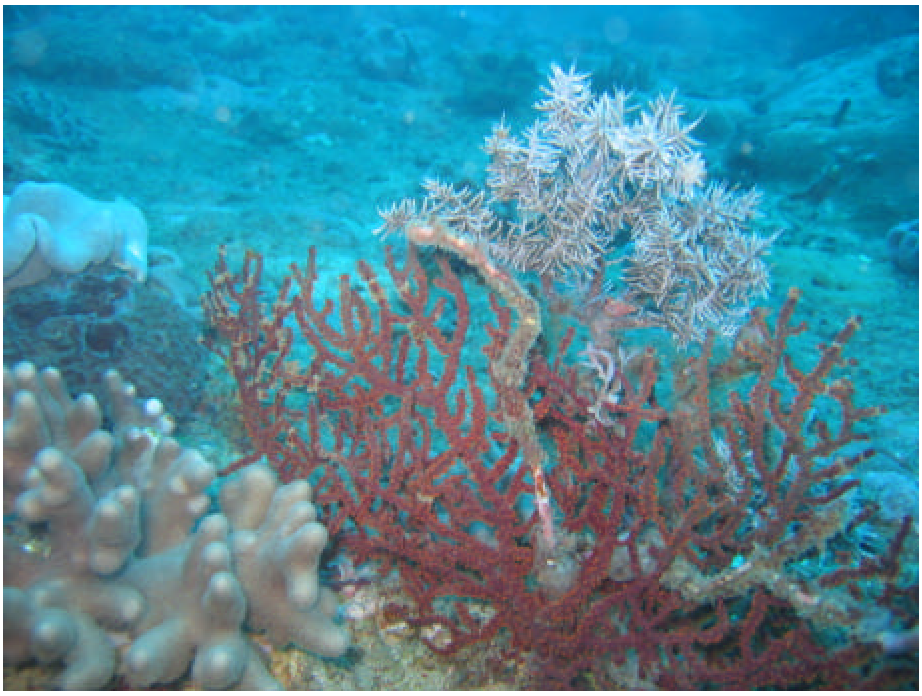
Coral Reef Monitoring and Biodiversity Assessment to support the planning of a proposed MPA at Andavadoaka.



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September 2006

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EXECUTIVE SUMMARY

- A comprehensive coral reef monitoring and biodiversity assessment was conducted at Andavadoaka, southwest Madagascar during November and December 2005.

- Coral reef monitoring was completed for benthic cover, reef fish biomass and macro-invertebrates at nine permanent sites across three main reef types with preliminary information collected at a tenth site (a deep offshore patch reef). Monitoring data provided further detail of coral reef status, complementing and enhancing the existing monitoring completed in the Andavadoaka region.

- An assessment of marine biodiversity in the Andavadoaka region was made by international taxonomic experts for hard corals, reef fish and marine molluscs at a range of habitats and reef types.

- The condition of coral reefs in the region varied between the main reef types. Nearshore fringing reefs were generally in poor condition with low hard coral cover, high non-calcified algal cover and low reef fish biomass. Seaward facing barrier reefs are in better condition with slightly higher coral cover and reef fish biomass. Patch reefs below 10 metres depth were in the best condition with high coral cover, high structural complexity and greatest reef fish biomass. Extensive coral bleaching events are thought to be responsible for low hard coral cover on shallow reefs (<10 m depth).

- Total reef fish biomass (14 main families) was similar to levels found for moderately fished reefs in East Africa and Beheloka, southwest Madagascar. Biomass for some herbivorous fish families was low on fringing reefs (Acanthurids) whilst Scarid biomass was reduced across all sites surveyed.

- Macro-invertebrate density varied between the main reef types with higher densities of herbivorous urchins and seastars (*Linckia* spp.) on fringing reefs and higher densities of giant clams, holothurians and large Cypraeads on offshore reefs.

- Biodiversity assessments revealed medium biodiversity levels for hard corals and reef fish and high biodiversity for marine molluscs. Some hard coral genera were recorded less often than expected which is likely to be related to bleaching mortality. Specialist reef fish associated with rich coral areas were also absent.

- Biodiversity assessments also showed that in order to adequately conserve the maximum number of species it is necessary to protect the full range of coral reef habitats across the different reef types present in the region. In particular the patch reef complex and the southern end of Nosy Hao reef are recommended for full protection.

- A number of recommendations for management are proposed including the use of multiple zones for marine protected and resource-use areas, restrictions on destructive fishing practices, full investigation of a range of alternative livelihoods for fishers and building capacity for community based management within local villages.

- It is crucial that management of any designated marine protected areas in the region is made with the full co-operation and continuous support of the local communities.

INTRODUCTION

This study was conducted specifically for two main reasons; firstly to undertake a detailed assessment of the marine biodiversity within the Andavadoaka region and secondly to complement and enhance the previous ecological monitoring completed on coral reefs at Andavadoaka. The dataset collected aims to record the current status of the marine ecosystem and will provide crucial information to enable the demonstration of effectiveness of the proposed marine protected area (MPA) over time. The work undertaken directly contributes to Objective 4 of the Plan of Action (Cadre Logique) for the 'Andavadoaka Project' originally devised for funding secured from the French Government's 'Fonds de Solidarité Prioritaire' (FSP) for the period January 2005 – June 2006.

The 'Andavadoaka Project's overall aim is to demonstrate the effectiveness of marine protected areas for the conservation of the coastal environment and the sustainable management of marine resources. It is a multi-partner project involving national and local government, international conservation NGO's, the national marine institute for Madagascar (I.H.S.M.), a commercial fish collection company and local communities in the Andavadoaka region. The project has a range of objectives which include baseline ecological and socio-economic assessments; ongoing ecological, fisheries, and socio-economic monitoring; investigation and demonstration of fisheries management practices and the setting up of alternative sources of income for fishing communities.

Ecological monitoring and baseline studies of the marine and coastal environment at Andavadoaka has been completed over the last two years by Blue Ventures, a UK not-for-profit NGO, which has been based on site since 2003. Data collected between September 2004 and July 2005 is presented in Nadon et al. (2005). The majority of the manpower used for data collection are volunteers with no or little previous marine biological background. The level of detail that can be recorded by volunteers on marine surveys is limited. However studies confirm that, given the proper training and supervision, data collected by volunteers can be relied upon to assess the diversity and status of coral reefs at a low to medium level of taxonomic complexity for fish, hard corals and selected macro-invertebrates (Mumby et al., 1995; Harding et al., 2000). The accuracy of the data collected is maintained by rigorous training and testing of volunteers before they are permitted to take part in assessments. A standardized coral reef monitoring programme has been in place since September 2004 using a combination of trained, non-specialist volunteers and marine biologists.

To increase the level of detail a second programme of marine assessment and monitoring was proposed. This will enable the status of the marine environment and the subsequent effectiveness of marine protection to be revealed in more detail. Collaboration with international taxonomic experts enabled the production of a thorough species inventory for selected taxa of marine fauna, notably hard corals, reef fish and marine molluscs. The presence and status of nationally or globally threatened and regionally endemic species was also recorded. These species can then be incorporated as targets in subsequent monitoring programs.

The results of this monitoring and assessment program also contribute to the 'Durban Vision' of substantially increasing the total amount of protected areas on a national scale by 2008, as initially announced by the President of Madagascar at the World Parks Congress in 2003 and reiterated in June 2006 at the Biodiversity Symposium organised by Conservation International in Antananarivo.

Objectives

The main objectives of this study were to:

1. Conduct a rapid assessment of biodiversity in the Andavadoaka region involving international experts;
2. Initiate a more detailed level of biological monitoring at range of reef habitats using a combination of experienced surveyors from WCS, Blue Ventures, IRD / ARVAM and I.H.S.M (depending on availability)
3. Use the information collected to make recommendations for the designation of the proposed MPA and the management of marine resources in the region.

METHODS

Marine Biodiversity

Biodiversity assessments were conducted by taxonomic experts for reef fish, hard corals and molluscs incorporating both in-situ observation (reef fish, hard corals) and sample collection (hard corals, molluscs) to record fauna to the species level. Sampling sites were chosen to represent all known habitat types in shallow coastal waters around Andavadoaka to a depth of 30 metres. Full details of the methods used for the biodiversity assessments can be found in the individual reports for reef fish (Allen, 2005), hard corals (Fenner, 2005) and molluscs (Barrere, 2005) which are included in this report as Appendices I - III.

Ecological Monitoring

The monitoring completed during this assessment was designed to complement the existing ecological data set collected by Blue Ventures by recording faunal groups in more detail. The advanced monitoring undertaken is summarized below (Table 1) which also provides information on the routine monitoring completed by Blue Ventures throughout the year.

Table 1. Summary of Ecological Monitoring at Andavadoaka

Level of Ecological Monitoring	Organisation responsible	Monitoring Type	Sampling Period
Basic	BV	Benthic cover and hard coral recruits	Bi-annually
Basic	BV	Reef fish abundance (selected families)	Bi-annually
Basic	BV	Target invertebrates	Bi-annually
Advanced	WCS	Reef fish biomass: belt transects	Annually
Advanced	WCS	Reef fish biomass: timed swims	Annually
Advanced	WCS / BV	Target invertebrates: belt transects	Annually
Advanced	WCS / BV	Target invertebrates: timed swims	Annually
Advanced	WCS	Benthic cover: Identification to genus	Annually

The above table shows the types of advanced monitoring originally proposed for completion at Andavadoaka. However, a lack of trained personnel for most survey dives meant that it was not possible to complete ‘timed swim’ surveys for invertebrates and reef fish. Ecological monitoring of coral reefs and associated systems followed standard methodology as used by the Global Coral Reef Monitoring Network (GCRMN) and outlined in Hill and Wilkinson (2004).

Study Sites

The more advanced monitoring was completed at a number of existing sites used for routine monitoring by Blue Ventures in order to provide further ecological detail for these locations covering a range of reef types (patch, barrier and fringing) which are also positioned both within and outside of the proposed MPA for Andavadoaka. Details of the study sites and their relative locations are provided in Table 2 and Figure 1 respectively. Three sites for each main reef type were assessed plus one site at a fourth reef habitat, the deeper offshore patch reef at Andravamaike. Site names followed those given by Blue Ventures surveyors with the exception of the offshore patch site, which uses the local name.

Table 2. Details of Ecological Monitoring Sites.

Site Name	General Location	Reef Type	Latitude (South)	Longitude (East)	Depth (m)
007 (S)	East of the southern end of Nosy Hao Reef	Patch	22° 07' 25.30"	43° 11' 49.10"	8-10
Recruitment (N)		Patch	22° 07' 20.30"	43° 11' 53.60"	11-13
THB (S)		Patch	22° 07' 25.40"	43° 11' 54.40"	10-12
Valleys	NW Nosy Hao reef	Barrier	22° 04' 46.50"	43° 10' 55.80"	6-10
Shark Alley	Southern end of Nosy Hao reef	Barrier	22° 07' 47.60"	43° 10' 52.70"	8-12
Nosy Fasy	SW side of Nosy Fasy reef	Barrier	22° 04' 01.10"	43° 10' 54.00"	8-12
Coco Beach	SW of Coco Beach Resort	Fringing	22°05' 03.80"	43° 13' 39.40"	5-9
Half Moon	West of Coco Beach Resort	Fringing	22°04' 27.00"	43° 13' 34.90"	6-10
Andavadoaka Rock	Adjacent to Andavadoaka Rock	Fringing	22°04' 22.00"	43° 13' 34.30"	5-8
Andravamaike	3 km west of Nosy Hao	Offshore Patch	22° 04' 32.2"	43° 09' 15.50"	20-22

Survey Methods

Environmental Parameters

On each survey dive a number of environmental parameters were recorded on the boat either just before or immediately after the survey. These included sea surface temperature (SST°C), sea state (Beaufort Scale; 1-12), wind direction and cloud cover (0-8).

Benthic Cover

Benthic cover was recorded using the point intercept transect method (PIT) on permanent transects established by Blue Ventures (except at Andravamaike). For all but three of the survey sites 8 replicate transects each 10 metres in length were completed by laying a tape measure along the transect between fixed points (permanent metal stakes). For the remaining sites 6 transects were completed at two of the patch reef sites (Recruitment and 007) while 4 transects were surveyed at the deep offshore patch reef, Andravamaike. The type of cover (biotic or abiotic) present under each 20 cm increment along the tape was recorded using the standard categories recommended by GCRMN (Hill and Wilkinson, 2004) and listed in Appendix 4c. Sessile organisms were recorded to genus 'in situ' when possible. Digital cameras were used to record organisms not fully identified during the survey for subsequent identification at the field base using the following guides and texts: Veron (2000) for hard corals; Fabricus and Alderslade (2004) for soft corals; Littler and Littler (2003) for marine algae and Richmond (2002) as a general guide.

Reef Fish

Underwater visual censuses were conducted to estimate the biomass of sixteen fish families (Appendix 4a) representing the main trophic groups of reef fish occurring in the Andavadoaka region and most of the main fish families targeted by local fishers. At each site the selected families were counted along three replicate belt transects 50 metres in length, 5 metres wide and 5 metres deep giving a total area of 250 m^2. Individual fish in each selected family were recorded and allocated either to 5 cm size classes between 0 and 50 cm total length (TL) or to 10 cm size classes between 50 and 100 cm TL. Pomacentrids were split into two trophic groups, herbivores and planktivores according to their feeding habit. Reef fish biomass for each family was calculated using biometric equations derived from reef fish populations sampled in Kenya (McClanahan et al., 1996) and converted to kg per hectare (kg/ha) of reef area.

Macro Invertebrates

Selected macro-invertebrates were also recorded along each of the 50 x 5 metre belt transects (Appendix 4b). Individual organisms were identified to species when possible. Commercially harvested (sea cucumbers, octopus), rare (large Gastropod molluscs) or ecologically significant (herbivorous urchins) invertebrates were those selected for monitoring.

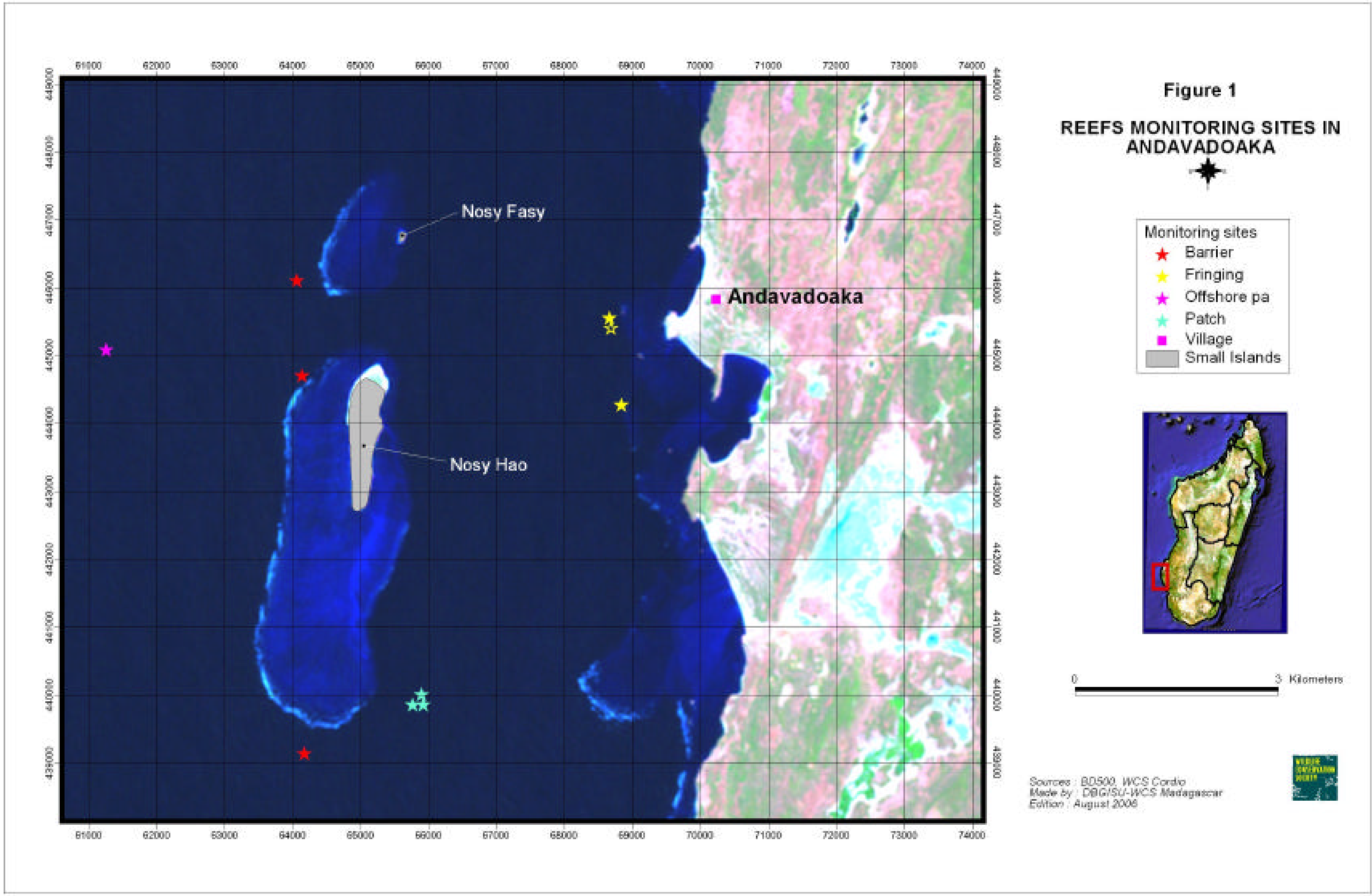


Figure 1
REEFS MONITORING SITES IN ANDAVADOAKA
Nosy Fasy
Nosy Hao
Andavadoaka
Monitoring sites
Barrier
Fringing
Offshore pa
Patch
Village
Small Islands
0
3 Kilometers
Sources : BD500, WCS Cordio
Made by : DBGISU-WCS Madagascar
Edition : August 2006

RESULTS

The majority of information presented derives from the data collected during monitoring surveys completed between the 26th of November and the 6th of December 2006. For some comparisons biodiversity data derived from Appendices I - III and collected in the same time period are also presented.

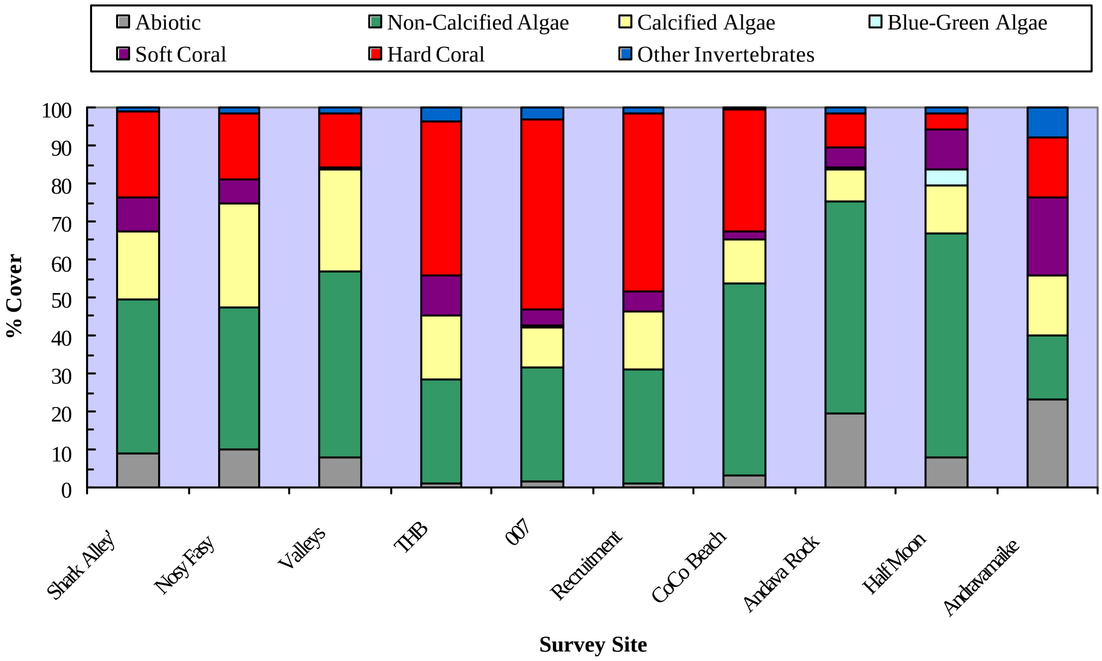
Environmental Parameters

A complete set of environmental data collected can be found in Appendix 5. Sea surface temperature remained between 28 and 29 °C during the monitoring. Sea state ranged between 2 and 4 on the Beaufort Scale and usually increased throughout the day. Cloud cover was generally low when surveys took place and never exceeded 4 octets. The wind was predominantly from the southwest with occasional days where it came from the north or northwest.

Benthic Composition

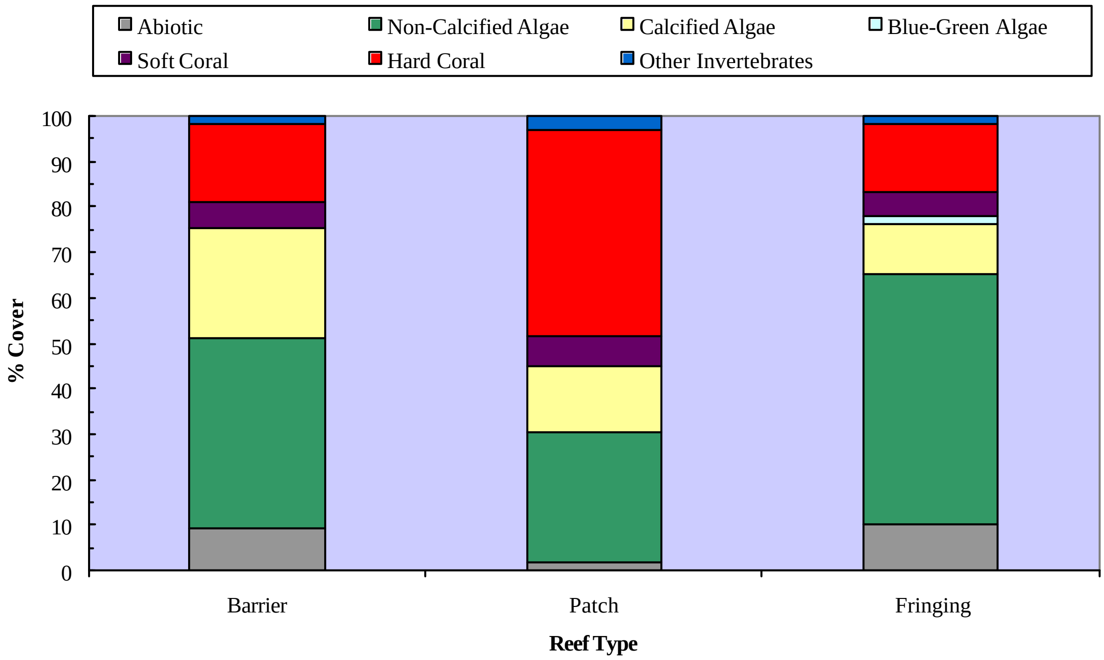
Mean values of percent cover for all benthic categories recorded at each site are presented in Appendix 6. Values for the major categories are highlighted in bold and presented graphically in Figure 2 for individual sites and Figure 3 for the three main reef types (not including Andravamaike). Hard coral cover was significantly higher at the patch reef sites (THB, 007 and Recruitment), between 40 and 50 %, than at the barrier reef or nearshore fringing reef sites (Table 4). At one nearshore site (Coco Beach) hard coral cover was moderately high (32 %) and can be attributed to a large submassive colony of *Pavona clavus*, which constituted 27.5 % of all benthic cover at this site (Table 3). Hard coral cover at the other fringing reef sites was less than 10 % and very low at Half Moon (4 %).

