.0	0.4	1.3	0.2	0.0	0.0	0.0
Soft Coral	0.0	0.0	0.0	48.6	15.4	0.0	0.0
Dead Coral	0.0	32.4	0.0	32.4	1.0	3.0	37.7

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Macro-Algae	0.7	0.0	1.0	0.0	0.0	0.0	0.0
Turf Algae	10.3	28.5	0.0	0.3	3.7	0.9	16.2
Coralline Algae	79.2	28.2	88.0	3.3	24.3	84.2	17.3
Rubble	0.0	1.7	0.0	1.8	30.0	0.0	13.0
Sand	0.0	0.0	0.0	2.3	1.2	0.0	0.0

Table A5. The mean number of fish species present at the 7 reef flat sites.

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
Medium dark surgeons 20-40cm	0.0	23.3	0.0	0.0	0.0	5.0	0.0
Small dark surgeons <20cm	0.7	42.0	7.7	12.3	0.0	23.3	24.3
Acanthurus triostegus	0.7	4.3	2.0	1.3	0.0	2.7	0.7
Naso lituratus	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Naso unicornis	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Zebrasoma desjardinii	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Zebrasoma scopas	0.0	0.0	0.0	1.7	0.0	0.0	0.0
Chaetodon auriga	0.3	0.3	0.0	0.0	0.0	0.0	0.3
Chaetodon guttatissimus	0.0	0.7	0.0	0.0	0.0	0.0	0.3
Chaetodon lunula	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Chaetodon melannotus	0.0	0.0	0.0	5.0	0.3	0.3	0.0
Chaetodon trifascialis	0.0	1.3	0.0	1.7	0.0	2.3	0.0
Chaetodon trifasciatus	0.0	3.3	0.3	1.0	0.7	1.3	1.3
Chaetodon vagabundus	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Chaetodon xanthocephalus	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Cheilinus trilobatus	0.3	0.0	2.3	0.0	1.7	0.0	0.0
Cheilinus chlororus	0.0	0.7	0.0	0.3	0.0	0.0	0.0
Coris aygula	2.7	0.0	0.7	0.0	0.3	0.0	0.0
Hemigymnus fasciatus	0.0	0.0	0.7	0.0	0.7	0.0	0.0
Gomphosus caeruleus	0.0	0.7	0.7	0.0	1.0	0.0	0.3
Halichoeres marginatus	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Halichoeres scapularis	0.0	0.0	0.0	1.3	0.7	0.3	0.0
Thalassoma genivittatum	20.7	6.3	9.7	1.3	2.7	4.0	1.7
Thalassoma hardwicke	0.3	0.7	1.7	2.7	3.7	2.0	0.0
Gnathodentex aurolineatus	0.0	0.0	0.0	0.7	0.0	0.0	0.7
Lutjanus fulvus	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Mulloidichthys flavolineatus	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Parupeneus barberinus	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Parupeneus bifasciatus	1.0	0.0	1.3	0.3	0.0	0.0	0.0
Abudefduf sexfasciatus	0.0	13.3	0.0	1.7	0.0	0.0	6.3
Abudefduf sparoides	0.0	0.0	0.0	0.7	0.0	0.0	1.7
Chromis viridis	0.0	150.0	0.0	3.3	0.0	0.0	0.0
Chrysiptera glauca	0.0	0.3	0.0	5.7	7.7	0.7	0.0
Dascylus aruanus	0.0	1.3	0.0	107.0	65.0	0.0	99.0
Plectroglyphidodon johnstoniatus	0.7	1.0	0.0	0.0	0.0	0.0	0.0
Pomacentrus indicus	14.7	3.3	0.3	0.0	0.3	3.3	0.0
Stegates limbatus	6.0	57.7	0.0	59.7	14.7	47.3	20.7
Stegastes nigricans	0.0	14.7	0.0	84.3	2.0	0.7	146.7
Stegastes lividus	0.0	0.0	0.0	0.0	0.0	0.0	15.7
Hipposcarus harid	0.0	1.0	14.0	0.7	0.0	0.0	1.0
Scarus ghobban	0.0	0.7	0.0	0.0	0.0	0.0	0.0

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
Scarus scaber	0.0	0.3	0.0	1.7	0.7	0.3	2.3
Scarus sordidus	1.3	1.0	17.0	3.3	12.3	14.0	4.0
Small immature Parrotfish	3.7	0.0	15.3	8.7	117.3	16.3	34.0
Cephalopholis argus	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Epinephelus spilotoceps	0.3	2.0	0.3	3.3	0.3	0.3	1.7
Siganus sutor	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Zanclus cornutus	0.0	1.3	0.7	0.3	0.0	1.0	0.0

Table A6. The mean number of invertebrate species present at the 7 reef flat sites.

	Rivière Banane	Passe Armand	Grand Bassin	Trou Blanc	Passe L'Ancre	Passe Cabris	Ile aux Fous
Echinothrix diadema	5.7	6.0	5.3	0.0	0.0	0.0	1.0
Echinometra mathaei	257.0	412.7	105.7	256.7	0.0	126.0	16.7
Echinostrephus molaris	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Tripneustes gratilla	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Holothuria atra	0.3	1.0	1.3	0.0	1.7	0.3	0.0
Stichopus chloronatus	2.3	9.0	0.0	0.0	0.0	0.3	0.0
Actinopyga mauritania	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Linckia multiflora	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Nardoa variolata	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Trochus maculatus	0.0	0.0	0.7	0.0	0.0	18.0	0.0
Turbo argyrostomus	0.0	1.7	2.3	0.3	0.0	1.7	0.0
Cypraea annulus	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Cypraea caputserpentis	2.7	1.0	4.0	0.0	0.3	1.7	0.0
Cypraea tigris	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Conus sp.	0.7	0.0	0.3	0.0	0.7	0.7	0.0
Vasum sp.	0.0	0.0	1.0	0.3	1.3	0.0	0.0
Morula sp.	2.0	0.0	1.0	0.0	0.0	4.7	0.0
Mitra sp.	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Tridacna maxima	0.0	0.7	0.0	1.0	0.0	0.0	0.0
Pectinidae	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Octopus cyanea	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Dardanus sp.	0.0	0.0	0.0	0.3	0.0	0.0	0.0