Figure 2. Mean benthic cover at 10 coral reef sites at Andavadoaka.



Algae covered more than half of the substratum at six of the ten sites visited, reaching 75 % cover at two of these sites, Valleys and Half Moon. Looking at algal cover in more detail barrier reef sites have a significantly higher proportion of calcified algae than either patch or fringing reef sites (Table 3). For the latter reef type, non-calcified algae (turf and macroalgae) consistently made up between 50 – 60 % of the total benthic cover (Figures 3-4, Appendix 6). Blue-green algae were recorded at three sites and were most prominent at the nearshore site Half Moon (4.25 %). Total non-calcified algal cover was significantly greater on fringing or barrier reefs than on patch reefs but also significantly higher on fringing compared to barrier reefs (Table 3).

Figure 3. Mean Benthic Cover by Reef Type for three main types of coral reef at Andavadoaka.



Soft corals and other benthic invertebrates (sponges, zooanthids, anemones and bivalve molluscs) generally covered less than 10 % of the substratum for the main reef types. The exceptions were THB (14 %) and Half Moon (12.25 %). The deeper patch reef at Andravamaike consisted of a different coral reef habitat with greater soft coral and sponge cover than any other site (Figure 2, Appendix 6). Algal cover was also lowest at Andravamaike (33 %) and abiotic substratum highest (23 %), the latter mainly consisted of sand patches between areas of reef.

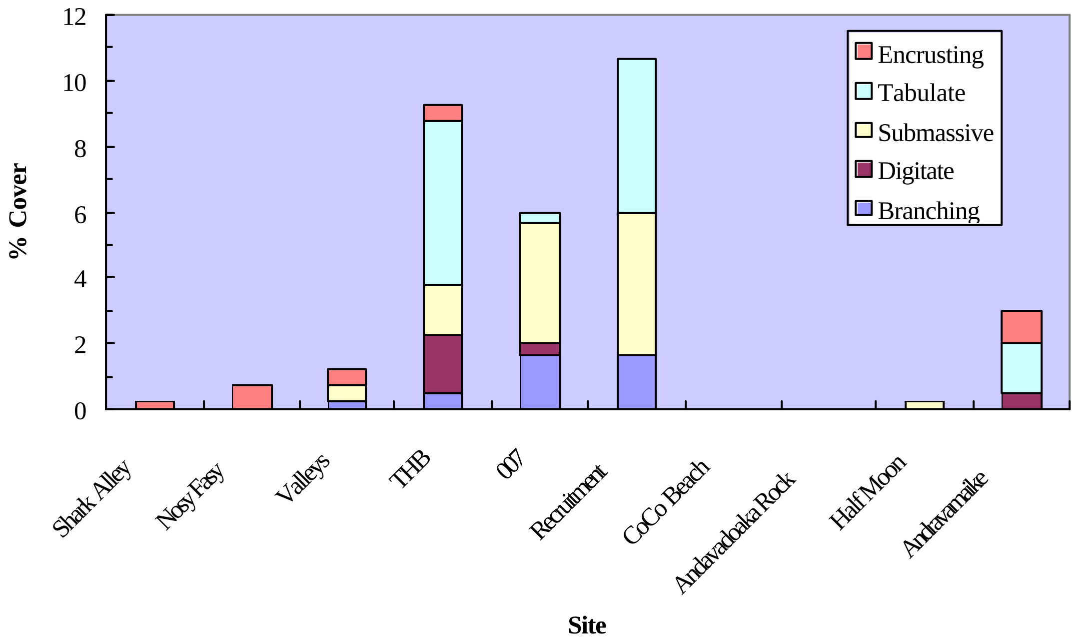
Table 3 Comparison of selected benthic categories between reef types.

Benthic Category	F	P	Comparison Between Reef Type		
			Barrier x Patch	Barrier x Fringing	Patch x Fringing
Total Hard Coral	33.01	<0.0001	P > B	n.s	P > F
Non-*Acropora* Corals	14.94	<0.0001	P > B	n.s	P > F
Acropora Corals	60.88	<0.0001	P > B	B > F	P > F
Calcified Algae	15.94	<0.0001	B > P	B > F	n.s
Non-Calcified Algae	16.29	<0.0001	B > P	F > B	F > P

Oneway ANOVA on arcsin transformed data. (df = 2, 65; F critical = 3.138) with a Tukey test to identify significant differences ($p < 0.05$) between groups (n.s. = not significant).

Hard coral types (*Acropora* or Non-*Acropora*) and lifeforms varied considerably between survey sites and reef types (Appendix 6, Figures 4–5). *Acropora* corals were rarely recorded at the barrier and fringing reef sites (<2 % cover) and not recorded at all on transects at two of the nearshore sites. *Acropora* coral cover was significantly higher at patch reef sites than at barrier or fringing reef sites (Table 3). However, cover by this genus was generally less than 10 % and consistently less than 25% of all hard coral cover. Tabulate and digitate forms of *Acropora* were only recorded at patch reef sites.

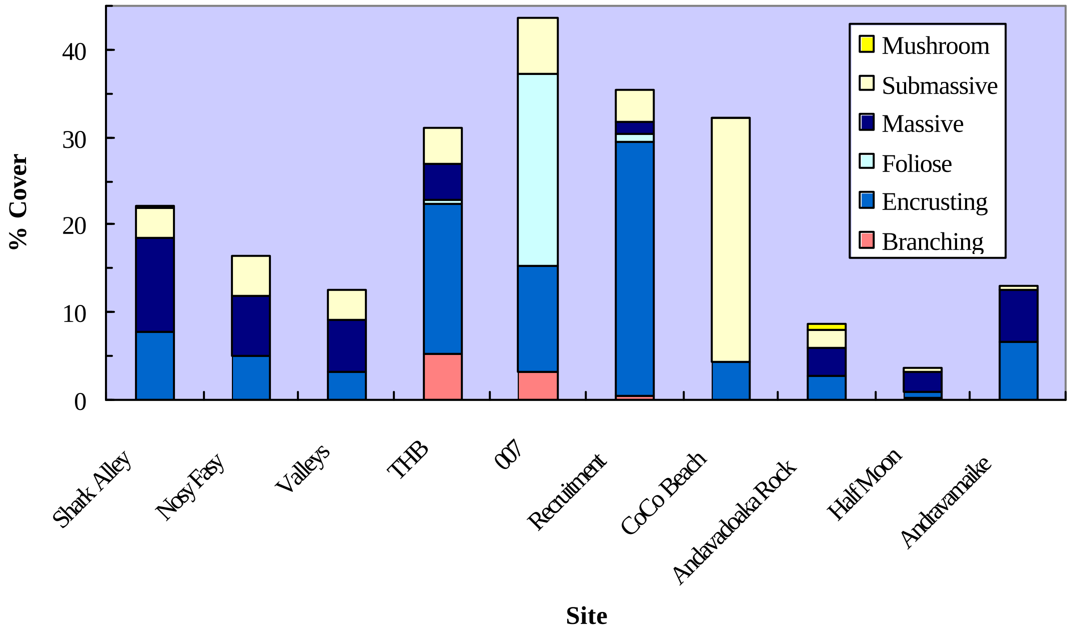
Figure 4. Proportion of Acropora Lifeforms at Andavadoaka coral reef sites



In contrast, non-*Acropora* corals covered between 12 and 44 % of the substratum at eight of the sites surveyed (Appendix 6, Figure 5). The two exceptions were both fringing reef sites, Andavadoaka Rock and Half Moon where cover was less than 10 %.

Cover of non-*Acropora* corals was significantly higher at patch reef sites than at the other two reef types (Table 3). Patch reefs were also the only sites where branching and foliose lifeforms were recorded with foliose *Montipora* colonies covering more than 20% of the reef area at one site ('007').

Figure 5. **Proportion of Non-Acropora Lifeforms at Andavadoaka coral reef sites**



A total of 28 hard coral genera were recorded during monitoring surveys (Appendix 7). On average 93.4 % of hard coral colonies recorded along the transects were identified to genus (all sites combined). The highest number of hard coral genera was recorded at three sites; Shark Alley, 'THB' and Recruitment. More hard coral genera were recorded on transects at patch and barrier reef sites than at fringing reef sites. Patch reef sites also contained a larger range of hard coral lifeforms than the other two reef types (Figure 7).

Figure 6 **Total Number of Hard Coral Genera and Lifeforms recorded at 10 sites during monitoring surveys.**

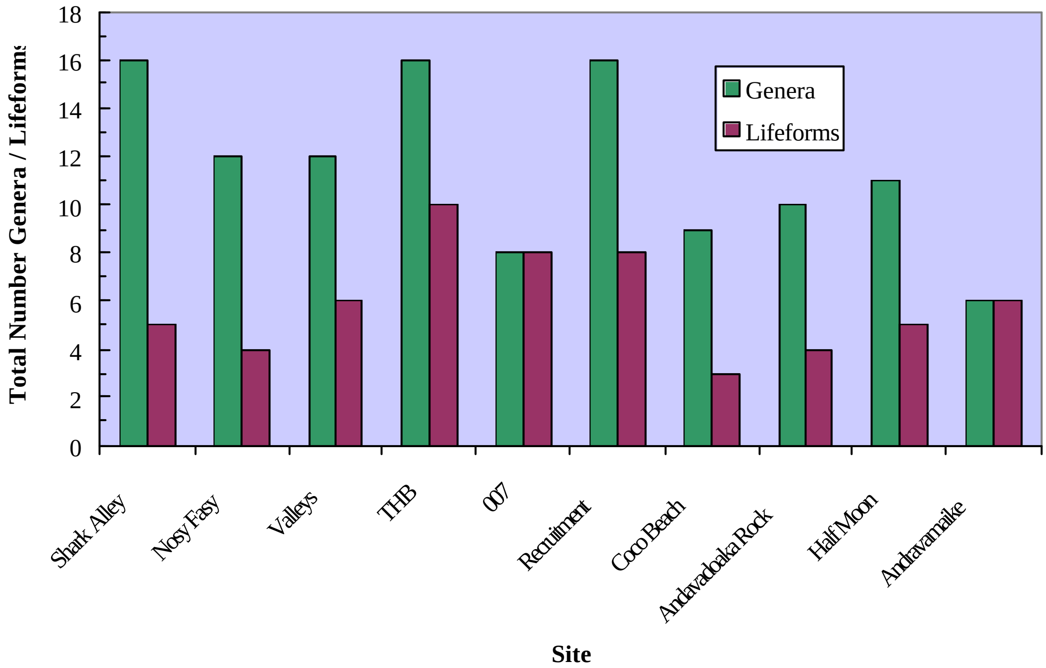
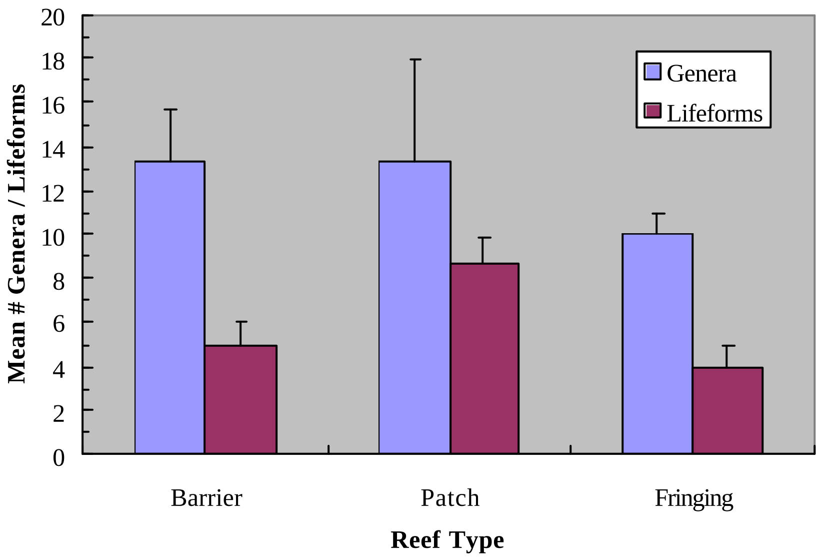


Figure 7 **Number of hard coral genera and lifeforms for each main reef type at Andavadoaka (mean values + S.D., n = 3).**



In terms of hard coral species the assessment by Fenner during the monitoring trip (see report in Appendix 1) showed the total number recorded on one dive can vary considerably between sites of the same reef type (Figure 8). Fringing reef sites produced the highest and lowest counts of hard coral species, 66 and 40 respectively for one 60 minute dive. When sites are combined into the three main reef types (Figure 9) the mean number of species is slightly higher at barrier and patch reef sites than at the nearshore sites but not significantly so (Oneway ANOVA, p = 0.857).

Figure 8 **Maximum number of hard coral species recorded on one 60 minute dive at nine sites at Andavadoaka (Fenner, 2005).**

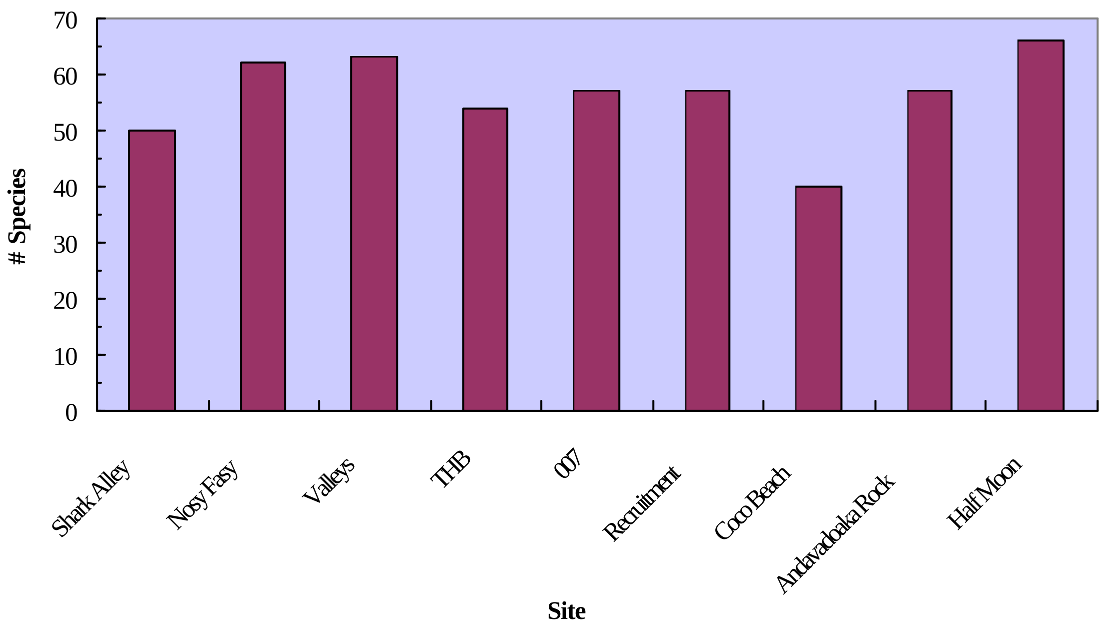
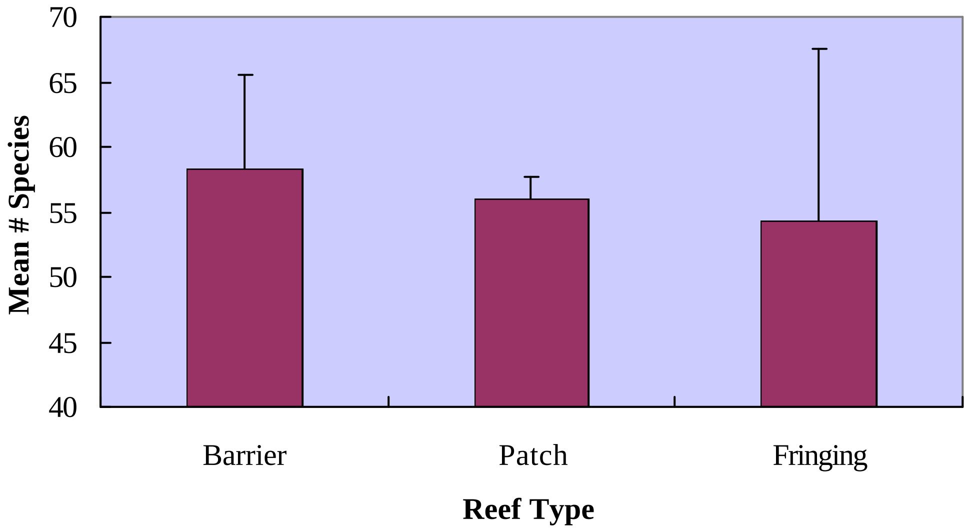


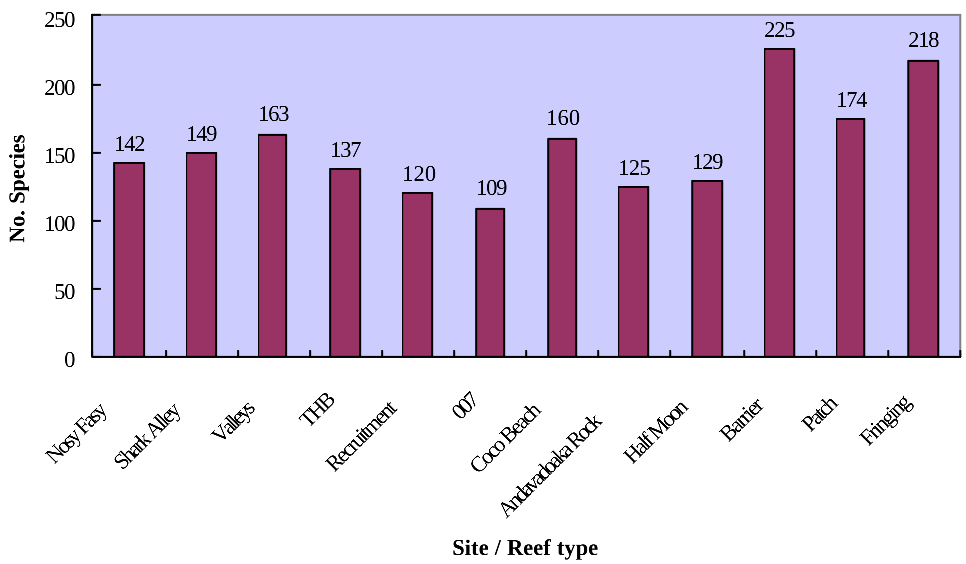
Figure 9 **Number of hard coral species for each main reef type at Andavadoaka (mean values + S.D., n = 3).**



Reef Fish

Reef fish diversity was assessed by G. Allen at the nine sites visited for monitoring surveys (Allen, 2005: Appendix 2). Comparison of reef fish diversity between sites and reef types is depicted below (Figure 10). The total number of species recorded at each site varied between 109 ('007') and 163 (Valleys). Coco Beach was the only other site to have more than 150 species. Analysis by reef type indicates that the highest number of species was found at the barrier reef sites, closely followed by fringing reefs (Figure 10). Patch reef sites were considerably less diverse with a total of 174 species compared to counts in the early 200's for the other reef types.

Figure 10 **Total number of reef fish species recorded over 2 dives for nine sites with accumulated values for reef types at Andavadoaka (Allen, 2005).**



Reef fish biomass was also assessed at nine sites covering the three main reef types. Mean values for the main fish families recorded at each site are presented in Figure 11 and Appendix 8a, with standard errors provided in Appendix 8b. Values for Caesionids are omitted from Figure 11 but present in Appendix 8. Reef fish biomass was highest at two of the patch reef sites, THB and Recruitment with 514 and 607 kg/ha respectively, not including Caesionids. Lowest values for biomass were recorded at the fringing reef site Half Moon with a total of 52.5 kg/ha. The high values at the two patch reef sites were caused by the presence of schools of Lethrinids and Lutjanids which were absent from almost all other reef sites, with the exception of Coco Beach (Lutjanids). Acanthurids made up a significant part of the total reef fish biomass for most sites, particularly at the barrier reef sites where they represented between 37 and 62 % of total biomass for the families recorded.

Comparison of fish biomass by main reef type indicates that the patch reefs harbour the greatest mass of reef fish, and the highest biomass of Lethrinids, Lutjanids, Chaetodontids and Scarids compared to barrier and fringing reefs (Figure 12). There was a significant difference in total reef fish biomass (excluding Caesionids) between reef types (Oneway ANOVA on log(x) transformed data: df = 2, 21; $p = 0.032$) with fringing reefs recording significantly less total biomass than patch reefs (Tukey test; $p < 0.05$).

Figure 11 Mean reef fish biomass for 13 fish families at nine sites at Andavadoaka

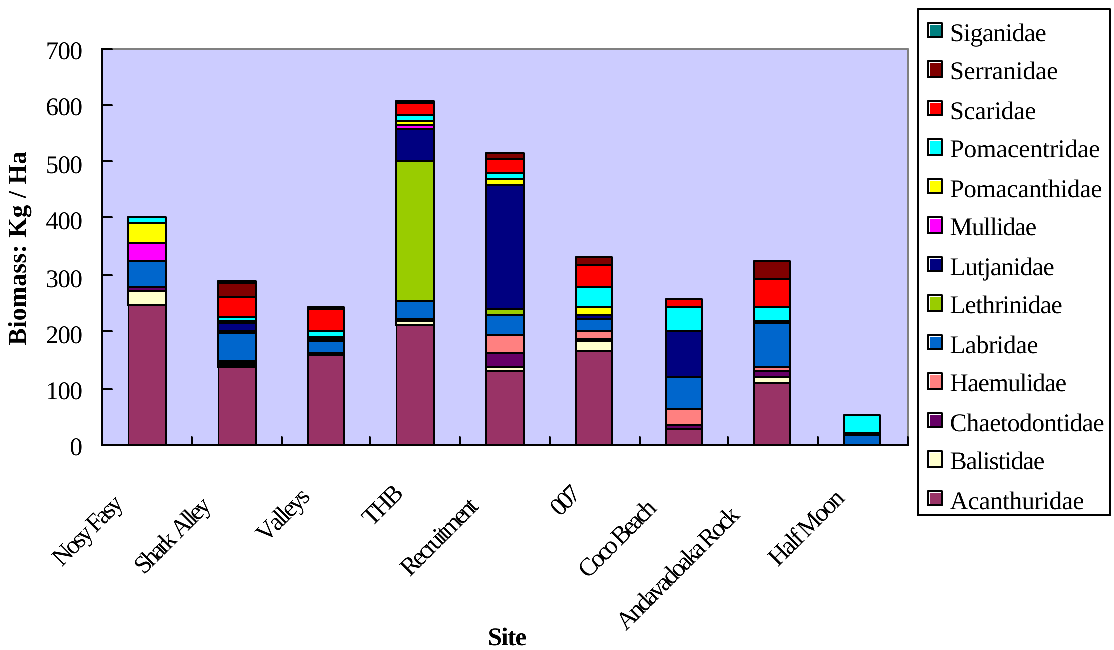
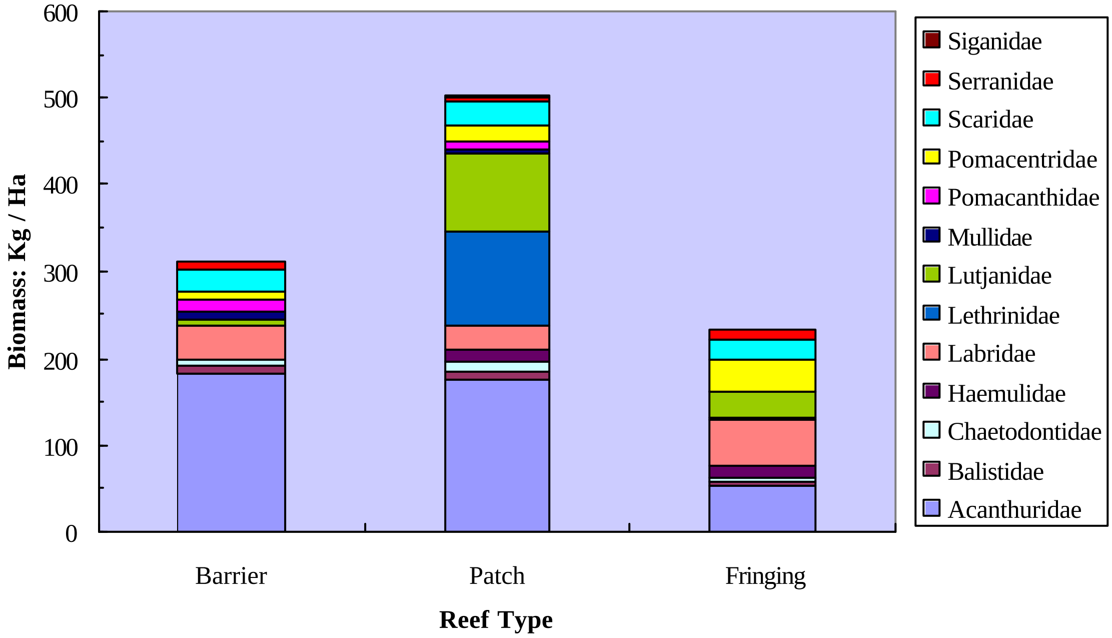


Figure 12 Mean reef fish biomass for 13 fish families at the main reef types



Three families significantly differed in biomass between reef types (Table 4). Biomass of Acanthurids was lower on fringing reefs than barrier or patch reefs while a higher biomass of Lutjanids was recorded on patch reefs than on the other reef types. Conversely biomass of Pomacentrids was significantly higher on fringing reefs than patch or barrier reefs. Labrids were also most abundant on fringing reefs but not significantly so (Table 4). Lethrinid biomass was significantly higher on patch reefs if accepted at a slightly lower level of probability ($p = 0.07$).

The variance in fish biomass between replicate counts for some families is highlighted in Figure 13 and partly accounts for the lack of statistical difference between reef types (Table 4). Standard errors are particularly high for Caesionids for all reef types and both Lutjanids and Lethrinids at patch reefs. Other families such as Scarids and Labrids provided relatively consistent results between transects and also between reef types.

Seven fish families did not exceed a mean biomass of 15 kg/ha at any reef type (Appendix 8a, Figure 13). These were mainly carnivores (Balistids, Serranids, Haemulids, Mullids) but also included mixed feeders (Chaetodontids, Pomacanthids) and one herbivorous family (Siganids).

Figure 13 Reef fish biomass for 14 families at three main reef types (Mean values + S.E).

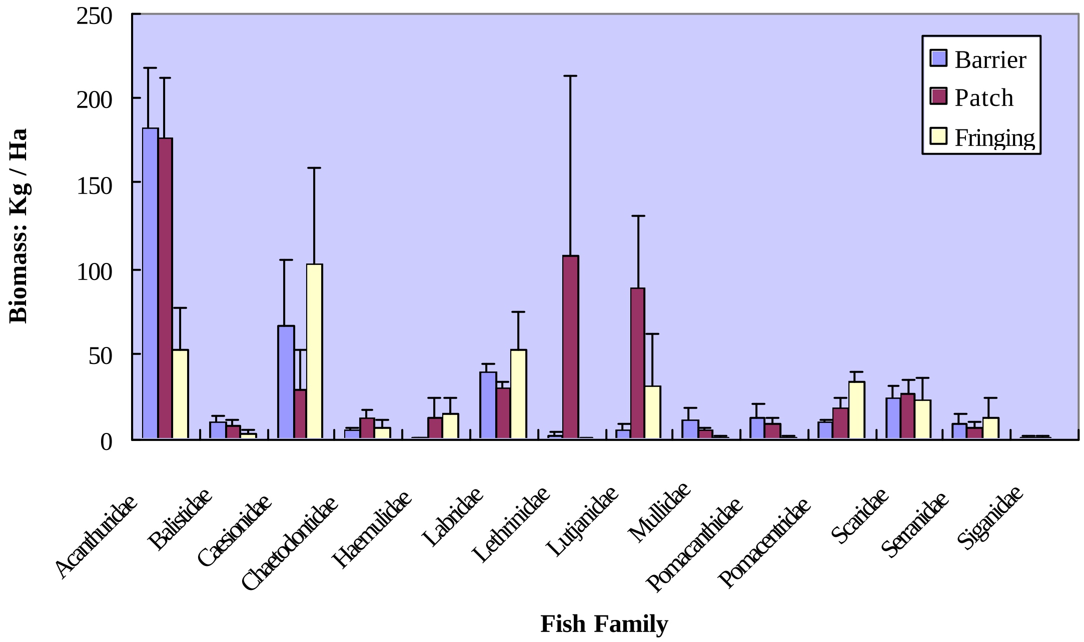


Table 4 Comparison of Reef Fish Biomass between Reef Types for 12 Families.
(Significant differences are highlighted in **bold**)

Oneway ANOVA on log(x+1) transformed data. (df = 2, 21; F critical = 3.47) with a Tukey test to identify significant differences (p < 0.05) between groups (n.s. = not significant, * = significant at p < 0.07).

Fish Family	F	P	Comparison Between Reef Type		
			Barrier x Patch	Barrier x Fringing	Patch x Fringing
Acanthuridae	**9.05**	**< 0.005**	n.s.	**B > F**	**P > F**
Balistidae	1.55	0.236	-	-	-
Caesionidae	0.30	0.745	-	-	-
Chaetodontidae	1.08	0.359	-	-	-
Labridae	0.42	0.660	-	-	-
Lethrinidae	**3.47**	**0.05***	n.s.	n.s.	**P > F***
Lutjanidae	**7.69**	**0.003**	**P > B**	n.s.	**P > F**
Mullidae	2.29	0.126	-	-	-
Pomacanthidae	1.78	0.193	-	-	-
Pomacentridae	**13.45**	**< 0.001**	n.s.	**F > B**	**F > P**
Scaridae	1.10	0.350	-	-	-
Serranidae	0.16	0.856	-	-	-

Macro-Invertebrates

Mean counts for assessed macro-invertebrates at each site are presented in Appendix 9 while overall means with standard errors for each reef type are depicted below (Table 4). A few macro-invertebrate targets were more notable by their absence, particularly Crown of Thorns starfish (*Acanthaster plancii*) and Lobsters (*Panulirus* spp.), which were not recorded along transects at any site. One octopus was observed during the surveys, at Nosy Fasy. A high density of large anemones (*Heteractis* sp.) was recorded at one patch reef site ('THB') but were either absent or rarely recorded at other sites.

In terms of Echinoderms herbivorous sea urchins (*Diadema, Echinometra and Echinothrix*), the sea star *Linckia* spp. and the sea cucumber *Pearsonothuria graeffei* were recorded most often. Four genera of sea-stars (*Culcita, Choriaster, Protoreaster and Nardoa*) were recorded occasionally (Appendix 8).

Large gastropod molluscs such as the giant triton (*Charonia tritonis*) and horned helmet shell (*Cassis cornuta*) were not seen at any of the nine sites. However, medium sized gastropods were observed. The conch (*Lambis* spp.) and two species of large cowrie, the Tiger (*Cypraea tigris*) and Egg Cowrie (*Ovula ovum*,) were recorded. The latter was frequently observed on barrier reef sites at Nosy Fasy and Valleys.

Table 4 Densities of selected macro-invertebrates for three reef types at Andavadoaka (no. individuals / hectare).

Invertebrate Category	Barrier		Patch		Fringing	
N:	9		7		8	
	Mean	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**
Diadema	**31.11**	**22.11**	**531.43**	**309.22**	**290.00**	**215.60**
Echinothrix	**0**	**-**	**142.86**	**75.93**	**640.00**	**291.48**
Echinometra	**302.22**	**164.33**	**0**	**-**	**15.25**	**7.75**
Acanthaster plancii	0	-	0	-	0	-
Linckia	**66.67**	**27.39**	**68.57**	**67.14**	**475.00**	**144.43**
Other Asteroidea	4.44	4.71	11.43	7.97	10.00	7.00
Total Asteroidea	71.11	27.18	80.00	72.42	485.00	140.31
Pearsonothuria graeffei	**22.22**	**10.27**	**74.29**	**14.69**	**25.00**	**16.04**
Holothuria atra	17.78	10.27	0	-	0	-
Other Holothurians	4.44	4.71	5.71	6.17	5.00	5.35
Total Holothurians	44.44	19.29	80.00	16.33	30.00	15.65
Lobster	0	-	0	-	0	-
Anemone	0	-	645.71	503.27	25.00	17.96
Tridacna	**53.33**	**22.36**	**11.43**	**12.34**	**25.00**	**21.29**
Octopus	4.44	4.71	0	-	0	-
Charonia tritonis	0	-	0	-	0	-
Cassis cornuta	0	-	0	-	0	-
Lambis	13.33	7.07	5.71	6.17	10.00	7.00
Cypraeidae	**57.78**	**26.56**	**11.43**	**7.97**	**5.00**	**5.35**

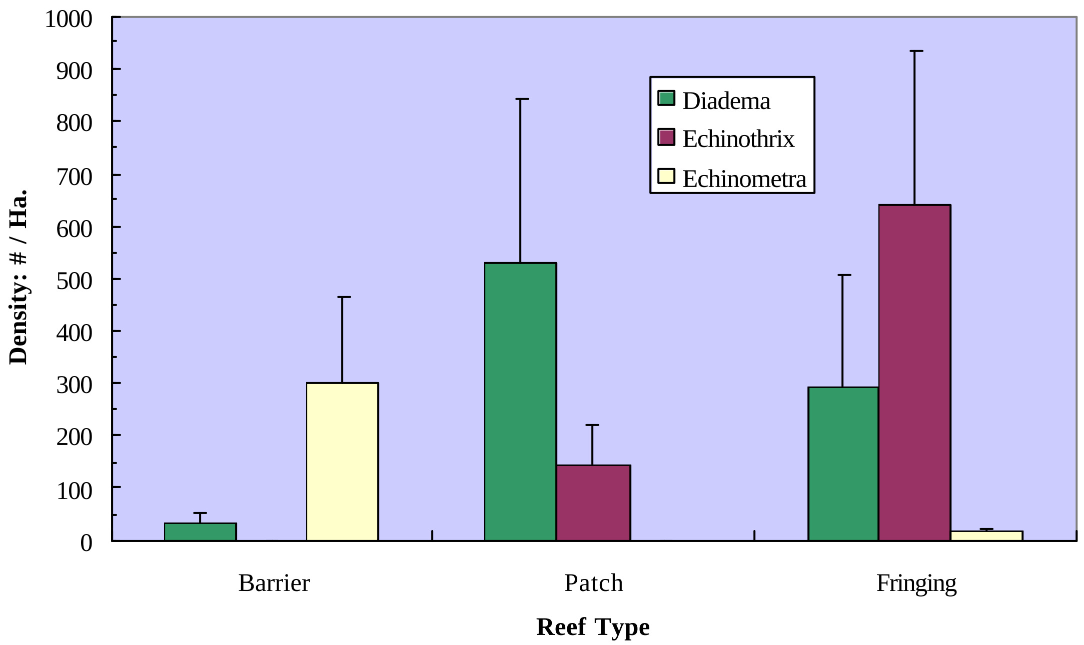
Invertebrate categories highlighted in bold in Table 4 are presented graphically in Figures 14 – 16 for Echinoderms and Figure 17 for Molluscs. Herbivorous urchins were generally more abundant on patch or fringing reef sites than barrier reef sites (Figure 14) with the exception of *Echinometra*, which was recorded at the northern end of Nosy Hao (Valleys) but not at the other two barrier reef sites. Statistical comparison of urchin densities revealed a significant difference in the abundance of *Echinothrix* between reef types but not for the other two genera (Table 5). *Diadema* were recorded more often on patch and fringing reefs than on barrier reef sites but counts were not significantly different statistically.

Table 5 **Statistical Comparison of Invertebrate Densities between Reef Type. (Significant differences are highlighted in bold)**

Oneway ANOVA on v(x + 0.5) transformed data. (df = 2, 21; F critical = 3.47) with a Tukey test to identify significant differences ($p < 0.05$) between groups (n.s. = not significant).

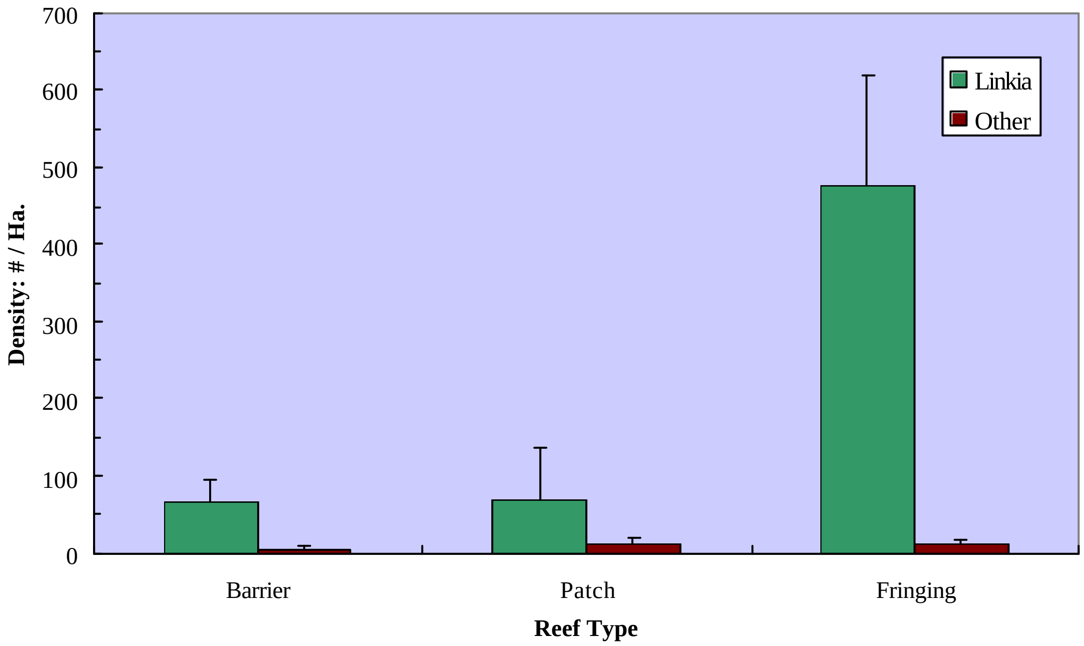
Invertebrate	F	P	Comparison Between Reef Type		
			Barrier x Patch	Barrier x Fringing	Patch x Fringing
Diadema	1.47	0.253	-	-	-
Echinothrix	**5.33**	**0.013**	n.s.	**F > B**	n.s
Echinometra	2.54	0.103	-	-	-
Linckia	**9.77**	**0.001**	n.s.	**F > B**	**F > P**
Pearsonothuria graeffei	**5.56**	**0.011**	**P > B**	n.s.	**P > F**
Tridacna	2.09	0.148	-	-	-
Cypraeaidea	**4.10**	**0.031**	n.s.	**B > F**	n.s.

Figure 14 **Density of herbivorous sea urchins for three reef types at Andavadoaka (Mean values + S.E.)**



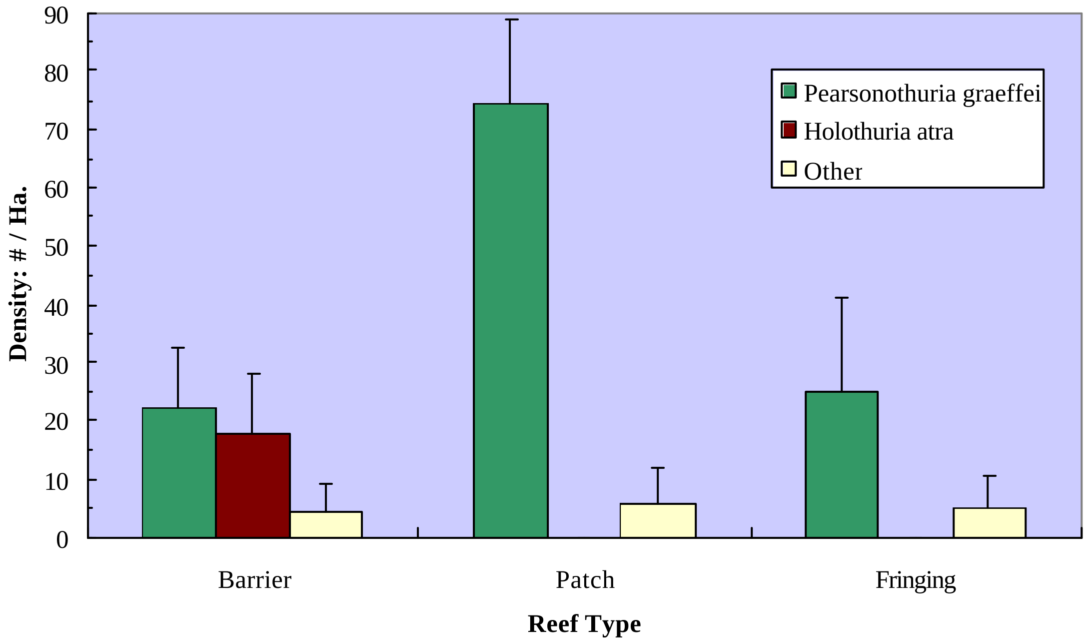
There was a highly significant difference in the densities of *Linckia* between reef types (Figure 15, Table 5). This genus dominated the sea-star fauna at most survey sites but was significantly more abundant at fringing reef sites than at the other two reef types (Table 5).

Figure 15 Densities of large starfish for three reef types at Andavadoaka (Mean values + S.E.)



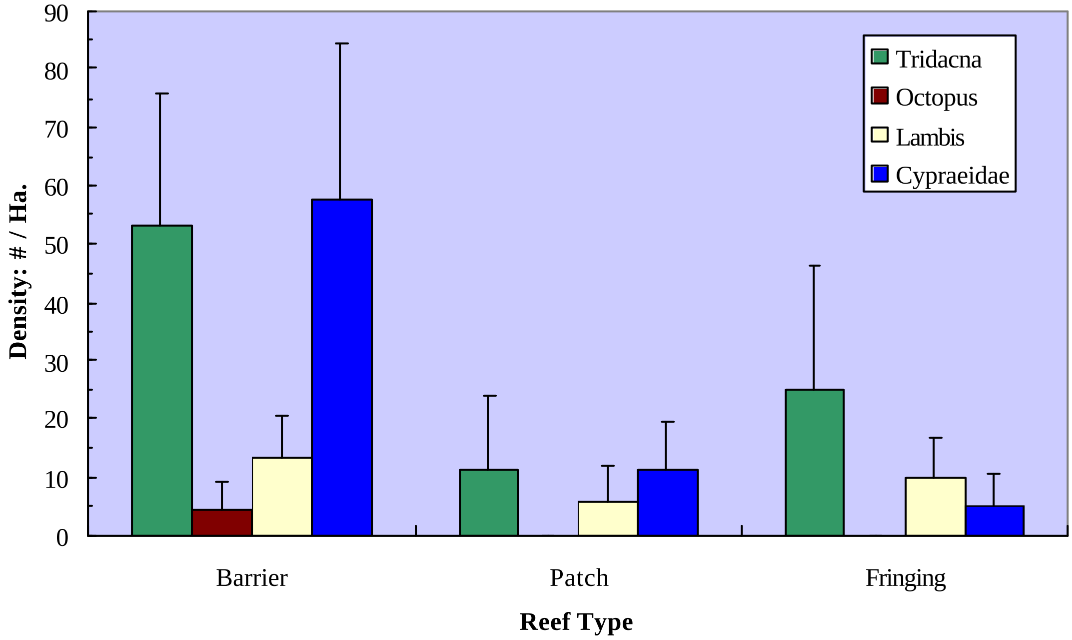
For holothurians, one species (*Pearsonothuria graeffei*) was recorded most often and was significantly more abundant at patch reef sites than at either fringing or barrier reefs (Figure 16, Table 5). Few individuals of other holothurian species were seen.

Figure 16 Holothurian densities at Andavadoaka (Mean values + S.E.)



Lastly, a comparison of molluscan densities for four selected taxa indicates that giant clams (*Tridacna*) and large cowries were recorded more often on barrier reefs. However, only large cowries, in particular *Ovula ovum*, were significantly more abundant at barrier reef sites than at fringing reefs (Table 5). Although considerably more *Tridacna* were recorded on barrier reef sites there was no significant difference in densities of giant clams between reef types.

Figure 17 **Densities of selected molluscs for reef types at Andavadoaka (Mean values + S.E.)**



DISCUSSION

Routine monitoring of coral reefs by Blue Ventures between September 2004 and June 2005 has been documented in some detail for coral reef benthic composition, reef fish abundance and macro-invertebrate density (Nadon et al., 2005). In this section we will not focus on the aspects that have been previously reported but concentrate on the more detailed information that has been collected, particularly for the types of hard coral (lifeform and genera) that are present and the biomass of the main reef fish families. Where major differences in data trends are found for similar criteria studied then these will be highlighted and discussed briefly. However, the two studies are not strictly comparable as we assessed 9 permanent sites during this study over a short time period (10 days) while Nadon et al. (2005) assessed 11 sites over a 10 month period.

Benthic Composition

Data collected for total hard coral cover is in good agreement with that collected previously by Blue Ventures (Nadon et al., 2005). The patch reef complex to the south-east of Nosy Hao reef contains the highest cover of hard corals while barrier reef sites have intermediate levels and fringing reefs the lowest cover. Patch reefs are also the most complex in terms of micro-topography which can be largely attributed to the greater range of hard coral life-forms present. The higher level of physical complexity provides a greater range of microhabitats for coral reef fauna, particularly reef fish and motile invertebrates.

Barrier reef sites were topographically complex at the macro-level with the presence of well-established spur and groove formations. The high energy environment is characterised by relatively low hard coral cover dominated by encrusting and massive colonies, more adapted to the extreme physical conditions of surge and swell in shallow waters (<10m depth). Calcified algae, particularly crustose types (CCA) are prevalent here and coverage was significantly higher for this reef type.

Fringing reef sites are the most sheltered of the three reef types and usually contain a range of hard coral lifeforms including branching, tabulate and foliose colonies. The overall low hard coral cover and lack of coral topographical diversity for fringing reefs at Andavadoaka can be attributed to previous coral bleaching events. There have been severe bleaching events caused by elevated sea surface temperatures along this coast of Madagascar in recent years, particularly in 1998 and 2000. Bleaching mortality was high and extended to a depth of 10 metres. These events have caused the rapid decline of hard coral cover on fringing reefs in the region. However, the presence of large, intact and living colonies of *Pavona clavus* along the nearshore reefs is encouraging. These areas act as localized havens for remaining reef fish populations and should be considered for protection in any management discussions.

The overall lack of *Acropora* coral cover and diversity on barrier and fringing reefs is also a symptom of previous bleaching mortality events. Usually dominant branching forms of this genus are extremely susceptible to bleaching and mortality caused by a low tolerance to temperature changes (Sheppard et al., 2000). The demise of *Acropora* after the 1998 bleaching event has been well documented in the central and Western Indian

Ocean (McClanahan, 2000; McClanahan, et al., 2001). Although more common at patch reef sites *Acropora* colonies still only covered up to 10 % of available substratum at this reef type. *Acropora* colonies on patch reefs may have been affected to a certain extent by phenomena such as bleaching or tropical storms, particularly at the slightly shallower site ('007'). A marked decrease of hard coral cover was recently observed at another patch reef site ('Fish Bowl') near Andavadoaka after the region was affected by a cyclone in January 2006 (A. Curd, pers. obs.). At barrier reef sites there was some indication of recovery with small encrusting and submassive colonies of *Acropora* present at all sites surveyed. Recovery at fringing reef sites was not evident and is a cause for concern. These nearshore reefs are the most accessible and exploited of the three reef types. It is worth considering reef restoration techniques for the nearshore reefs as a means to accelerate hard coral recovery. A potential technique involving transplanting recruits on plates is proposed by Fenner (2005) in Appendix 1.

Non-calcified algal cover was particularly high on fringing reefs. Nearshore reefs are used more intensively than offshore reefs by the local population for fishing and gleaning. One of the fringing reef sites (Half Moon) was the only location where blue-green algae was recorded at notable levels. This may be an early indicator of nutrient elevation on nearshore reefs close to areas of human habitation. Nutrient and solid waste pollution along the coast warrants further investigation and requires careful consideration in any future development plans for the region.

Reef Fish Biomass

Estimates of the biomass of the major reef fish families indicate that there are considerable differences in the composition and total weight of the reef fish fauna between reef types. Patch reefs contain the highest overall biomass of reef fish, followed by barrier reefs with fringing reefs recording the lowest levels (total for 14 families). Nearshore fringing reefs had consistently high biomass of Pomacentrids and Labrids compared to patch or barrier reefs. Other families (Acanthurids, Caesionids and Lutjanids) showed both high inter-site and intra-site variation in abundance and biomass on the same reef type suggesting that the fish fauna are patchily distributed, particularly for some Acanthurids, pelagic schooling families such as Caesionids, and more sedentary schools of Lutjanids.

Comparison with other studies of reef fish biomass in Madagascar and the Western Indian Ocean region is possible to a certain extent. Estimates of reef fish biomass in northwest Madagascar (Maharavo, 2005) are considerably higher than our estimates for Andavadoaka. Maharavo reported a mean biomass of 182.3 tons/km^2 compared to our estimates for Andavadoaka reefs of 33.5–53 tons/km^2. Although fishing pressure is likely to be higher in southwest Madagascar than in the northwest, which will explain some of the difference in estimates, it is also likely that differences in the conversion factors used to estimate biomass from fish length are causing some of the disparity.

A better comparison can be made with estimates of fish biomass for East African reefs as more similar methods were employed to calculate biomass for fish families (McClanahan, 1994; McClanahan and Kaunda-Arara, 1996). Studies in Kenya by McClanahan and co-workers have focused on the nearshore shallow lagoonal reefs which are comparable to the nearshore fringing reefs in this study. Estimates for Andavadoaka's fringing reefs

(335.6 kg/ha ± 126.9 SE) are similar to those for a moderately fished lagoonal reef in Kenya (McClanahan and Kaunda-Arara, 1996) or Tanzania (McClanahan et al., 1999). For offshore reefs (barrier and patch) our estimates of 377.4 ± 41.4 kg/ha and 530.2 ± 161.4 kg/ha respectively are comparable to those collected on seaward reefs (640 ± 170 kg/ha) at Beheloka in southwest Madagascar (Woods-Ballard et al., 2003) which were also regarded as moderately fished. Therefore we can suggest that reefs at Andavadoaka are currently subject to moderate fishing pressure with higher pressure exerted on fringing reefs than barrier reef sites. There is also considerable variation in fishing pressure between individual sites for barrier reefs depending on position and proximity to fishing villages. For example fishing effort is higher at the northern end of Nosy Hao (Valleys) than at the more exposed southern end (Shark Alley).

Estimates for Scarid biomass appear to be considerably lower at Andavadoaka on all reef types than at Beheloka (Woods-Ballard et al., 2003) or for moderately fished reefs in East Africa (McClanahan, 1994; McClanahan et al., 1999). This may be an indication that fishing pressure is beginning to significantly influence the reef fish fauna at Andavadoaka. However, more extensive monitoring work should be conducted to verify this suggestion. Some reef fish such as large piscivores (e.g. Serranids) require a larger sampling area to reliably estimate their biomass. The timed swim method was originally proposed to estimate these larger, more mobile species but was not undertaken because of a lack of trained personnel and diving limitations. We recommend that the next detailed monitoring completed at Andavadoaka undertakes timed swim assessments, as well as belt transects, to reliably estimate the biomass of larger reef fish.

Macro-Invertebrates

Timed swims are also useful for estimating densities of particular invertebrates such as holothurians, giant clams and large gastropod molluscs. Our estimates collected from belt transects were subject to considerable variation which may have been reduced for the low-density targets by using the 'timed swim' method. The variability of the data between transects contributed to the lack of significant differences in densities of targeted invertebrates between reef types (e.g. *Tridacna*). However, some differences were apparent, namely the higher density of *Linckia* seastars on fringing reefs compared to other reef types, the higher density of *Pearsonothuria graeffei* on patch reefs and the higher numbers of large cowries (*Ovula ovum*) recorded on barrier reef sites. The higher densities of *Linckia* at fringing reefs may be related to a decrease in predation of these seastars caused by reduced populations of their natural predators such as Balistids. This in turn may be an indirect effect of overfishing on the nearshore reefs at Andavadoaka. Densities of herbivorous urchins were also highest at fringing reefs and appear to be greater in shallow water (< 5m) which was not surveyed during this assessment (S. Harding; pers. obs.) but could also be an indication of overfishing of urchin predators such as Balistids and Labrids (see McClanahan and Shafir, 1990).
Sea cucumbers have been exported from Madagascar for the international market since the early 20th century (Conand and Mara, 2000). Collectors are known to operate along the coast between Toliara and Morombe with most species of sea cucumber harvested by free diving or using SCUBA. Local fishers at Andavadoaka also harvest sea cucumbers when gleaning (Langley, 2006). The higher density of *Pearsonothuria graeffei* at the patch reef sites may indicate that these small patch reefs are not yet known to collectors. Alternatively, the habitat at these sites (high hard coral cover and more complex micro-

topography) may support a higher density of this species than at the barrier or fringing reefs. However, it is known from local fishers that sea cucumber numbers have decreased dramatically since collection began, primarily on the nearshore reefs (Langley, 2006) although P. graeffei is not a species previously preferred by collectors.

One striking difference between this study and the former one documented for Andavadoaka (Nadon et al., 2005) was that we did not record a single triton shell (*Charonia tritonis*) during belt surveys whilst the aforementioned study reports that triton shells were recorded on all reef types. We assessed 6000 m^2 for invertebrate counts during this study while Nadon et al. (2005) covered 5560 m^2 but over a much longer time period. Triton shells, particularly *Charonia tritonis*, are sold in Toliara as part of the ornamental shell trade industry (Wells, 2005) and are very likely targeted in the Andavadoaka region. The difference may partly be due to seasonal changes in abundance at the sites visited but mis-identification of the species may also be a factor.

Biodiversity Assessments

The studies included with this report by Fenner, Allen and Barrere (Appendicies 1-3) provide a detailed insight into the faunal diversity of the Andavadoaka region for hard corals, reef fish and molluscs respectively. In this section we will briefly highlight a few main points from these assessments. Further detail can be found in the individual reports.

Hard Corals

A medium diversity of hard corals (164 species) was found at Andavadoaka (Fenner, 2005: Appendix 1) which was more than for previous studies in the southwest of Madagascar (113 species; Pichon, 1978) and similar to levels found in Mozambique (151 species; Reigl, 1996). However, the total was considerably less than that recorded for northwest Madagascar by Veron and Turak (2003) who reported 323 species. Of the 164 species found at Andavadoaka 4 species are regarded as rare (Appendix 1, Table 3) and were recorded across the range of reef types, 19 species were new records for Madagascar (Appendix 1, Table 4) and 16 species had their geographical ranges extended (Appendix 1, Table 5).

Only 21 species of *Acropora* were reported for Andavadoaka, which is markedly less (33%) than the total Veron and Turak (2003) recorded in north-west Madagascar (63 species). This striking fact and the lower total diversity for hard corals are most likely caused by the extensive mass bleaching events in 1998 and 2000 which occurred all along the southwest coast but did not effect the northwest coast of Madagascar.

In terms of the distribution of hard coral diversity at the sites visited at Andavadoaka similar diversity of 107 – 110 species was recorded at all three main reef types (Table 6). However, fringing reefs had the greatest number of species that were recorded at only one reef type, followed by barrier reefs and lastly patch reefs. For the latter reef type, most of these species (69%) were in one family, the Acroporidae.

Table 6 Comparison of biodiversity between main reef types for hard corals and reef fish at Andavadoaka

Taxa	Criteria	Reef Type		
		Barrier	Patch	Fringing
Hard Corals	Total No. Species	109	110	107
	No. species at one reef type	18	13	20
	% species at one reef type	16.51	11.82	18.69
Reef Fish	Total No. Species	225	174	218
	No. species at one reef type	44	21	52
	% species at one reef type	19.56	12.07	23.85

Reef Fish

The total of 386 species of reef fish recorded (Allen, 2005: Appendix 2) indicates that Andavadoaka can be regarded as a region with medium reef fish diversity. The fauna at Andavadoaka is very similar to that described for northwest Madagascar (Allen, 2003). Although fewer species were recorded at Andavadoaka, most of the species recorded only in the northwest were either rarely encountered or cryptic species collected with rotenone, which was not used in Andavadoaka. A comparison of predicted totals for reef fish using the Coral Fish Diversity Index (CFDI) after Allen (1998) indicates that similar approximate totals are expected; 529 species for Andavadoaka (Allen, 2005: Appendix 2) and 576 species for northwest Madagascar (Allen, 2003). A total of 66 species were identified at Andavadoaka which were not seen in the northwest and a total of 20 species were new records for Madagascar (Allen, 2005: Appendix 2).
A total of 3 species reported at Andavadoaka are presently endemic or near endemic to Madagascar (Table 7). In addition a new undescribed species of wrasse (*Pseudocoris* sp.) was recorded at Andravamaike, the deep offshore patch reef (Allen, pers. comm.). It is likely that other nationally or regionally endemic species may be present at Andavadoaka but were not seen during the surveys. A number of these are cryptic species which were not accurately assessed during our mission and require the use of rotenone for collection.

Table 7 Endemic or near endemic fishes of Madagascar reported at Andavadoaka

Family	Species	Known Distribution
Caesionidae	*Caesio* sp. 1	Madagascar
Pomacentridae	*Pomacentrus caeruleopunctatus*	Madagascar
Pomacentridae	*Amphiprion latifasciatus*	Madagascar & Comores

Comparison of reef fish diversity between the main reef types at Andavadoaka (Table 6) indicates that there are different species assemblages at barrier, patch and fringing reefs, which was also confirmed statistically by Nadon et al. (2005). In particular, almost one quarter (24%) of all species recorded on fringing reefs were not seen on either barrier or patch reef sites. This emphasizes the need to protect all reef types and their associated habitats in any conservation plans in order to maximize species protection.

The absence of fish species closely associated with high coral cover and diversity (the cardinalfish *Cheilodipterus artus* and the filefish *Oxymonacanthus longirostris*), that were commonly seen in northwest Madagascar, may indicate that the reduction in live hard corals through bleaching mortality at Andavadoaka has resulted in the local reduction or loss of these specialist reef fish species.

Other more obvious fish fauna were also rare or absent in the Andavadoaka region. During the monitoring trip only one white-tip reef shark (*Triaenodon obesus*) was observed while no humphead wrasse (*Cheilinus undulatus*) or bumphead parrotfish (*Bolbometopon muricatum*) were seen. There have been occasional sightings of sharks (*Galeocerdo cuvier* and *Sphyrna lewini*) at offshoe sites in the Andavadoaka region in the past (recorded in the Blue Ventures photo library) but these species sightings are very rare. Sharks are targeted by specialist local fishers for the shark fin trade (S. Andramanaitra, pers. comm.). Reef fish such as humphead wrasse and larger Serranids are also caught as bycatch in the large-mesh gill nets used by shark fishers. There are, however, regular sightings of a pair of Humphead Wrasse at 'Shark Alley' at the southern end of the Nosy hau reef (A. Curd, pers. comm.)

Molluscs

The assessment of the molluscan fauna at Andavadoaka identified 238 species at 19 sites covering a range of coastal habitats over a period of five days (Barrere, 2005: Appendix 3). The sites visited for this assessment differed slightly from the sites surveyed for coral reef monitoring and the other biodiversity assessments (hard corals and reef fish). In particular, no observations were made on the patch reef complex southeast of Nosy Hao reef. We cannot therefore make the same comparisons between sites and reef types for molluscs as were made for the other biodiversity datasets.

The total count of 238 species in five days indicates that the region has a high diversity of marine molluscs. A similar assessment in northwest Madagascar over 16 days produced a total of 525 species (Wells, 2003). It therefore follows that a more extensive assessment of molluscs in the Andavadoaka region is likely to result in a count of 400-500 species (Barrere, 2005). A full list of the species identified at Andavadoaka is available in Appendix 3.

In terms of the habitats assessed a number of notable observations were made. Firstly the shallow (0-5 m) reef flat areas around Nosy Hao and Nosy Fasy support high densities of the cowrie *Cypraea annulus*, giant clams (*Tridacna* spp.) and conch shells (*Lambis* and *Strombus* spp.). Giant clams are of particular importance as they are listed as a protected species under CITES and were observed to reach a density of 10 individuals / 100 m^2 on parts of the reef flat (Barrere, 2005). On the outer reef slopes (= barrier reef sites) a high diversity and abundance of nudibranchs was noted. A high density of bivalve molluscs (*Anadara* spp. and *Donax* spp.) was recorded in the sandy lagoonal areas between the barrier and fringing reefs. Two families were notable by their absence: Bursidae and Turridae, but this could be a factor of the limited time spent on the survey. A more extensive assessment over a longer time period is bound to substantially increase the molluscan species list for the Andavadoaka region.

Recommendations for Conservation and Management

The data collected during this study provides a detailed baseline for the condition of coral reefs at Andavadoaka for both the health and status of the main reef types and the level of biodiversity present. This information enhances the marine biological information previously collected at Andavadoaka (Nadon et al, 2005). Using some of the key findings of our assessment we can make recommendations for conservation and management of the marine environment so that sites of high biodiversity and habitats in good condition are considered for protection.

One of the main outcomes of this more detailed study is to reinforce the fact that any marine protected area (MPA) that is set up in the Andavadoaka region must incorporate all habitats across the range of reef types in order to protect the greatest number of species. Table 8 summarises the areas that should be included within one or more MPA's at Andavadoaka with justification for the protection. Although all reef habitats need appropriate conservation the patch reef complex adjacent to Nosy Hao reef is one particular location that merits full protection (i.e. no fishing) as it is the only known location with high cover of hard corals and the presence of mature colonies of Acroporidae (*Acropora* and *Montipora* spp.) in the region.

Although not fully assessed during this study the deeper offshore patch reefs should also be considered for protection in the near future which could follow on from the initial MPA designation at Andavadoaka. Our preliminary assessment at Andravamaike revealed a unique habitat diverse in soft corals and sponges which supports and attracts a rich fish fauna including large schools of *Caranx sexfasciatus* (S. Harding; pers. obs.) and large individuals of a number of families, including groupers (Serranidae), moray eels (Muraenidae) and triggerfish (Balistidae). These reefs are currently too far from land to be fished regularly by the local population but are likely to become more accessible as fishing gear improves (i.e. through the provision of outboard engines for local fishers).

Table 8 Summary of areas recommended for protection at Andavadoaka.

Reef Type / Habitat	General or Specific Location	Justification
Representative areas of all reef habitats.		Species assemblages unique to each main reef type and their associated habitats.
Patch Reef Complex	Recruitment, THB and 007 patch reefs.	High levels of: ▪ hard coral cover and diversity, particularly for Acroporids (locally) ▪ reef fish biomass (Lutjanids / Lethrinids) ▪ Targeted invertebrates (Holothurians)
Outer reef slope around offshore islands (barrier reefs)	Shark Alley / southern end of Nosy Hao reef	High reef fish diversity and biomass (Acanthurids), high densities of macro-invertebrates (e.g. *Tridacna* spp.)
Fringing reefs – areas with large *Pavona clavus* colonies	Coco Beach / south of Half Moon	Localised high hard coral cover and fish biomass.
Shallow reef flats around offshore islands	Nosy Hao / Nosy Fasy	High density of giant clams (*Tridacna* spp.). Foraging area for octopus; protection from gleaning
Deeper offshore patch reefs	e.g. Andravamaike	High reef and pelagic fish biomass, unique habitat, new / unrecorded species.

Other more general recommendations for the management of the coastal zone and its resources are as follows:

- Coral reef monitoring at the level completed for this study needs to continue on a regular basis (annually or biannually) in order to monitor coral reef status, including the effect of the proposed MPA on marine habitats and resources.
- Environmental monitoring should include an assessment of nutrient levels on nearshore reefs adjacent to local villages and resorts / hotels.
- Potential alternative sources of income for local fishers need to be further investigated and put in place if viable. Current suggestions include seaweed farming (*Eucheuma*), small-scale pearl oyster farming (*Pinctada margaritifer*) and income through tourism (local tour guides).
- Small-scale coral reef restoration projects need to be considered to determine whether it is feasible to accelerate recovery for fringing reefs, for example, through coral transplantation (see Fenner, 2005: Appendix 1).
- Octopus fisheries management through the full rotational closure of shallow reef areas needs further investigation. Results from the current practice of closing an area for 4-6 months are encouraging but may not be sufficient to maintain the fishery. Rotational closure of two or three areas over 12 months will ensure that an area of reef flat is always closed to octopus fishing at any one point in time.
- Fisheries management practices should be considered and incorporated into the multiple zoning scheme for the MPA. Destructive fishing practices such as beach seine netting need to be controlled or stopped completely.
- Existing coastal conservation programs in Madagascar should be further consulted to learn 'best practise' for the successful execution of management plans at Andavadoaka. Examples are MPA management at Masoala and Mananara-Nord National Parks and coastal zone management in Antongil Bay.
- The capacity for local communities to manage their own MPA's and fishing co-operatives needs to be increased through appropriate training schemes and workshops.
- A regional management committee representing local stakeholders (fishers, tourism operators etc.) and interested parties (e.g. NGO's, local government, commercial fishing companies) should be considered for the Andavadoaka coastal zone.

It is likely that a combination of full and partial protection of marine areas at Andavadoaka will be the most acceptable solution for stakeholders and project partners. A zoning scheme incorporating permanent no-take areas with limited fishing (gear or time restrictions) and open access areas is recommended. The details of position and designation will need to be discussed in depth with the fishing communities involved and factors such as existing fishing grounds, local customs and taboos (fady's) all need to be taken into account. It is very important that the final management plan for the region is a combination of conservation recommendations and the wishes of the local stakeholders. It is also critical that the local communities completely understand why conservation measures are being put in place, fully support the idea of an MPA and are completely involved in the designation and management processes.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Allen, G. R. 1998. Reef Fishes of Milne Bay Province, Papua New Guinea. *In*: Werner, T. B. and G. R. Allen (eds.). A Rapid Marine Biodiversity Assessment of the coral reefs of Milne Bay Province, Papua New Guinea. Bulletin of the Rapid Assessment Program 11. Conservation International. Washington, DC.

Allen, G.R. 2003. Reef Fishes of Northwestern Madagascar. *In*: McKenna S.A. and G.R Allen (eds.). A Rapid Marine Biodiversity Assessment of Northwest Madagascar. Bulletin of the Rapid Assessment Program 31, Conservation International, Washington, DC.

Conand, C. and Mara E. 2000. Sea Cucumbers in the Southwest of Madagascar.: Problems of the Fishery and Sustainable Management. *In* Coral Reefs of the Indian Ocean, Their Ecology and Conservation, eds. T. R. McClanahan, C. R. C. Sheppard and D. O. Obura, pp. 436-437. Oxford University Press, New York.

Fabricus, K. and Alderslade, P. 2004. Soft Corals and Sea Fans: A Comprehensive Guide to the tropical shallow-water genera of the Central-West Pacific, the Indian Ocean and the Red Sea. 272 pp. Australian Institute of Marine Science, Townsville, Australia.

Harding, S., Lowery, C., and Oakley, S. 2002 Comparison between complex and simple reef survey techniques using volunteers: is the effort justified? Proceedings of the Ninth International Coral Reef Symposium, Bali, 23-27 October 2000, Volume 2. pp: 883-889.

Hill, J and Wilkinson, C. 2004. Methods for Ecological Monitoring of Coral Reefs – A Resource for Managers. Australian Institute of Marine Science, Townsville, Australia. 117 pp.

Langley, J. 2006. Vezo Knowledge: Traditional Ecological Knowledge in Andavadoaka, southwest Madagascar. 73 pp. Blue Ventures Conservation. London, U.K.

Littler, D.S. and Littler, M.M. 2003. South Pacific Reef Plants. A divers' guide to plant life of the south pacific coral reefs. Offshore Graphics, Washington D.C. 331 pp.

Maharavo, J. 2003. Fisheries of Northwest Madagascar. *In*: McKenna S.A. and G.R Allen (eds.). A Rapid Marine Biodiversity Assessment of Northwest Madagascar. Bulletin of the Rapid Assessment Program 31, Conservation International, Washington, DC.

McClanahan, T.R. 1994. Kenyan coral reef lagoon fish: effects of fishing, substrate complexity, and sea urchins. Coral Reefs 13: 231-241.

McClanahan, T.R. 2000. Bleaching damage and recovery potential of Maldivian coral reefs. Marine Pollution Bulletin 40: 587-597.

McClanahan, T.R. and Shafir, S.H. 1990. Causes and consequences of sea urchin abundance and diversity on Kenyan coral reef lagoons. Oecologia 83: 362-370.

McClanahan, T.R. and Kaunda-Arara, B., 1996. Creation of a coral-reef marine park: Recovery of fishes and its effect on the adjacent fishery. Conservation Biology 10: 1187-1199.

McClanahan, T.R., Kamukuru, A.T., Muthiga, N.A., Gilagabher Yebio, M. and Obura, D. 1996. Effect of sea urchin reductions on algae, coral and fish populations. Conservation Biology 10: 136-154.

McClanahan, T.R., Muthiga, N.A., Kamukuru, A.T., Machano, H. and Kiambo R. 1999. The effects of marine parks and fishing on the coral reefs of northern Tanzania. Biological Conservation 89: 161–182.

McClanahan, T.R., Muthiga, N.A. and Mangi, S. 2001. Coral and algal response to the 1998 coral bleaching and mortality: interaction with reef management and herbivores on Kenyan reefs. Coral Reefs 19: 380-391.

Mumby P.J., Harborne A.R., Raines P.S. and Ridley J.M. 1995. A Critical Assessment of Data Derived from Coral Cay Conservation Volunteers. Bull Mar Sci, 56(3): 737-751.

Nadon, M.-O., Griffiths, D. and Doherty, E. 2005. The coral reefs of Andavadoaka, southwest Madagascar. 30 pp. Blue Ventures Conservation, London, U.K.

Pichon, M. 1978. Recherches sur les peuplements à dominance d'Anthozoaires dans les récifs corallines de Tuléar (Madagascar). Atoll Research Bulletin 222: 1-447.

Richmond, M.D. (ed.). 2002. A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands. 461 pp. SIDA/SAREC – USDM.

Riegl, B. 1996. Hermatypic coral fauna of subtropical Southeast Africa: a checklist. Pacific Science 50: 404-414.

Sheppard, C. R. C., Wilson, S. C., Salm, R. V. and Dixon, D. 2000. Reefs and coral communities of the Arabian Gulf and Arabian Seas. *In* Coral Reefs of the Indian Ocean, Their Ecology and Conservation, eds. T. R. McClanahan, C. R. C. Sheppard and D. O. Obura, pp. 257-294. Oxford University Press, New York.

Veron, J. E. N. 2000. Corals of the World. Volumes 1-3. Australian Institute of Marine Science, Townsville, Australia.

Veron, J.E.N and Turak, E. 2003. Zooxanthellate Scleractinia of Madagascar. *In*: McKenna S.A. and G.R Allen (eds.). A Rapid Marine Biodiversity Assessment of Northwest Madagascar. Bulletin of the Rapid Assessment Program 31, Conservation International, Washington, DC.

Wells, F.E. 2003. Molluscs of Northwestern Madagascar. *In*: McKenna S.A. and G.R Allen (eds.). A Rapid Marine Biodiversity Assessment of Northwest Madagascar. Bulletin of the Rapid Assessment Program 31, Conservation International, Washington, DC.

Woods-Ballard, A.J., Chiaroni, L.D. and Fanning E., 2003. Fin-fish resource use: artisanal fisheries of Beheloka. Frontier Madagascar Environmental Research Report 11**.** Society for Environmental Exploration, U.K. and L' Institut Halieutique et des Sciences Marines, Toliara, Madagascar.

APPENDICIES

APPENDIX 1

Hard Coral Diversity Survey, Andavadoaka, Southwest Madagascar.

Report for the Wildlife Conservation Society Marine Program, Madagascar and Blue Ventures, UK as part of the Andavadoaka Project.

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Executive Summary

- A list of corals was compiled for 10 sites near Andavadoaka, SW Madagascar. The survey involved about 20 hours of scuba diving by D. Fenner to a maximum depth of 31.5 meters.

- The reefs of the Andavadoaka area have a medium diversity coral fauna. A total of 164 species in 55 genera of hard corals (155 species and 50 genera of zooxanthellate Scleractinia) were observed during the present survey, including seven species that were found only in the Blue Ventures coral collection on site. This is slightly more than found by the author in a similar study at Rodrigues Island, Mauritius (140 species in 40 genera). It is also much more than the total known in Hawaii (66: Fenner, 2005). However, it is less than the number found in similar studies by the author in American Samoa (220 species), in Danjugan (236), and Cagdanao (234) Philippines, Leyte Island, Philippines (264), and eastern Australia (257), and significantly less than from eastern Papua New Guinea (332). However, these numbers do not reflect equivalent search time, area, or effort. The number 164 is approximate, due to difficulties in identifying corals.

- The total number of Scleractinian species found (155) in this study is more than that found in the first study of the Tulear region (113 species: Pichon, 1978), and in South Africa (96 species: Riegl, 1996), and similar to that reported from southern Mozambique (151 species: Riegl, 1996), but considerably less than the 323 species found by Veron and Turak (2003) in northwestern Madagascar, or the total known from Madagascar (380). The corals on the reefs of SW Madagascar have suffered considerable damage from mass coral bleaching in 1998 and 2000. Coral cover was reduced a great deal, making it much more difficult to find some species, and possibly making some species locally extinct. The damage to coral populations may have contributed to the low species count. Coral populations in the north are reported to be in good condition (Veron and Turak, 2003; S. Harding, personal comm.) In addition, there may be a latitudinal gradient within Madagascar, though a latitudinal gradient is not apparent in reef fish diversity data (G. Allen, personal comm.), so this seems less likely. In addition, the different studies did not have equivalent search time, area, effort, or personnel.

- The number of species found after 10 one-hour dives at different sites was 133 species, which is much more than in Hawaii after the same number of dives (about 35), more than in Rodrigues (98 species), slightly less than in American Samoa (147), less than in Peninsular Malaysia (166), Sarawak, Malaysia (170), the Andaman Islands (180), the Great Barrier Reef (190), Fiji (203), and the average of 12 sites in the Coral Triangle (222 species). The number in Madagascar after 10 dives was 60% of that in the average Coral Triangle site.

- The number of species at individual sites ranged from 28 to 64, with an average of 49 per site. In Rodrigues, there was an average of 34 species per site. Sites in Hawaii average about 18 species per site, Fiji averages 70 species per site, and both American Samoa and eastern Australia average 71 species per site. The average number per site for 13 areas in the "Coral Triangle" area of highest diversity was 94.4 species per site. Thus, the diversity was 52% of that in the area of highest diversity, and 2.7 times as diverse as a low diversity area (Hawaii), and 44% higher than that in Rodrigues.

- The coral diversity of SW Madagascar is much greater than in Hawaii, greater than in Rodrigues, but less than that in Malaysia, the Andaman Islands, American Samoa, Fiji, the Great Barrier Reef, and the Coral Triangle.

- 53% of the species found have ranges that extend north, west and east, 30% have ranges that extend in all four directions, 14% have ranges that extend north and east, and 2.5% have ranges that extend only eastward.

- 44% of the species shown by Veron (2000) to have SW Madagascar within their range were found in this study, but only 24% of the *Acropora*. *Acropora* is one of the most sensitive genera to bleaching. The lower percentage of *Acropora* found is consistent with the possibility that mass coral bleaching had removed some species or made them so rare that they could not be found in a brief study. This is consistent with the finding of G. Allen that fish diversity is similar to that in northern Madagascar, and suggests that the cause of the low diversity finding is mass bleaching, not a latitudinal gradient within Madagascar.

- *Acropora*, *Fungia*, *Montipora*, *Favia*, *Porites*, *Pavona*, and *Goniastrea* were the genera richest in species, with 21, 10, 9, 7, 6, 6, and 6 species, respectively. This is typical of rich Indo-Pacific reefs, except that *Montipora* normally has more species than *Fungia*, and *Porites* more species than *Favia*. Mass bleaching may have caused differential mortality in some of these genera, causing deviations from the normal relative generic diversity.

- The overwhelming majority (95%) of corals on these reefs are zooxanthellate Scleractinia, with only a few non-scleractinian and azooxanthellate species, as is typical of Indo-Pacific reefs.

- 4 rare species were found.

- A total of 16 species were found which are outside the published ranges for those species.

- A total of 19 species were found which were not previously reported for Madagascar, bringing the total number of species of coral known in Madagascar to 400 species. Several of the 20 identifications are tentative.

- Four species were found that could only be identified to genus, and may possibly be new species. Much more study will be required to determine if they are new species, including collecting samples and studying their cleaned skeletons. Some of these may be previously named but not be well known.

- General observations revealed that most of the reefs had been devastated by mass coral bleaching and undergone a phase shift from coral to algae, but that the Recruitment patch reefs were in very good shape. A high priority would be to protect the patch reefs so they may help reseed surrounding reefs. Since they survived the previous mass bleaching for unknown reasons, they may also be more resilient to future mass bleaching, which is another reason to protect them. There is an urgent need to increase herbivores by reducing fishing and decrease nutrient runoff from villages and resorts. Doing so might help bring the algae under control and increase coral settlement, and would increase resilience to further coral deaths from future events.

Introduction

The following is a report of the reef coral fauna of 10 sites in the Andavadoaka area of SW Madagascar, based on results of the author's observations during a visit to the Blue Ventures base at Coco Beach Resort near Andavadoaka village in November and December, 2005, organised and sponsored by the Wildlife Conservation Society Marine Program Madagascar and part funded by Conservation International..

The principle aims of the coral survey was to provide an inventory of the coral species growing on reefs and associated habitats and compare the coral fauna on different sites. The primary group of corals is the zooxanthellate scleractinian corals, that is, those that contain single-cell algae and which contribute to building the reef. Also included are a small number of zooxanthellate non-scleractinian corals which also produce large skeletons which contribute to the reef (e.g., *Millepora* and *Tubipora*: fire coral and organ-pipe coral, respectively), and a small number of azooxanthellate scleractinian corals (in genus *Tubastrea*). And lastly, there are a few azooxanthellate non-scleractinian corals (*Distichopora, Stylaster*). All produce calcium carbonate skeletons that contribute to reef building to some degree.

The results of this survey facilitate a comparison of the faunal richness of the reefs of SW Madagascar with those of northern Madagascar, Rodrigues Island (Mauritius), the Coral Triangle area (Philippines, Indonesia and Papua New Guinea), and Hawaii, American Samoa, the Great Barrier Reef, and Fiji in the Pacific. However, the list of corals presented below is incomplete, due to the limited number of dives in the survey (about 20 hours of diving and snorkeling at 10 sites), the highly patchy distribution of corals and the difficulty in identifying some species in the water. Corals are sufficiently difficult to identify that there are significant differences between leading experts on some identifications. Visual identifications are tentative and require confirmation from microscopic examination of the cleaned skeletons of collected specimens.

Methods

Corals were surveyed in about 20 hours of diving in 20 scuba dives by D. Fenner to a maximum depth of 31.5 m. Lists of coral species were recorded at 10 sites, which were dove an average of 2 times each. The basic method consisted of underwater observations, during one 60 minute dive. At the deepest site, dives were limited to about 35 minutes. The name of each species identified was marked on a plastic sheet on which species names were printed. A direct descent was made in most cases to the maximum depth of the reef, which varied from about 10 to 25 m depth. The bulk of the dive consisted of a slow ascent along the reef in a zigzag path to the top of the reef. Sample areas of all habitats encountered were surveyed. Many corals can be identified to species with certainty in the water and a few must be identified alive since they cannot be identified without living tissues. Also, there are some that are easier to identify alive than from skeletons. However, some are difficult to identify in the field or require confirmation from collected specimens. Field guides assisted identification (Veron and Stafford-Smith, 2002; Veron, 2000; Wallace, 1999ab). Additional references supporting identification are listed in references (Best & Suharsono, 1991; Boschma, 1959; Cairns & Zibrowius, 1997; Claereboudt, M. 1990; Dai, 1989; Dai & Lin 1992; Dineson, 1980; Fenner, in preparation; Hodgson, 1985; Hodgson & Ross, 1981; Hoeksema, 1989; Hoeksema &

Best, 1991; Hoeksema & Best 1992; Moll & Best, 1984; Lamberts, 1982; Nemenzo 1986; Nishihira, 1986; Ogawa & Takamashi, 1993, 1995; Randall & Cheng, 1984: Sheppard & Sheppard, 1991; Suharsono, 1996; Veron, 1985, 1986, 1990, 2000; Veron & Nishihira, 1995; Veron & Pichon 1976, 1980, 1982; Veron, Pichon & Wijman-Best, 1977; Wallace 1994, 1997a, Wallace & Wolstenholme 1998). Dive sites are listed in Table 1. The site names are mainly those given by Blue Ventures and correspond to monitoring sites, with the exception of Andraviamaike.

Table 1: Dive sites and numbers of coral species found.

Dive No.	Location; Site Name	Reef Type	No. of coral species
1	Shark Alley	Barrier	50
2	Coco Beach	Fringing	40
3	Nosy Fasy	Barrier	62
4	Nosy Fasy	Barrier	43
5	Andraviamaike	Offshore Deep Patch	28
6	Shark Alley	Barrier	34
7	THB	Patch	42
8	THB	Patch	54
9	Valleys	Barrier	64
10	Valleys	Barrier	63
11	Coco Beach	Fringing	39
12	Coco Beach	Fringing	29
13	Andavadoaka Rock	Fringing	57
14	Andavadoaka Rock	Fringing	45
15	007	Patch	51
16	007	Patch	57
17	Recruitment	Patch	57
18	Recruitment	Patch	55
19	Half Moon	Fringing	66
20	Half Moon	Fringing	50
21	Andraviamaike	Offshore Deep Patch	Not Recorded

Results

A total of 164 species in 55 genera of hard corals (155 species and 50 genera of zooxanthellate Scleractinia) were found in the survey of these reefs, (Appendix A). All of these species are illustrated in Veron (2000) and Veron and Stafford-Smith (2002). The total of 164 species is more than that found in the first study of the Tulear region (113 species: Pichon, 1978), and in South Africa (96 species: Riegl, 1996), and similar to that reported from southern Mozambique (151 species: Riegl, 1996), but much less than the 323 species found by Veron and Turak (2003) in northwestern Madagascar, and much less than the total of 380 species known from Madagascar (Veron and Turak, 2003). It is, however, slightly more than that found by the author in a similar study at Rodrigues Island, Mauritius (140 species in 40 genera: Fenner et al 2004). It is also much more than the total known in Hawaii (66: Fenner, 2005). It is less than the number found in similar studies in American Samoa (220 species), in Danjuan (236) and Cagdanao (234)

Philippines, Leyte, Philippines (264), and eastern Australia (257), and significantly less than from eastern Papua New Guinea (332). However, many more dives were made in these other surveys, and additional dives increase the number of species found. The present numbers of species are approximate, due to the difficulty in identifying coral species in the water, and the fact that only a few skeletons in a pre-existing collection were examined.

The number of species found after 10 one-hour dives on 10 different sites (counting only the first dive on each site) was 133 species, which is much more than the number found after the same number of hours diving in Hawaii (about 35), more than in Rodrigues (98 species), slightly less than in American Samoa (147), less than in Peninsular Malaysia (166), Sarawak, Malaysia (170), the Andaman Islands (180), the Great Barrier Reef (190), Fiji (203), and the average of 12 sites in the Coral Triangle (222 species). The number in Madagascar after 10 dives was 60% of that in the average Coral Triangle site. These comparisons are much better than those of the total number of species found, since the number of dives and sites was equated, and the same researcher collected all the data. The number of dives or amount of search effort is a particularly powerful variable and must be equated for a valid comparison.

The number of species at individual sites ranged from 28 to 64, with an average of 49 per site. In Rodrigues, there was an average of 34 species per site. Sites in Hawaii average about 18 species per site, Fiji average 70 species per site, and both American Samoa and eastern Australia average 71 species per site. The average number per site for 13 areas in the "Coral Triangle" area of highest diversity was 94.4 species per site. Thus, the diversity was 52% of that in the area of highest diversity, and 2.7 times as diverse as a low diversity area (Hawaii), and 44% higher than that in Rodrigues. The average number of corals found per site, like the number of species found in 10 sites, is equated between these studies, to make a valid comparison. The two methods produce similar results, with 52 and 60% of the diversity in the Coral Triangle.

The coral diversity of SW Madagascar is much greater than in Hawaii, greater than in Rodrigues, but less than that in Malaysia, the Andaman Islands, American Samoa, Fiji, the Great Barrier Reef, and the Coral Triangle. Hawaii is very far east in the Pacific and thus far down the longitudinal diversity gradient in the Pacific, and it is also very isolated. It is not clear why SW Madagascar should have higher diversity than Rodrigues Island. The diversity also appears to be much less than in Northern Madagascar.

The reefs of SW Madagascar suffered considerable loss of live coral during the mass bleaching episodes of 1998 and 2000 (S. Harding, personal comm.). This was apparent in the very low coral cover of most reefs, with some appearing to have lost as much as 99% of their coral cover. The Recruitment group of patch reefs is unusual for Andavadoaka reefs in that it retains very high live coral cover of about 60% (Nadon *et al*., 2005). The loss of much of the living coral during mass coral bleaching may have driven some coral species close to local extinction, making them much harder to find, that is making the number of species found within a fixed search time such as a one hour dive, much lower. In the present study, 44% of the species shown by Veron (2000) to have SW Madagascar within their range were found in this study, but only 24% of the *Acropora* species. *Acropora* is one of the most sensitive genera to bleaching. G. Allen reports that the diversity of reef fish he found in SW Madagascar to be very similar that he found in NW Madagascar (G. Allen, personal comm.). In NW Madagascar, live coral cover is reported to be much better (Veron and Turak, 2003; S. Harding, personal comm.). Fish would not be affected by mass coral bleaching like coral populations are. All of these facts are consistent with the view that the lower diversity of corals found in SW Madagascar compared to northern Madagascar is due to mass coral bleaching in the southwest, not due to a latitudinal diversity gradient within Madagascar.

General faunal composition

The coral fauna consists mainly of Scleractinia. The genera with the largest numbers of species found were *Acropora, Fungia, Montipora, Favia, Porites, Pavona* and *Goniastrea.* These seven genera account for about 21% of the total observed species (Table 2). (Families are less stable and useful in corals than genera, and thus were not used.)

Table 2: Genera with the greatest number of species

Rank	Genus	No. of species
1	Acropora	21
2	Fungia	10
3	Montipora	9
4	Favia	7
5	Porites	6
6	Pavona	6
6	Goniastrea	6

Acropora, *Montipora*, and *Porites* are usually the three most species-rich genera on rich Indo-Pacific reefs. The farther down the list one moves, the more variable the order becomes, with both the number of species and the differences between genera decreasing.

Most of the corals were zooxanthellate (algae-containing, reef-building) Scleractinian corals, with 95% of the corals in this group. There were two species that are azooxanthellate (lacking algae) Scleractinia for 1% of the total, and there were seven corals that were not Scleractinia, for 4% of the total.

Zoogeographic affinities of the coral fauna

The reef corals of SW Madagascar reefs belong to the overall Indo-west Pacific faunal province, which stretches from the Red Sea and eastern Africa to the Pacific coast of the Americas. A few species span the entire range of the province, but most do not. The area of highest biodiversity in corals ("Coral Triangle") appears to be an area enclosing the Philippines, central and eastern Indonesia, and northern (Hoeksema, 1992) and eastern Papua New Guinea and the Solomon Islands. Diversity declines in all directions from this center, reaching low levels in Hawaii and even lower levels on the Pacific coast of the Americas.

The biodiversity of corals falls off from the Coral Triangle in all directions, reaching 80 species at an island near Tokyo, 65 species at Lord Howe Island southeast of Australia, about 66 species in Hawaii, and about 20 species at Pacific Panama. Species fall-off is significantly less to the west in the Indian Ocean and Red Sea. About 300 species may currently be known in the Red Sea, though this area, like many others, is insufficiently studied to provide accurate figures.

Most coral species found in this area have fairly wide distributions within the Indo-Pacific. A majority of corals have a pelagic larval stage, with a minimum of a few days pelagic development for broadcast spawners (a majority of species), and larval settling competency lasting for at least a few weeks. A minority of species release brooded larvae that may be capable of anything from immediate settlement to a long pelagic dispersal period. 53% of the species found have ranges that extend north, west and east, 30% have ranges that extend in all four directions, 14% have ranges that extend north and east, and 2.5% have ranges that extend only eastward.

Estimate of total diversity

The total number of coral species in SW Madagascar can be estimated by looking at the percentage of the species for which SW Madagascar is within their known range as shown in Veron (2000) which were found in this study. 44% of the species shown to be within their known range in SW Madagascar were found in this study. Dividing the number of species found (164) by 0.44 gives a total of 373 species, which is close to the total known in Madagascar (Veron and Turak, 2003). This depends on the ranges shown in Veron (2000) to be accurate, however, range extensions to these maps are frequently found by the author and others. Thus, the total eventually found is likely to be higher than 373 species, and indeed with the present report the total is now 400 and likely to go higher.

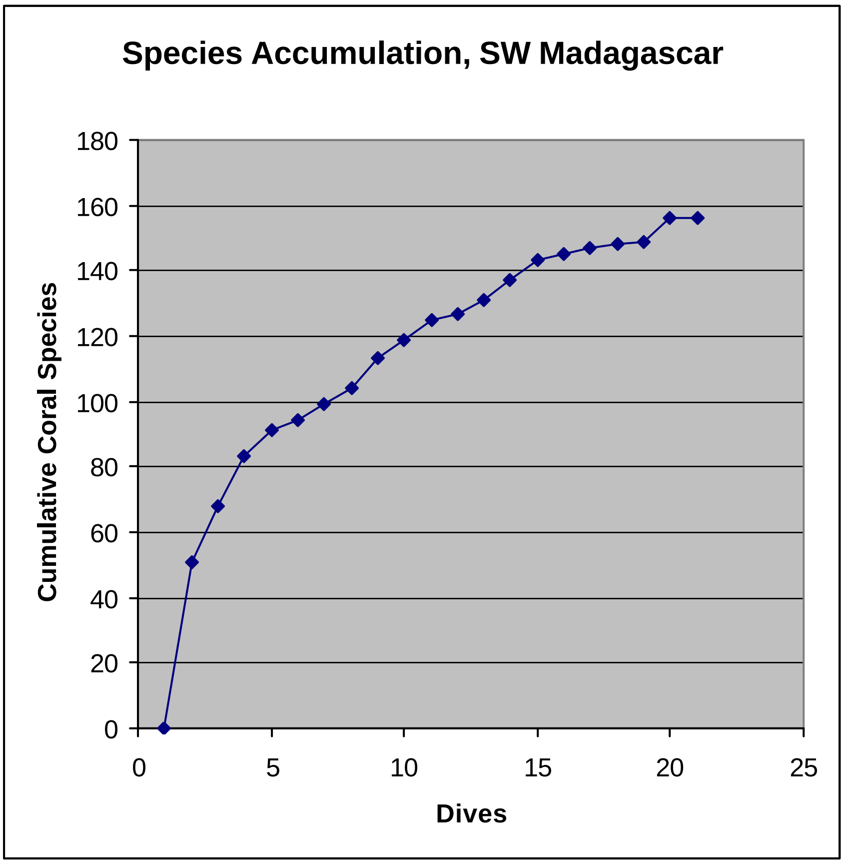
Diversity at individual sites

The number of coral species was highest at Half Moon and Valleys, with 66 and 64 species, respectively. The number of coral species was lowest at Andraviamaike and Coco Beach, with 28 and 29 species, respectively. The dive on Andraviamaike was shorter than on other reefs, reducing the number of species found, and Coco Beach fringing reef had some of the lowest coral cover, making it harder to find many species.

The number of species at all sites is presented in Annexe I.

Species are found quickly at first, but additional species are found at a slower and slower pace as more species are found. Thus there are diminishing returns for additional work, yet species continue to be found.

Figure 1:



Habitats and Reefs

Corals are habitat-builders and appear to have less niche-specialization than some other groups. Some zonation occurs by depth and exposure to waves or currents. Thus, there are a few corals that are restricted to zones such as very shallow areas, protected areas, deep water, shaded niches, soft bottoms, or exposed areas. However, many corals can be found over a relatively wide range of exposure and light intensity. Corals are primarily autotrophic, relying on the products of the photosynthesis of their symbiotic algae, supplemented by plankton caught by filter-feeding and suspension feeding. Most require hard substrate for attachment, but a few grow well on soft substrates.

The reefs in this study could be divided into fringing, barrier, patch, and deep reefs. The reefs around offshore islands were considered barrier reefs. The fringing reefs averaged 47.8 coral species per dive, the barrier reefs averaged 52.7 species per dive, the patch reefs averaged 52.7 species per dive, and the deep reef had 28 species in the one short dive on it. A one-way ANOVA for the first three groups gave an F of .39 and p = .68, so the differences were not significant.

Dominant Species

Coco Beach fringing reef had a large mass of *Pavona clavus*, and also a large mass of *Galaxea astreata* columns. THB patch reef also had a mass of *Galaxea astreata* columns. 007 patch reef had fields of foliose *Montipora aequituberculata* and a large mass of *Pavona clavus*. The patch reefs had significant areas of *Porites cylindrica* and a fuzzy branching *Porites* species that was unidentified. At the base of some of the fringing reefs there were significant patches of unattached *Goniopora stokesi* colonies. This species forms small "polyp balls" that have a ball of skeleton in the center, which detach from the parent colony and start a new colony. The patches are likely to be clones, though two tentacle shapes could be distinguished, blunt and thin. The patch reefs especially, and the barrier reefs also, had high amounts of dead coral substrate covered with algae. On the patch reefs, much of it appeared to be dead staghorn *Acropora*, though near the columnar *Galaxea astreata* there were areas of dead columns that were likely from *Galaxea astreata.* This all appeared to be due to the mass coral bleaching in 1998 and 2000.

Species of special interest

Stylophora madagascarensis, a species so far known only from Madagascar (though only described in 2002 and quite possibly will be found outside Madagascar), was quite common. It was described by Veron from the Tulear region, but not found in northwestern Madagascar by Veron and Turak (2003) at all. *Acropora branchi*, which has a small known range extending from South Africa to SW Madagascar, was found on the patch reefs in small numbers. *Horoastrea indica* was not seen in this study, although one sample is in the Blue Ventures collection. Veron and Turak (2003) reported it was common in northwestern Madagascar, but Veron (2000) did not find it at all in Tulear. This is consistent with the findings here.
Several species where found that are uncommon to rare, which are listed in Table 3. All were documented with photographs. *Leptoseris incrustans* and *Millepora foveolata* were rare in the author's previous research. *Millepora foveolata* is cryptic and difficult to recognize. *Montastrea serageldini* and *Plesiastrea devantieri* are recently described corals (Veron, 2002), which the author had not seen before. *P. devantieri* particularly may not be rare. A puzzling coral that appears similar but not identical to *Blastomussa merleti* may be the new species of *Blastomussa* referred to in Veron and Turak, 2003. It was quite common.

Table 3: Rare Corals

1. *Leptoseris incrustans*
2. *Montastrea serageldini*
3. *Plesiastrea devantieri*
4. *Millepora foveolata*

Twenty species were found that have not been reported previously from Madagascar. Non-scleractinian corals have not been reported previously from Madagascar.

Table 4: New reports for Madagascar (not reported in Veron and Turak, 2003).

"x" indicates a single sighting or tentative identification; "y" indicates a photograph, "z" a skeleton examined.

1.	*Acropora crateriformis*	x, y
2.	*Acropora vaughani*	x
3.	*Montipora capitata*	x, y

4. *Montipora corbettensis*	y
5. *Montipora incrassata*	x
6. *Montipora vietnamensis*	y
7. *Goniopora fruiticosa*	x
8. *Mycedium robokakai*	x, y
9. *Acanthastrea subechinata*	x, y
10. *Favia bestae*	y
11. *Favia rotundata*	y
12. *Goniastrea favulus*	x, y
13. *Tubipora musica*	
14. *Millepora dichotoma*	
15. *Millepora exesa*	
16. *Millepora foveolata*	y, z
17. *Millepora intricata*	y
18. *Distichopora violacea*	
19. *Stylaster sp.*	

Table 5 presents species for which the present SW Madagascar report is an extension of the range shown in Veron (2000) or given in Randall and Cheng (1984) for that species.

Table 5: Range Extensions

1. *Acropora crateriformis*
2. *Montipora capitata*
3. *Montipora capitata*
4. *Montipora vietnamensis*
5. *Fungia granulosa*
6. *Fungia moluccensis*
7. *Acanthastrea subechinata*
8. *Scolymia vitiensis*
9. *Diploastrea heliopora*
10. *Favites bestae*
11. *Leptastrea pruinosa*
12. *Montastrea serageldini*
13. *Oulophyllia bennettae*
14. *Plesiastrea devantieri*
15. *Millepora intricata*
16. *Millepora foveolata*

A total of four species were recognized which could not be identified to species. Some of these may be discovered to already be named, with their names hidden in obscure literature. There was one species of *Acropora*, two of *Porites*, and one of *Coscinaraea*. In addition, there were a several photographs of corals that could only be identified to genus. There may be new species among these, particularly the *Coscinaraea*, since Veron and Turak (2003) indicates that he found a new species of *Coscinaraea*. Considerable time and work, including examining skeletons of samples, will be necessary to document these.

Overview of the coral fauna

The coral fauna of SW Madagascar was quite a bit less than that reported from northern Madagascar. All the evidence indicates that this is because mass coral bleaching in 1998 and 2000 killed large amounts of some kinds of corals, making some species rare enough to be very hard to find, or perhaps locally extinct. The overall level of diversity that remains was intermediate, about 52-60% of that of sites in the Coral Triangle area of highest diversity. Nearly 400 species may eventually be found in Madagascar.

Other observations

The only coral disease observed was a colony with some small circular, uniform, white spots, about 1 cm diameter. There is a "White Patch" syndrome on corals that is widespread, but is not known to cause the death of the affected part of the coral. The patches are usually larger than these white spots, about 3-10 cm in diameter, and they are usually polygonal but can be round or oval. These white spots appear to be no threat at all, and in fact the lack of any other coral disease was surprising good news. Many Pacific reefs now have noticeable numbers of diseased corals, such as the author has observed in American Samoa and the Philippines. The most common lethal disease is "White Syndrome," where a band of white moves across a table coral, often in a wedge going around it, followed by a gradient of increasing growth of filamentous green algae. The other common disease is growth abnormalities, often called neoplasms or cancers. They are usually non lethal.

The author saw and photographed "CLOD" = Coralline Lethal Orange Disease. It was seen only once, but the observation and photo are very clear and there is no doubt about the identification. This appears to be a major range extension of this disease, since it was first discovered in the South Pacific and still only known from the Pacific. The disease is caused by a bacterium. The author will be publishing this in an article with Dr. Greta Aeby. Although it has reduced coralline algae considerably in Fiji, it is not known to have caused problems elsewhere. It has been moderately common in American Samoa for quite a while, yet crustose coralline algae continue to have healthy populations there and dominate reef slopes. It does not appear to be a threat.

The author also observed and photographed the "golden noodle algae," *Chrysocystis fragilis*, which has recently been reported to bloom each summer on the Great Barrier Reef. It is in a group of algae called "golden algae" or Chrysophytes, which are so poorly known and rarely reported that they are not even included in algae identification guides. The author has observed it elsewhere, and the observation here is a major range extension for this species. It is not yet known to cause problems. This will also be announced in a publication.

The author also saw and photographed the Skunk Anemonefish, *Amphiprion akallopisos*. This will be used to aid the identification of a similar looking anemonefish in American Samoa, along with photos of *A. sandaracinos* from the Philippines.

General Observations

Most of the reefs in the area have been badly damaged by mass coral bleaching. They have undergone a phase shift from coral reefs to algae beds. The Recruitment patch reef group retains very high live coral cover, however. The Recruitment patch reef group has the potential to help reseed other nearby reefs with corals, and so should receive a high

priority for conservation measures. In addition, since for some unknown reason they survived the mass coral bleaching, they may be more resilient than the other reefs. Conserving them may keep at least some reefs in the area healthy for as long as possible, helping to reseed other reefs. The mass coral bleaching is not the fault of the people of Madagascar, and is largely outside the control of anyone there. The dead coral is colonized with algae, with few new coral recruits. The few dead corals on the Recruitment reefs have many vigorous new recruits on them, supporting the view that these reefs are largely self-seeding, even though reefs are only a few kilometers apart. Settlement plates placed at different distances from the Recruitment reefs might reveal a pattern showing the source of recruits to be at the Recruitment reefs (as with the Helix Reef on the Great Barrier Reef: Sammarco and Andrews, 1988), and how far the larvae disperse, but this is more of an academic research project than a practical management action. Active work to restore the damaged reefs could use the high recruitment level on the Recruitment Reefs. Objects such as settlement plates could be placed in areas of dead coral and algae (never on live corals) on the Recruitment Patch Reefs. Once the objects had corals settled and growing on them, the objects could then be moved to reefs that have lost most of their corals. Clustering the objects on the recipient reefs would increase the fertilization rates once coral spawning begins, and speed the reseeding of the recipient reefs by the new corals. The objects would need to be secured to the reef. Moving settlement objects has several major advantages over coral transplantation. First, it does no harm to existing corals. This is probably an important first rule, “do no harm.” Coral transplantation does harm existing corals. Second, survival during transplantation should be very high, since the corals are not stressed by breakage and are already attached. And third, the method captures coral larvae that would otherwise be lost, and distributes the recruits from a highly productive reef to other reefs much faster than currents seem to be dispersing them. Although only small amounts of coral recruit moving can be done, the clusters of new corals on other reefs can then reseed those other reefs in coming years.
McManus et al (2000) noted that the mass coral bleaching of 1998 opened up dead substrate, much as Hurricane Allen did in Jamaica in 1980, followed by the death of the last herbivores (urchins) there in 1983. This was followed by a phase shift to algae bed, which has persisted. McManus pointed out that the same thing may occur on some reefs where corals were killed by mass bleaching. Certainly the dead coral in the Andavadoaka area is covered with a blanket of algae, 5-7 years after the bleaching events, with few recruits. Thus, the algal phase appears to be stable. Overfishing of herbivorous fish, probably coupled with nutrient runoff from rapidly growing villages and resorts, provide conditions conducive to persistence of the algae beds. Poor visibility in the water during our visit is consistent with the view that there is too much nutrient runoff. If herbivorous fish are not allowed to return and nutrient runoff continues, the algae beds may persist for much longer. Increasing herbivores and reducing nutrient inputs increase the resilience of the reefs. If there had been enough herbivores and low nutrients, when the coral died it might have been covered with coralline algae, which would have been followed by coral recruitment and a return to healthy reefs (coralline algae will grow best where wave surge is greatest, and herbivory is greatest). Building herbivore populations and reducing nutrient inputs should be high priorities, though they will not be easy.

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References

Best, M. B. and B. W. Hoeksema. 1987. New observations on Scleractinian corals from Indonesia: 1. Free-living species belonging to the Faviina. Zoologishe Mededelingen Leiden. 61: 387-403.

Best, M. B. and Suharsono. 1991. New observations on Scleractinian corals from Indonesia: 3. Species belonging to the Merulinidae with new records of *Merulina* and *Boninastrea*. Zoologishe Mededelingen Leiden 65: 333-342.

Borel Best, M., B. W. Hoeksema, W. Moka, H. Moll, Suharsono and I. Nyoman Sutarna. 1989. Recent scleractinian coral species collected during the Snellius-II Expedition in eastern Indonesia. Netherlands J. Sea Res. 23: 107-115.

Boschma, H. 1959. Revision of the Indo-Pacific species of the genus *Distichopora*. Bijdragen tot de Dierkunde 29: 121-171.

Claereboudt, M. 1990. *Galaxea paucisepta* nom. nov. (for *G. pauciradiata*), rediscovery and redescription of a poorly known scleractinian species (Oculinidae). Galaxea 9: 1-8.

Dai, C-F. 1989. Scleractinia of Taiwan. I. Families Astrocoeniidae and Pocilloporiidae. Acta Oceanographica Taiwanica 22: 83-101.

Dai, C-F. and G-H. Lin. 1992. Scleractinia of Taiwan III. Family Agariciidae. Acta Oceanographica Taiwanica 28: 80-101.

Dineson, Z. D. 1980. A revision of the coral genus *Leptoseris* (Scleractinia: Fungiina: Agariciidae). Memoires of the Queensland Museum 20: 181-235.

Fenner, D. 2001. Reef corals of Tubbataha Reefs, Philippines. Report for WWF, KKP, Philippines.

Fenner, D. 2001. Reef corals of Cagdanao Reefs, northern Palawan, Philippines. Report for CCC, London.

Fenner, D. 2003. Reef corals of Cagancillio area reefs, Philippines. Report for WWF, KKP, Philippines.

Fenner, D., Clark, T. H., Turner, J. R., and Chapman, B. 2004. A checklist of the corals of the island state of Rodrigues, Maruitius. J. Nat. History 38: 3091-3102.

Fenner, D. 2005. Corals of Hawai'i, the hard, soft, and black corals of Hawai'i, including the Northwest Hawaiian Islands and Midway. Mutual Publishing, Honolulu.

Hodgson, G. 1985. A new species of *Montastrea* (Cnidaria, Scleractinia) from the Philippines. Pacific Science 39: 283-290.

Hodgson, G. and M. A. Ross. 1981. Unreported scleractinian corals from the Philippines. Proceedings of the Fourth International Coral Reef Symposium, 2: 171-175.

Hoeksema, B. W. 1989. Taxonomy, phylogeny and biogeography of mushroom corals (Scleractinia: Fungiidae). Zoologishe Verhandelingen 254: 1-295.

Hoeksema, B. W. 1992. The position of northern New Guinea in the center of marine benthic diversity: a reef coral perspective. 7th International Coral Reef Symposium 2: 710-717.

Hoeksema, B. W. and M. B. Best. 1991. New observations on scleractinian corals from Indonesia: 2. Sipunculan-associated species belonging to the genera *Heterocyathus* and *Heteropsammia*. Zoologishe Mededelingen 65: 221-245.

Hoeksema, B. and C-F. Dai. 1992. Scleractinia of Taiwan. II. Family Fungiidae (including a new species). Bulletin of the Institute of Zoology Academia Sinica 30: 201-226.

Lamberts, A. E. 1982. The reef coral Astreopora (Anthozoa, Scleractinia, Astrocoeniidae): A revision of the taxonomy and description of a new species. Pacific Science 36: 83-105.

McManus, J. W., L. A. B. Menez, K. N. Kesner-Reyes, S. G. Vergara, and M. C. Ablan. 2000. Coral reef fishing and coral-algal phase shifts: implications for global reef status. ICES Journal of Marine Science 57: 572-578.

Moll, H. and M. B. Best. 1984. New scleractinian corals (Anthozoa: Scleractinia) from the Spermonde Archipelago, south Sulawesi, Indonesia. Zoologische Mededelingen 58: 47-58.

Nadon, M.-O., Griffiths, D. and Doherty, E. 2005. The coral reefs of Andavadoaka, southwest Madagascar. 30 pp. Blue Ventures, London, U.K.

Nemenzo, F. Sr. 1986. Guide to Philippine Flora and Fauna: Corals. Natural Resources Management Center and the University of the Philippines. 273 pp.

Nishihira, M. 1991. Field Guide to Hermatypic Corals of Japan. Tokai University Press, Tokyo. 264 pp. (in Japanese)

Nishihira, M. and J. E. N. Veron. 1995. Corals of Japan. Kaiyusha Publishers Co., Ltd, Tokyo. (in Japanese) 439 pp.

Ogawa, K., and K. Takamashi. 1993. A revision of Japanese ahermatypic corals around the coastal region with guide to identification- I. Genus *Tubastraea*. Nankiseibutu: The Nanki Biological Society 35: 95-109. (in Japanese)

Ogawa, K. and K. Takamashi. 1995. A revision of Japanese ahermatypic corals around the coastal region with guide to identification- II. Genus *Dendrophyllia*. Nankiseibutu: The Nanki Biological Society 37: 15-33. (in Japanese)

Randall, R. H. and Y-M. Cheng. 1984. Recent corals of Taiwan. Part III. Shallow water Hydrozoan Corals. Acta Geologica Taiwanica 22: 35-99.

Riegl, B. 1996. Hermatypic coral fauna of subtropical Southeast Africa: a checklist. Pacific Science 50: 404-414.

Sammarco, P. W. and J. C. Andrews. 1988. Localized dispersal and recruitment in Great Barrier Reef corals: the Helix experiment. Science 239: 1422-1424.

Sheppard, C. R. C. and A. L. S. Sheppard. 1991. Corals and coral communities of Arabia. Fauna of Saudi Arabia 12: 3-170.

Veron, J. E. N. 1985. New scleractinia from Australian reefs. Records of the Western Australian Museum 12: 147-183.

Veron, J. E. N. 1986. Corals of Australia and the Indo-Pacific. Univ. Hawaii Press. 644 pp.

Veron, J. E. N. 1990. New scleractinia from Japan and other Indo-West Pacific countries. Galaxea 9: 95-173.

Veron, J. E. N. 1993. A Biogeographic Database of Hermatypic Corals. AIMS Monograph 10: 1-433.

Veron, J. E. N. 2000. Corals of the World. Volumes 1-3. AIMS.

Veron, J. E. N. and D. Fenner. 2000. Corals (zooxanthellate Scleractinia) of the Calamaians Islands, Palawan Province, Philippines. Pages 24-26 in Werner, T. B. and G. R. Allen (eds.), A rapid marine biodiversity assessment of the Calamianes Islands, Palawan Province, Philippines. RAP Bulletin of Biological Assessment 17. Washington, D.C.: Conservation International

Veron, J. E. N. and G. Hodgson. 1989. Annotated checklist of the hermatypic corals of the Philippines. Pacific Science 43: 234-287.

Veron, J. E. N. and M. Pichon. 1976. Scleractinia of Eastern Australia. I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae. Australian Institute of Marine Science Monograph Series 1: 1-86.

Veron, J. E. N. and M. Pichon. 1980. Scleractinia of Eastern Australia. III. Families Agariciidae, Siderastreidae, Fungiidae, Oculilnidae, Merulinidae, Mussidae, Pectiniidae, Caryophyllidae, Dendrophyllidae. Australian Institute of Marine Science Monograph Series 4: 1-422.

Veron, J. E. N. and M. Pichon. 1982. Scleractinia of Eastern Australia. IV. Family Poritidae. Australian Institute of Marine Science Monograph Series 5: 1-210.

Veron, J. E. N., M. Pichon, and M. Wijsman-Best. 1977. Scleractinia of Eastern Australia. II. Families Faviidae, Trachyphyllidae. Australian Institute of Marine Science Monograph Series 3: 1-233.

Veron, J.E.N. and Stafford-Smith, M. 2002. Coral ID, CD-ROM. Australian Institute of Marine Science.

Veron, J. E. N. and E. Turak. 2003. Zooxanthellate Scleractinia of Madagascar. Pages 23-25 in McKenna S.A. and G.R Allen, eds. A Rapid Marine Biodiversity Assessment of Northwest Madagascar. Bulletin of the Rapid Assessment Program 31, Conservation International, Washington, DC.

Veron, J. E. N. and C. Wallace. 1984. Scleractinia of Eastern Australia. V. Family Acroporidae. Australian Institute of Marine Science Monograph Series 6: 1-485.

Wallace, C. C. 1994. New species and a new species-group of the coral genus *Acropora* (Scleractinia: Astrocoeniina: Acroporidae) from Indo-Pacific locations. Invertebrate Taxonomy 8: 961-88.

Wallace, C. C. 1997a. New species of the coral genus *Acropora* and new records of recently described species from Indonesia. Zoological Journal of the Linnean Society 120: 27-50.

Wallace, C. C. 1997b. The Indo-Pacific centre of coral diversity re-examined at species level. Proceedings of the 8th International Coral Reef Symposium 1: 365-370.

Wallace, C. C. 1999a. Staghorn corals of the world, a revision of the genus *Acropora*. CSIRO Publ., Collingwood, Australia. 422 pages.

Wallace, C. C. 1999b. Staghorn corals of the world: a key to species of Acropora. CD-ROM. CSIRO Publ., Collingwood, Australia

Wallace, C. C. and J. Wolstenholme. 1998. Revision of the coral genus *Acropora* in Indonesia. Zoological Journal of the Linnean Society 123: 199-384.

ANNEXE I: List of all species of Corals recorded at Andavadoaka, SW Madagascar in November / December 2005

Genera No.	Species No.	SPECIES	New report	photo	sample	SITE RECORDS
		Family Astrocoeniidae				
1	1	*Stylocoeniella guentheri* Bassett-Smith, 1890				2R, 9R, 18R
		Family Pocilloporidae				
2	2	*Pocillopora damicornis* (Linnaeus, 1758)				1U, 2U, 3U, 7U, 8U, 11R, 13U, 14U, 15R, 17U, 18U, 19U, 20R
	3	*Pocillopora dana* Verrill, 1864				7U,
	4	*Pocillopora eydouxi* Milne Edwards & Haime, 1860				1R, 3R, 4R, 7R, 8U, 9R, 10R, 13U, 14R, 15R, 16R, 17U, 18U, 19R, 20R
	5	*Pocillopora verrucosa* (Ellis & Solander, 1786)			X	3U, 6U, 7C, 8C, 9U, 10U, 13U, 15U, 16U, 17C, 19U
3	6	*Seriatopora aculeata* Quelch, 1886			X	Collection
	7	*Seriatopora caliendrum* Ehrenberg, 1834				2U, 4R, 6R, 7C, 9R, 10R, 12R, 13R, 14R, 19R, 20R
	8	*Seriatopora hystrix* Dana, 1846				5R, 11R, 13R, 19R
4	9	*Stylophora madagascarensis* Veron, 2002		X	X	1R, 2U, 5R, 7R, 8C, 9R, 10R, 11U, 12U, 13U, 15R, 17C, 18C, 19U, 20U
	10	*Stylophora pistillata* Esper, 1797				3R, 10R, 17R, 20R
	11	*Stylophora subseriata* Ehrenberg, 1834				19U, 20R
		Family Acroporidae				
5	12	*Acropora abrotanoides* (Lamarck, 1816)				7R,8U, 15R, 16U, 17R, 18R,
	13	*Acropora austera* (Dana, 1846)		X		8U, 15R, 16R, 17U, 18U,
	14	*Acropora branchi* Riegl, 1995		X		16U, 17U, 18U,
	15	*Acropora cerealis* (Dana, 1846)				19R
	16	*Acropora clathrata* (Brook, 1891)				4U,5U,7U,8U, 9R, 13R, 14R, 15U, 16U, 17U, 18U,
	17	*Acropora crateriformis* (Gardiner, 1898)	X	X		1U, 3C, 4U, 5U, 9C,
	18	*Acropora cuneata* (Dana, 1846)		X		13U,
	19	*Acropora cytherea* (Dana, 1846)		X		14R,15R, 16R, 17U, 18U, 19R,
	20	*Acropora glauca* (Brook, 1892)		X		13C, 14C, 15U, 16U, 17C, 18C, 19U, 20R
	21	*Acropora humilis* (Dana, 1846) like				7R, 8R, 10R, 11R, 13R, 16R, 17R, 18R, 19R
	22	*Acropora insignis* Nemenzo, 1967				9R,
	23	*Acropora loripes* (Brook, 1892)		X		13U,14R,16R,17U,18U, 19R
	24	*Acropora microphthalma* (Verrill, 1859)		X		13R,14U,18R,
	25	*Acropora muricata* (Linnaeus, 1758) (=*formosa*)				2U, 13R, 14R,

	26	*Acropora nobilis* (Dana, 1846) like				8U, 17R,
	27	*Acropora roseni* (Wallace, 1999)	X	X		Several, 17U, 18U
	28	*Acropora samoensis* (Brook, 1891)				14R,
	29	*Acropora secale* (Studer, 1878)		X		10R, 14R, 17U, 18U,
	30	*Acropora tenuis* (Dana, 1846)				2R, 7U, 8U,
	31	*Acropora vaughani* Wells, 1954	X			7U, 8U, 10R,
	32	*Acropora* raspy branch				Most sites, 17U, 18U, 19R, 20R
6	33	*Astreopora listeri* Bernard, 1896			X	13R
	34	*Astreopora myriophthalma* (Lamarck, 1816)			X	1R, 3R, 6R, 9R, 10R, 13R, 14R, 16R,
	35	*Astreopora suggesta* Wells, 1954				1R, 4R, 5R, 6R, 7R, 8R, 9R, 10R, 14R, 17R, 19R
7	36	*Montipora aequituberculata* Bernard, 1897		X		15A, 16A,
	37	*Montipora capitata* Dana, 1846	X	X		17R
	38	*Montipora corbettensis* Veron & Wallace, 1984	X	X		4R, 5R,
	39	*Montipora incrassata* (Dana, 1846)	X			?8R
	40	*Montipora informis* Bernard, 1897				4R, 7R, 16U, 18R,
	41	*Montipora nodosa* (Dana, 1846)				?8R
	42	*Montipora tuberculosa* Lamarck, 1816)				1U, 3U, 4R, 6R, 7R, 8U, 9R,
	43	*Montipora verrucosa* (Lamarck, 1816)				18R,
	44	*Montipora vietnamensis* Veron, 2002	X	X		3R, 16U, 17U,
		<u>**Family Poritidae**</u>				
8	45	*Goniopora albiconus* Veron, 2002		X		10U, 11R, 13R, 20R
	46	*Goniopora pendulus* Veron, 1985		X		14R
	47	*Goniopora fruiticosa* Saville-Kent, 1893	X			??3R,
	48	*Goniopora somaliensis* Vaughan, 1907		X		14R
	49	*Goniopora stokesi* Edwards & Haime, 1851		X	X	12C, 13U, 14C, 19C
9	50	*Porites cylindrica* Dana, 1846			X	14R, 19R
	51	*Porites lutea* Milne Edwards & Haime, 1851			X	1R, 3R, 10R, 20R
	52	*Porites profundus* Rehberg, 1892		X	X	1U, 2U, 3U, 4U, 6R, 7C, 8C, 9U, 19U, 12R, 14R, 15U, 16U, 17U, 18U, 19R
	53	*Porites rus* (Forskål, 1775)		X	X	2R,3R,6C,7C,9U,10U,11R, 15U, 16U, 17U, 18U, 19R, 20R
	54	*Porites* massive				1C, 8U, 13C, most others
	55	*Porites* fuzzy branch		X		6U, 7A, 8A, 15A, 16A, 17U
		<u>**Family Siderasteridae**</u>				
10	56	*Coscinaraea columna* (Dana, 1846)		X		1U, 4U, 7R, 8U, 10R, 16R, 17R, 18R,

	57	*Coscinaraea crassa* Veron & Pichon, 1980	X	X	6R, 9R, , 13R, 16R, 19U
	58	*Coscinaraea wellsi* Veron & Pichon, 1980	X	X	9R,
	59	*Coscinaraea* sp. 1	X		8R, 9R, 10U, 17R, 18R, 19U
11	60	*Craterastrea* cf. *levis* Head, 1983		X	Collection
12	61	*Horoastrea indica* Pichon, 1971		X	Collection
13	62	*Psammocora explanulata* van der Horst, 1922		X	Collection
	63	*Psammocora nierstraszi* van der Horst, 1921		X	2R, 7R, 20R
	64	*Psammocora profundacella* Gardiner, 1898		X	1R,2R,3R,4R,6R,7U,8U,9R,10R,11R, 13R, 14R, 15R, 16R, 18R, 19U, 20R
14	65	*Siderastrea savignyana* Milne Edwards and Haime, 1850		X	Collection
		<u>Family Agariciidae</u>			
15	66	*Gardineroseris planulata* Dana, 1846		X	1U, 3U, 4R, 7U, 8R, 10R, 11R, 12R, 13R, 14R, 15R, 16R, 17R, 18R,
16	67	*Leptoseris explanata* Yabe & Sugiyama, 1941		X	5U, 16, 17U, 18U, 20R
	68	*Leptoseris incrustans* (Quelch, 1886)	X		10R,
	69	*Leptoseris mycetoseroides* Wells, 1954		X	1U, 2R, 3U, 5R, 6R, 8U, 9U, 19U, 11R, 13R, 16R, 17R, 18R, 20R
17	70	*Pachyseris speciosa* (Dana, 1846)		X	1R, 2U, 3U, 4U, 5C, 7U, 8U, 9C, 10U, 11U, 12U, 13U, 14U, 15R, 19U, 20U
18	71	*Pavona cactus* (Forskål, 1775)			11R, 15R,
	72	*Pavona clavus* (Dana, 1846)		X	2A, 8C, 15C, 17U, 19U, 20U
	73	*Pavona duerdeni* Vaughan, 1907		X	1U, 2R, 3R, 6R, 7C, 9R, 11R, 12R, 13R, 15C, 16C, 18U, 19U, 20R
	74	*Pavona explanulata* (Lamarck, 1816)		X	1U, 2R, 3R, 4R, 5R, 6R, 7R, 8R, 9R, 10R, 11R, 12R, 14R, 15R, 16R, 17U, 18U, 19R
	75	*Pavona maldivensis* (Gardiner, 1905)		X	4R, 7R, 8R, 11R, 15R, 16U, 17U, 18U, 19U
	76	*Pavona varians* Verrill, 1864		X	1U, 2U, 3R, 4R, 6R, 7R, 8R, 9R, 10R, 11R, 13C, 15R, 16R, 17U, 19R, 20R
		<u>Family Fungiidae</u>			
19	77	*Cycloseris cyclolites* (Lamarck, 1801)	X		10R
	78	*Cycloseris tenuis* (Dana, 1846)			1R, 3U, 4U, 6C, 8R, 9R, 10R, 14R, 18R, 19R, 20R,
	79	*Cycloseris vaughani* (Boschma, 1923)			4R,
20	80	*Fungia concinna* Verrill, 1864			6R, 7R, 10R, 19R,
	81	*Fungia fungites* (Linneaus, 1758)			1R, 2R, 4R, 8U, 10R, 11R, 13R, 15R, 16R, 18R, 19R,

						20R
	82	*Fungia granulosa* Klunzinger, 1879			X	1U, 3R, 4U, 5R, 6C, 7R, 10R, 12R, 13R, 16R, 18R, 19R, 20R
	83	*Fungia gravis* Nemenzo, 1955		X		8R,
	84	*Fungia horrida* Dana, 1846				1R, 2R, 3R, 6R, 11R, 16R, 19R
	85	*Fungia klunzingeri* Döderlein, 1901				2R, 7U, 10R, 13R, 18R,
	86	*Fungia moluccensis* Horst, 1919		X		6R, 7R,
	87	*Fungia paumotensis* Stutchbury, 1833				1U, 2U, 3R, 7U, 8U, 9R, 10R, 11U , 12U, 13R, 14U, 16R, 18U, 19U, 20U
	88	*Fungia scruposa* Klunzinger, 1816		X		2U, 5U, 10R, 16R, 17U, 18U,
	89	*Fungia scutaria* Lamarck, 1816			X	1U, 2R, 3U, 6R, 7U, 8U, 9R, 10U, 15R, 16R, 17U, 18U,
21	90	*Halomitra pileus* (Linnaeus, 1758)			X	2R, 15R, 18R, 19U
	91	Herpolitha limax *(Houttuyn, 1772)*				1U, 2U, 3U, 5R, 6R, 7R, 8R, 9R, 10R, 11U, 12U, 13U, 15R, 17R, 19U, 20U
	92	Herpolitha weberi *Horst, 1921*				2R, 3R, 10R, 16U, 17R, 18R, 20R
22	93	Podabacia crustacea *(Pallas, 1766)*				2R,
	94	*Podabacia motuporensis* Veron, 1990			X	3R, 4R, 5R, 6R, 7R, 9U, 10R, 11R, 13R, 15R, 17R, 18R, 19R, 20R
		Family Oculinidae				
23	95	*Galaxea astreata* (Lamarck,. 1816)		X	X	2A,3R, 4R, 7A, 8A, 9R, 10R, 11C, 12C, 15C, 16R, 17U, 19R
	96	*Galaxea fascicularis* (Linnaeus, 1767)				1U, 3R, 4R, 5R, 6R, 8R, 10R, 11R, 12R, 13U, 14R, 17R, 18R, 19U, 20U
		Family Pectinidae				
24	97	Echinophyllia aspera *(Ellis & Solander, 1788)*			X	8R, 10R, 11R, 14R, 15R, 16R, 17R, 19R
	98	*Echinophyllia orpheensis* Veron & Pichon, 1980		X		8R, 14R, 18R, 19R, 20R
25	99	*Mycedium elephantotus* (Pallas, 1766)			X	2R. 3R, 4R, 7R, 8R, 9U, 12R, 13R, 15U, 16U, 18R, 19U
	100	*Mycedium robokaki* Moll & Borel-Best, 1984	X	X		2R, 9R, 12R, 19R, 20R
26	101	*Oxypora lacera* Verrill, 1864			X	1R, 2U, 3R, 7R, 8R, 9R, 11R, 13R, 15R, 16R, 17U, 18U, 19R, 20R
27	102	*Pectinia africana* Veron, 2002		X		9R
		Family Mussidae				
28	103	*Acanthastrea brevis* Milne Edwards & Haime, 1849		X	X	X

	104	*Acanthastrea echinata* (Dana, 1846)			X	1U, 2R, 3R, 4R, 7U, 8R, 9U, 11R, 13R, 15R, 16R, 19R, 20R
	105	*Acanthastrea hemprichii* (Ehrenberg, 1834)				3R, 7R, 9U, 10R, 13R, 14R, 19R
	106	*Acanthastrea ishigakiensis* Veron, 1990		X		1R, 2R, 3R, 4R, 7R, 8R, 9R, 10R, 12R,13R,15U,16U,17R, 18U, 19U
	107	*Acanthastrea subechinata* Veron, 2002	X	X		3R,16R,
29	108	*Blastomussa sp.*	X	X		5R. 9U, 16U, 17U
30	109	*Cynarina lacrymalis* (Milne Edwards & Haime, 1848)			X	Collection
31	110	*Lobophyllia hemprichii* (Ehrenberg, 1834)				7U, 8U, 10R, 11U, 13R, 14R, 15C, 16C, 19R, 20R
32	111	*Scolymia vitiensis* Brüggemann, 1877		X		19R
		Family Merulinidae				
33	112	*Hydnophora exesa* (Pallas, 1766)			X	1U, 2R, 3R, 4R, 5R, 6R, 7U, 8R, 9R, 10R, 11R, 12R, 13R, 14R, 15U, 16U, 17U, 18U, 19U, 20R
	113	*Hydnophora microconos* (Lamarck, 1816)				3R,
34	114	*Merulina ampliata* (Ellis & Solander, 1786)			X	2U, 7U, 9U, 10R, 11R, 12R, 13R, 14U, 16R, 18R, 19U, 20R
		Family Faviidae				
35	115	*Caulastrea connata* (Ortmann, 1892)				12R
36	116	*Cyphastrea* encrusting				1U, 2R, 3R, 6R, 8R, 9R, 10R, 12R, 16R, 19R, 20R
37	117	*Diploastrea heliopora* (Lamarck, 1816)			X	1U, 3U, 6R, 7R, 8R, 9R, 10R, 11R, 12R, 13U, 14U, 16R, 17R, 18R, 19R, 20R,
38	118	*Echinopora forskaliana* (Milne Edwards and Haime, 1850)		X	X	1C, 2U, 4U, 5C, 6U, 8C, 9U, 10U, 12R, 13R, 14R, 15C, 16C, 17C, 18C, 19R, 20U
39	119	*Favia bestae* Veron, 2002	X	X		9R
	120	*Favia matthai* Vaughan, 1918				3R,
	121	*Favia pallida* (Dana, 1846)				19R,
	122	*Favia rotundata* Veron & Pichon, 1977	X	X		9R, 10R, 17R, 18R,
	123	*Favia speciosa* Dana, 1846				1U, 2U, 3C, 10U, 13U, 14R, 18R, 19R, 20R,
	124	*Favia stelligera* (Dana, 1846)				1U, 3U, 4U, 5R, 7R, 8U, 9R, 10R, 11R, 15U, 16U, 17U, 19R,
	125	*Favia truncatus* Veron, 2002		X		3R, 13R, 14R, 19R
40	126	*Favites abdita* (Ellis & Solander, 1786)				10R,
	127	*Favites flexuosa* (Dana, 1846)				19R
	128	*Favites paraflexuosa* Veron, 2002		X		1C,3U, 6R,7R, 8R, 9R, 10R, 12R, 13R, 14R, 17R,

						18R, 19R, 20R
	129	*Favites pentagona* Esper, 1794				1R, 3U, 6R, 10R, 13R, 14R, 17R, 18R,
41	130	*Goniastrea edwardsi* Chevalier, 1971			X	3U, 4C, 6U, 9U, 11R, 13R, 16R, 17R, 20R
	131	*Goniastrea favulus* (Dana, 1846*)*	X	X		3R, 4C, 7R, 9R, 16R,
	132	*Goniastrea pectinata* (Ehrenberg, 1834)			X	1R, 2R, 3R, 4R, 5R, 8R, 10R, 11R, 12R, 13R, 14R, 16R, 17R, 18R, 19U, 20R
	133	*Goniastrea peresi* (Faure & Pichon, 1978)		X	X	1U, 2R, 4R, 5R, 7R, 8R, 9R, 10R, 11R, 13R, 14R, 17R, 18R,
	134	*Goniastrea* platygyra-like				19R, 20R
	135	*Goniastrea retiformis* (Lamarck, 1816)				1U, 16R,
42	136	*Leptastrea pruinosa* Crossland, 1952				6R, 7R, 10R,
	137	*Leptastrea purpurea* (Dana, 1846) like				3R,14R, 15R, 16R, 17R,
	138	*Leptastrea transversa* Klunzinger, 1879			X	1C, 3U, 5R, 8R, 9R, 10R, 11R, 13R, 15R, 16R, 17U, 18U, 19R, 20R
43	139	*Leptoria phrygia* (Ellis & Solander)			X	1U, 3R, 4R, 8R, 9R, 10R, 13R, 16R, 17R, 19R
44	140	*Montastrea curta* (Dana, 1846)				1R, 3R, 10R,
	141	*Montastrea serageldini* Veron, 2002		X	X	3R, 4R, 9U, 13R, 14R
45	142	*Oulophyllia bennettae* Veron, Pichon, & Wijsman-Best, 1977		X	X	12R,
	143	*Oulophyllia crispa* (Lamarck, 1816)		X	X	3U, 5R, 8R, 9R, 10R,
46	144	*Platygyra acuta* Veron, 2002		X		1R, 5R, 6R,
	145	*Platygyra crosslandi* Matthai, 1928		X		19R
	146	*Platygyra daedalea* (Ellis & Solander, 1786)				1C, 2U, 3R, 4U, 6R, 9C, 10U, 11C, 12C
	147	*Platygyra pini* Chevalier, 1975				1C, 4U, 9U,
47	148	*Plesiastrea devantieri* Veron, 2002		X		?10U, 17R, 19R, 20R
	149	*Plesiastrea versipora* (Lamarck, 1816)			X	1R, 3R, 5R, 9R, 12R, 13R, 17R
		Family Euphilliidae				
49	150	*Physogyra lichentensteini* Milne Edwards & Haime, 1786			X	1U, 2U, 3R, 4U, 6R, 9C, 10U, 11C, 12C, 13U, 14U, 16R, 19R, 20R
49	151	*Plerogyra sinuosa* (Dana, 1846)			X	1R, 2R, 3R, 4R, 9U, 10R, 11C, 12C, 13R, 14R, 17R, 19R, 20R
		Family Dendrophylliidae				
50	152	*Tubastraea coccinea* Lesson, 1829			X	12R
	153	*Tubastraea diaphana* (Dana, 1846)			X	Collection
51	154	*Turbinaria mesenterina* (Lamarck, 1816)			X	1U, 3R, 4R, 9U, 10U, 14R, 17U, 18C

	155	*Turbinaria peltata* (Esper, 1794)			X	8R, 13R, 14R
	156	*Turbinaria reniformis* Bernard, 1896			X	9U, 10U, 17R, 18R
	157	*Turbinaria stellulata* (Lamarck, 1816)				4R, 9R, 10R, 11R, 17R
		Family Clavulariidae				
52	158	Tubipora musica *Linnaeus, 1758*	X		X	2R, 4R, 8R,
		Family Milleporidae				
53	159	Millepora dichotoma *Forskål, 1775*	X	X	X	16U, 17U,
	160	*Millepora exaesa* Forskål, 1775	X		X	4U, 6U, 7R, 8R, 11R, 16R, 17R, 20R
	161	*Millepora foveolata* Crossland, 1952	X	X	X	4U, 6U, 7R, 16R,
	162	*Millepora intricata* Milne-Edwards & Haime, 1857	X	X		15U, 16A,
		Family Stylasteridae				
54	163	Stylaster *sp. 1 white*	X			11U, 12U,
55	164	*Distichopora violacea* (Pallas, 1766)	X			1U, 6U, 8R, 9R, 11R, 12R, 15R, 17R,

APPENDIX 2

Reef Fishes of Andavadoaka, South-western Madagascar

Gerald R. Allen

- A list of fishes was compiled during 21 scuba dives and several hours of snorkelling in the vicinity of Andavadoaka, south-western Madagascar. The survey involved 25 hours of scuba diving and approximately three hours of snorkelling to a maximum depth of 25 m. Additional species were added to the list on the basis of photographs provided by Blue Ventures.

- A total of 385 species belonging to 182 genera and 57 families were recorded during the survey. An extrapolation method utilizing six key index families (Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae) indicates a total fauna for the Andavadoaka region consisting of at least 529 species.

- Wrasses (Labridae), damselfishes (Pomacentridae), and groupers (Serranidae) are the dominant groups at Andavadoaka with 55, 48, and 23 species respectively. Gobies (Gobiidae), usually the most speciose family at most Indo-Pacific localities were represented by only 20 species, but due to their cryptic nature and the small size of many species, they were probably not adequately surveyed.

- Species numbers at visually sampled sites during the survey ranged from 74 to 139, with an average of 105. The latter figure is relatively low and was no doubt influenced by poor underwater visibility which averaged about 5-6 m.

- A total of 66 species recorded during the present survey were not seen during the previous (2002) Conservation International RAP survey of north-western Madagascar, including 20 species that represent new records for Madagascar (Table 1).

- A total of 123 species recorded during the previous CI survey of north-western Madagascar were not seen at Andavadoaka, but most of these records were based on rare sightings of 1-3 individuals or cryptic species collected with rotenone.

- In terms of differences in common species between Andavadoaka and NW Madagascar, *Lutjanus notatus* was abundant at Andavadoaka and rare in the northwest, and conversely *Pomacentrus pavo* was common in the northwest and absent at Andavadoaka. Otherwise, discounting numerous rare species that were seen only at NW Madagascar or around Andavadoaka, the faunas of the two areas are very similar.

- Two species commonly associated with rich coral areas, the cardinalfish *Cheilodipterus artus* and the filefish *Oxymonacanthus longirostris*, which were seen regularly in the northwest, were absent at Andavadoaka, perhaps the result of significant loss of live coral habitat due to recent bleaching events.

- A review of the literature combined with results of the current RAP survey reveal a total reef fish fauna for Madagascar consisting of 815 species.

- In terms of number of species and general faunal composition, Madagascar is similar to other insular localities in the western Indian Ocean including Mauritius, Seychelles, Chagos, and Maldives.

- The majority of Madagascar fishes have broad distributions in the Indo-west and central Pacific. Approximately 20 % of the species range widely over the entire tropical Indian Ocean or are restricted to the western Indian Ocean

- About 30 species are confined to Madagascar and adjacent regions including Mozambique, East Africa, Comoro Islands, St. Brandon's Shoals, and the Mascarene Group

- Eight species are presently known only from the seas of Madagascar. Another four species are known only from Madagascar and the Comoros/Saint Brandon's Shoals.

Table 1 New Reef Fish Species Records for Madagascar recorded at Andavadoaka

Family	**Species**
Apogonidae	*Apogon nigrofasciatus*
Apogonidae	*Apogon holotaenia*
Apogonidae	*A. flagelliferus*
Blennidae	*Ecsenius midas*
Gobiidae	*Opua athernoides*
Gobiidae	*Vanderhorstia ornatissima*
Haemulidae	*Plectorhinchus vittatus*
Haemulidae	*Plectorhinchus picus**
Serranidae	*Epinephelus tukula**
Caesionidae	*Pterocaesio marri*
Pempheridae	*Pempheris schwenkii*
Pomacentridae	*Lepidozygus tapeinosoma*
Pomacentridae	*Chromis agilis*
Scynanceiidae	*Inimicus filamentosus**
Mullidae	*Upeneus pori*
Mullidae	*Mulloidichthys vanicolensis*
Syngnathidae	*Corythoichthys punctulatus*
Diodontidae	*Diodon liturosus**
Tetraodontidae	*Canthigaster smithae*
Tetraodontidae	*Torquigener flavoimaculatus**

* Identifications from BV Photo Library

Table 2 List of Reef Fish at Andavadoaka

SPECIES	SITE RECORDS
STEGOSTOMATIDAE	
Stegostoma fasciatum (Hermann, 1783)	1
CARCHARHINIDAE	
Galeocerdo cuvieri (Peron & LeSueur, 1822)	1
Triaenodon obesus (Rüppell, 1835)	5
SPHYRNIDAE	
Sphyrna lewini (Griffith & Smith, 1834)	1
RHINOBATIDAE	
Rhynchobatus djeddensis (Forsskål, 1775)	9
DASYATIDIDAE	
Dasyatis kuhlii (Müller and Henle, 1841)	6, 8
Taeniura lymma (Forsskål, 1775)	2, 6, 7
T. meyeni (Müller & Henle, 1841)	4
MYLIOBATIDAE	
Aetobatus narinari (Euphrasen, 1790)	4
MURAENIDAE	
Echidna nebulosa (Thünberg, 1789)	1
G. favagineus (Bloch & Schneider, 1801)	5
G. flavimarginatus (Rüppell, 1828)	2, 3
G. javanicus (Bleeker, 1865)*	8
G. undulatus (Lacepède, 1803)	1
Rhinomuraena quaesita Garman, 1888*	5
Siderea grisea (Lacepède, 1803)	1
U. micropterus (Bleeker, 1852)	6
CLUPEIDAE	
H. spilurus (Guichenot, 1863) ?????	3
Spratelloides delicatulus (Bennett, 1832)	9
PLOTOSIDAE	
Plotosus lineatus (Thünberg, 1787)	3, 7
SYNODONTIDAE	
Saurida gracilis (Quoy & Gaimard, 1824)	3, 7, 8
Synodus dermatogenys Fowler, 1912	2, 3, 5, 8, 10, 11
S. jaculum Russell and Cressy, 1979	5
S. variegatus (Lacepède, 1803)	2, 3, 6, 7, 9
BELONIDAE	
Tylosurus crocodilus (Lesueur, 1821)	1
HOLOCENTRIDAE	
Myripristis adusta Bleeker, 1853	2, 4, 7,
M. berndti Jordan & Evermann, 1902	2, 4, 5,
M. botche Cuvier, 1829*	1
M. hexagona (Lacepède, 1802)	7
M. kuntee Cuvier, 1831	2, 3, 4, 6, 7, 10, 11
M. violacea Bleeker, 1851	2, 3, 4, 7
Neoniphon sammara (Forsskål, 1775)	2, 3, 5, 6, 8, 9, 10, 11
Sargocentron caudimaculatum (Rüppell, 1835)	2, 3, 4, 5, 6, 7, 9, 10
S. diadema (Lacepède, 1802)	2, 3, 8
S. melanospilos (Bleeker, 1858)*	2, 3, 4, 8
S. spiniferum (Forsskål, 1775)	3, 4, 5
AULOSTOMIDAE	

Aulostomus chinensis (Linnaeus, 1766)	2, 3, 4, 6, 8, 9, 10
FISTULARIIDAE	
Fistularia commersoni Rüppell, 1835	6, 12
CENTRISCIDAE	
Aeoliscus punctulatus (Bianconi, 1855)	12
SYNGNATHIDAE	
Corythoichthys punctulatus	12
Doryrhamphus excisus	8, 10
Trachyrhamphus bicoarctatus (Bleeker, 1857)	8
SCORPAENIDAE	
Pterois antennata (Bloch, 1787)	4
P. radiata Cuvier, 1829	3
P. miles (Bennett, 1828)	3, 5, 8, 11
S. possi Randall & Eschmeyer, 2001	3, 4
Taenianotus triacanthus Lacepède, 1802	7
SYNANCEIIDAE	
Inimicus filamentousus (Cuvier, 1829)	1
Synanceja verrucosa (Bloch & Schneider, 1801)	3
PLATYCEPHALIDAE	
Papilloculiceps longiceps (Ehrenberg, 1829)	2, 7, 8
SERRANIDAE	
Aethaloperca rogaa (Forsskål, 1775)	5, 6, 7, 9
Anyperodon leucogrammicus (Valenciennes, 1828)	3
Cephalopholis argus Bloch & Schneider, 1801	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. boenack (Bloch, 1790)	3, 6, 8, 9, 11
C. leopardus	3
C. miniata (Forsskål, 1775)	5, 7
C. nigripinnis (Valenciennes,1828)	5
Epinephelus caeruleopunctatus (Bloch, 1790)	7,
E. fasciatus (Forsskål, 1775)	1
E. flavocaeruleus (Lacepède, 1802)	1
E. hexagonatus (Forster, 1801)	2
E. lanceolatus (Bloch, 1790)	1
E. multinotatus (Peters, 1876)	3
E. rivulatus (Valenciennes, 1830)	12
E. spilotoceps Schultz	4
E. tauvina (Forsskål, 1775)	5
E. tukula	1
Grammistes sexlineatus (Thünberg, 1792)	7, 8
Nemanthias carberryi Smith, 1954*	5
Plectropomus laevis (Lacepède, 1802)	1
P. punctatus Quoy & Gaimard, 1824	4, 5
Pseudanthias squamipinnis (Peters, 1855)	3, 5, 6, 7, 9, 10, 11
V. louti (Forsskål, 1775)	2, 4, 5
CIRRHITIDAE	
Cirrhitichthys oxycephalus (Bleeker, 1855)	2, 5, 6, 8, 9, 10, 11
Cirrhitus pinnulatus (Schneider, 1801)	2
Oxycirrhitus typus Bleeker, 1857*	9
Paracirrhites arcatus (Cuvier, 1829)*	5, 9, 10
P. forsteri (Schneider, 1801)	3
PSEUDOCHROMIDAE	
Pseudochromis dutoiti	1
PRIACANTHIDAE	
Priacanthus hamrur (Forsskål, 1775)	2, 3, 4, 6, 7, 9, 10, 11

APOGONIDAE	
Apogon angustatus (Smith and Radcliffe, 1911)	5, 7,
A. apogonides (Bleeker, 1856)	11, 12
A. aureus (Lacepède, 1802)	8, 11
A. cooki Macleay, 1881	8, 12
A. cyanosoma (Bleeker, 1853)	3, 7, 8, 11, 12
A. fleurieu (Lacepède, 1802)*	11, 12
A. fraenatus Valenciennes, 1832	9
A. fragilis Smith, 1961	3, 7, 11
A. guamensis Valenciennes, 1832	12
A. kallopterus Bleeker, 1856	3, 11, 12
A. nigrofasciatus Lachner	8
A. holotaenia	8
A. semiornatus Peters, 1876	8
A. flagelliferus	8
Archamia fucata (Cantor, 1850)	3, 6, 7, 11, 12
Cheilodipterus macrodon Lacepède, 1801*	2, 3, 4, 5, 8, 9, 11
C. quinquelineatus Cuvier, 1828	3, 7, 8, 9, 11, 12
Rhabdamia cypselurus Weber, 1909*	11
R. gracilis (Bleeker, 1856)	7
Siphamia mossambica Smith, 1955	3
CARANGIDAE	
Carangoides ferdau (Forsskål, 1775)	12
Caranx heberi	1
C. sexfasciatus Quoy & Gaimard, 1824	5
C. tille Cuvier, 1833	3, 9
Gnathanodon speciosus (Forsskål, 1775)	11
Scomberoides commersonnianus (Lacepède, 1802)	1
Selar crumenophthalmus (Bloch, 1793)	7
LEIOGNATHIDAE	
Gazza minuta (Bloch, 1797)	3
LUTJANIDAE	
Aphareus furca (Lacepède, 1802)	5
Aprion virescens Valenciennes, 1830	4, 5
Lutjanus bohar (Forsskål, 1775)	4, 5, 6, 7, 11
L. fulviflamma (Forsskål, 1775)	2, 3, 4, 5, 6, 7, 8, 9, 11, 12
L. fulvus (Schneider, 1801)	1,
L. gibbus (Forsskål, 1775)	2, 3, 4, 5, 6, 10
L. kasmira (Forsskål, 1775)	2, 11
L. lutjanus Bloch, 1790	3, 6, 10, 11
L. monostigma (Cuvier, 1828)	5
L. notatus (Cuvier, 1828)	2, 3, 4, 5, 6, 8, 9, 10, 11
Macolor niger (Forsskål, 1775)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
CAESIONIDAE	
Caesio caerulaurea Lacepède, 1802	2, 3, 4, 6, 7, 8, 11
C. lunaris Cuvier, 1830	2, 3, 6, 7, 8
C. xanthonota Bleeker, 1853	2, 3, 4, 5, 6, 7, 8
C. sp. 1*	4, 6, 7, 10
Pterocaesio marri	5
P. sp.*	4, 7
P. tile (Cuvier, 1830)	5
GERREIDAE	
Gerres oyena (Forsskål, 1775)	8
HAEMULIDAE	

Diagramma pictum (Thünberg, 1792)	3, 11
Plectorhinchus flavomaculatus	2, 3, 4, 11
P. gaterinus (Forsskål, 1775)	2, 3, 4, 5, 7, 8, 11
P. picus	1
P. plagiodesmus (Fowler, 1935)	1
P. playfairi (Pellegrin, 1914)	5
P. schotaf (Forsskål, 1775)	2, 3, 4
P. sordidus (Klunzinger, 1870)	3, 8, 10
P. vittatus	7, 12
SPARIDAE	
Acanthopagrus bifasciatus (Forsskål, 1775)	6
LETHRINIDAE	
Gnathodentex aurolineatus Lacepède, 1802	1
Gymnocranius elongatus	3, 9
Lethrinus borbonicus Valenciennes, 1830	2, 3, 4, 6, 7, 9, 10, 11, 12
L. harak (Forsskål, 1775)	3, 7, 8, 11
L. lentjan (Lacepède, 1802)	3, 6, 9, 10, 11, 12
L. mahsena (Forsskål, 1775)	2, 4, 7
L. nebulosus (Forsskål, 1775)	11
L. obsoletus (Forsskål, 1775)	3, 6
L. olivaceous Valenciennes, 1830	10
L. variegatus Valenciennes, 1830	12
L. xanthocheilus Klunzinger, 1870	8
Monotaxis grandoculis (Forsskål, 1775)	2, 3, 4, 5, 6, 7, 9, 10, 11
NEMIPTERIDAE	
Scolopsis bimaculatus Rüppell, 1828	3, 6, 8, 9, 10, 11
S. gahnam (Forsskål, 1775)	2, 3, 5, 6, 8, 10, 11
S. vosmeri (Bloch, 1792)	9
MULLIDAE	
Mulloidichthys vanicolensis	2, 10, 11
Parupeneus barberinus (Lacepède, 1801)	5, 6, 7, 8, 9, 10, 11, 12
P. bifasciatus (Lacepède, 1801)	7
P. cyclostomus (Lacepède, 1802)	2, 4, 5, 6, 8, 10
P. heptacanthus (Lacepède, 1801)	3, 6, 7, 9
P. indicus (Shaw, 1803)	2
P. macronema (Lacepède, 1801)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
P. pleurostigma (Bennett, 1830)	2, 5, 6
P. rubescens (Lacepède, 1801)	2, 7, 12
Upeneus pori	3
PEMPHERIDAE	
Parapriacanthus ransonneti Steindachner, 1870	7, 11
Pempheris oualensis Cuvier, 1831	1, 11
Pempheris schwenkii	3, 6, 8, 11
P. vanicolensis Cuvier, 1831	2, 3, 4, 6, 7
MONODACTYLIDAE	
Monodactylus argenteus (Linnaeus, 1758)	1
CHAETODONTIDAE	
Chaetodon auriga Forsskål, 1775	2, 3, 4, 5, 6, 7,8, 9, 10, 11, 12
C. blackburni Desjardins, 1836	6, 8, 9
C. falcula Bloch, 1793	3, 6, 8, 9, 11
C. guttatissimus Bennett, 1823	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. interruptus Ahl, 1923	4, 5, 9, 10
C. kleinii Bloch, 1790	3, 4, 5, 6, 9, 10, 11
C. lunula Lacepède, 1803	3, 5, 6, 7, 9, 10, 11

C. madagaskariensis Ahl, 1923	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. melannotus Schneider, 1801	3
C. meyeri Schneider, 1801	2, 6, 9, 10
C. trifascialis Quoy and Gaimard, 1824	6, 9, 10
C. trifasciatus Park, 1797	2, 3, 4, 6, 7,
C. vagabundus Linnaeus, 1758	2, 3, 4, 6, 7, 8, 9, 10
C. xanthocephalus Bennett, 1832	6, 9, 10
C. zanzibarensis Playfair, 1867	5, 10
Forcipiger flavissimus Jordan & McGregor, 1898	2, 4, 5, 7, 9, 10
F. longirostris	1
Hemitaurichthys zoster (Bennett, 1831)	2
Heniochus acuminatus (Linnaeus, 1758)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
H. diphreutes	5
H. monoceros Cuvier, 1831	3, 5, 6, 7, 8, 10
POMACANTHIDAE	
Apolemichthys trimaculatus (Lacepède, 1831)	2, 5, 6, 7, 9, 10
Centropyge acanthops (Norman, 1922)	1
C. bispinosa (Günther, 1860)	4
C. multispinis (Playfair, 1867)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Pomacanthus chrysurus Cuvier, 1831	2, 3, 4, 5, 6,
P. imperator (Bloch, 1787)	2, 4, 5
P. semicirculatus Cuvier, 1831	2, 4, 5, 6, 7, 8, 9, 10
Pygoplites diacanthus (Boddaert, 1772)	2, 4, 5, 6, 7, 10
POMACENTRIDAE	
Abudefduf notatus	1
A. septemfasciatus (Cuvier, 1830)	13
A. sexfasciatus Lacepède, 1802	3, 7, 8, 12
A. sordidus (Forsskål, 1775)	13
A. sparoides (Cuvier, 1830)	2, 3, 4, 6, 7, 8, 9, 10, 12
A. vaigiensis (Quoy and Gaimard, 1825)	6, 12
Amblyglyphidodon indicus (Allen & Randall, 2002)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Amphiprion akallopisos (Bleeker, 1853)	2, 3, 6, 7, 8, 9, 10, 11
A. latifasciatus Allen,1972	4, 6, 7, 8, 9, 10, 11
Chromis agilis Smith ?	3, 7
C. atripectoralis Welander & Schultz, 1951*	3
C. dimidiata (Klunzinger, 1871)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. lepidolepis Bleeker, 1877	2, 4, 5, 6, 7, 8, 10, 11
C. nigrura Smith, 1960	2, 3, 5, 6, 7, 9, 10
C. opercularis (Günther, 1867)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. ternatensis (Bleeker, 1856)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. viridis (Cuvier, 1830)	3, 7
C. weberi Fowler & Bean, 1928	2, 4, 5, 6, 7, 8, 10, 11
Chrysiptera annulata (Peters, 1855)	8, 12
C. brownriggii (Bennett, 1828)	13
C. sp.	1
Dascyllus aruanus (Linnaeus, 1758)	3
D. carneus Fischer, 1885	6, 11
D. trimaculatus (Rüppell, 1928)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Lepidozygus tapeinosoma	5
Neoglyphidodon melas (Cuvier, 1830)	2, 4, 7, 10, 11
Neopomacentrus azysron (Bleeker, 1877)	3, 8, 9, 11
N. cyanomos (Bleeker, 1856)	11
Plectroglyphidodon dickii (Liénard, 1839)	3, 6, 9, 10
P. johnstonianus Fowler & Ball, 1924*	10

P. lacrymatus (Quoy and Gaimard, 1824)	2, 3, 4, 7, 8, 9, 10, 11
P. leucozonus (Bleeker, 1859)	13
Pomacentrus aquilus Allen & Randall, 1980	3, 8, 11, 12
P. baenschi Allen, 1991*	2, 3, 4, 6, 7, 8, 9, 10, 11, 12
P. caeruleus Quoy & Gaimard, 1825	2, 3, 4, 6, 8, 10, 11
P. caeruleopunctatus Allen, 2002*	3
P. sulfureus Klunzinger, 1871	2, 3, 8, 11
P. trichorus (Günther, 1867)	2, 3, 4, 6, 7, 8, 9, 11
P. trilineatus Cuvier, 1830	3, 7, 8, 9, 11
Stegastes fasciolatus (Ogilby, 1889)	7
LABRIDAE	
Anampses caeruleopunctatus Rüppell, 1828	2, 4, 6, 7
A. lineatus Randall, 1972*	2, 5, 7, 8
A. meleagrides Valenciennes, 1840	2, 4, 5, 6, 7, 8
A. twistii Bleeker, 1856	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Bodianus anthioides (Bennett, 1831)	2, 4, 6, 7, 9, 10
B. axillaris (Bennett, 1831)	2, 3, 4, 5, 6, 7, 8, 9, 11
B. bilunulatus Lacepède, 1801)	1
B. diana (Lacepède, 1801)	5
Cheilinus chlorurus (Bloch, 1791)	3, 4
C. fasciatus (Bloch, 1791)	3, 4
C. oxycephalus (Bleeker, 1853)	2, 3, 4, 6, 7, 8, 11
C. trilobatus Lacepède, 1802	2, 3, 4, 6, 7, 8, 9, 11
C. undulatus Rüppell, 1835	1
Cheilio inermis (Forsskål, 1775)	12
Cirrhilabrus exquisitus Smith, 1957*	3, 5
Coris caudimacula (Quoy & Gaimard, 1834)	2, 4, 5, 6, 7, 8, 11
C. cuvieri (Bennett, 1831)	2, 4, 5, 7
Epibulus insidiator (Pallas, 1770)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Gomphosus caeruleus Lacepède, 1801	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Halichoeres cosmetus Randall & Smith, 1982*	2, 4, 5
H. dussumieri (Valenciennes,1839)	8
H. hortulanus (Lacepède, 1802)	2, 4, 5, 6, 7, 8, 9, 10, 11
H. marginatus Rüppell, 1835	2, 3
H. nebulosus (Valenciennes, 1839)	7, 8
H. scapularis (Bennett, 1832)	3, 11
Hemigymnus fasciatus (Bloch, 1792)	2, 3, 4, 6, 7, 8, 9, 10, 11
H. melapterus (Bloch, 1791)	2, 3, 4, 6, 7, 8, 10
Hologymnosus annulatus (Lacepède, 1801)	2, 3, 4, 6, 7, 8, 10
H. doliatus (Lacepède, 1801)*	10
Labrichthys unilineatus (Guichenot, 1847)	3
Labroides bicolor Fowler & Bean, 1928	2, 3, 4, 5, 6, 7, 9, 10, 11
L. dimidiatus (Valenciennes, 1839)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Labropsis xanthonota Randall, 1981	5
Macropharyngodon bipartitus Smith, 1957	4, 11
M. cyanoguttatus Randall, 1978*	2, 3, 4, 7, 8, 10
M, vivianae Randall, 1978	4
Novaculichthys macrolepidotus (Bloch, 1791)	12
N. taeniourus (Lacepède, 1802)	2
Oxycheilinus bimaculatus (Valenciennes, 1840)	3, 7, 8, 11
O. diagrammus (Lacepède, 1802)	3, 4, 5, 6, 7, 8, 9, 10, 11
O. mentalis (Rüppell, 1828)	3
Pseudocheilinus evanidus Jordan & Evermann, 1902	2, 3, 5, 6
P. hexataenia (Bleeker, 1857)	2, 3, 4, 5, 6, 8, 9, 10, 11

Pseudocoris sp.*	5
Pseudodax moluccanus (Valenciennes, 1840)	2, 4, 5, 7, 10
Pteragogus pelycus Randall, 1981	3, 8
Stethojulis albovittata (Bonnaterre, 1785)	3, 4, 5, 6, 7
S. bandanensis	10
S. interrupta (Bleeker, 1851)	8
S. strigiventer (Bennett, 1832)	3, 4, 9, 11, 12
Thalassoma amblycephalum (Bleeker, 1856)	3, 5, 6, 7, 8, 10
T. hardwicke (Bennett, 1828)	3, 7, 8, 11
T. hebraicum (Lacepède, 1801)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
T. lunare (Linnaeus, 1758)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
T. purpureum (Forsskål, 1775)	7
SCARIDAE	
Calotomus carolinus (Valenciennes, 1839)	2, 4, 7, 10
Cetoscarus bicolor (Rüppell, 1828)	2, 3, 7, 8
Chlorurus atrilunula Randall & Bruce, 1983*	2, 3, 4, 5, 6, 7, 8, 10, 11
C. cyanescens (Valenciennes, 1840)	2, 4, 6, 7, 8, 11
C. sordidus (Forsskål, 1775)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Hipposcarus harid (Forsskål, 1775)	1
Leptoscarus vaigiensis (Quoy & Gaimard, 1824)	12
Scarus caudofasciatus (Günther, 1862)	2, 4
S, frenatus Lacepède, 1802	2, 6, 7, 8
S. ghobban Forsskål, 1775	3, 5, 6, 7, 8, 9, 11
S. niger Forsskål, 1775	2, 3, 4, 6, 7, 8, 9, 10
S. psittacus Forsskål, 1775	7, 11
S. rubroviolaceus Bleeker, 1849	2, 5, 6, 7, 9, 10
S. russelli Valenciennes, 1840*	5, 6, 7, 9
S. scaber Valenciennes, 1840	1
S. tricolor Bleeker, 1849	9, 10
S. virdifurcatus (Smith, 1956)*	6, 7, 9, 10
PINGUIPEDIDAE	
Parapercis hexophthalma (Cuvier, 1829)	2, 3, 4, 6, 7, 8, 9, 10, 11
BLENNIIDAE	
Aspidontus taeniatus tractus Fowler, 1903	7
Blenniella periophthalmus (Valenciennes, 1836)	13
Cirripectes stigmaticus Strasburg & Schultz, 1953	3, 4
Ecsenius midas	11
E. nalolo Smith, 1959*	7, 9
Exallias brevis (Kner, 1868)	10
Istiblennius edentulus Bloch & Schneider, 1801	12
Meiacanthus mossambicus Smith, 1959	3, 4, 6, 7, 8, 11
Plagiotremus rhinorhynchus (Bleeker, 1852)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
P. tapeinosoma (Bleeker, 1857)	3, 8, 10
Petroscirtes breviceps (Valenciennes, 1836)	12
Salarias fasciatus (Bloch, 1786)	12
CALLIONYMIDAE	
Callionymus delicatulus Smith, 1963	3
GOBIIDAE	
Amblyeleotris periophthalma (Bleeker, 1853)	8
A. steinitzi (Klausewitz, 1974)	7
A. wheeleri (Polunin & Lubbock, 1977)	4, 6, 7, 8
Amblygobius albimaculatus (Rüppell, 1830)	3, 11
A. tekomaji Smith, 1959	3
Bathygobius albopunctatus (Valenciennes, 1837)	12

Cryptocentrus cryptocentrus (Valenciennes)	3
C. strigilliceps (Jordan & Seale, 1906)	3, 7, 8, 11, 12
Ctenogobiops crocineus Smith, 1959	3, 7, 11
Eviota nebulosa Smith, 1958	2
Fusigobius duospilus Hoese & Reader, 1985*	3
Gnatholepis anjerensis (Bleeker, 1851)	3, 12
G. cauerensis Bleeker, 1853	2, 3, 6, 7, 8, 9, 11
Istigobius decoratus (Herre, 1927)	2, 3, 4, 7, 8, 11
Macrodontogobius wilburi Herre, 1936*	11
Opua athernoides	3, 11
Oplopomus oplopomus (Valenciennes, 1837)	1
Valenciennea puellaris (Tomiyama, 1936)	3, 7, 11
V. strigata (Broussonet, 1782)	4, 5, 6
Vanderhorstia ornatissima Smith, 1959	3, 7, 11
MICRODESMIDAE	
Gunnelichthys. curiosus Dawson, 1968*	3, 8, 11
PTERELEOTRIDAE	
Nemateleotris magnifica Fowler, 1938	2, 4, 5, 6, 9, 10
Ptereleotris evides (Jordan & Hubbs, 1925)	2, 4, 6, 7, 8, 9, 10
EPHIPPIDAE	
Platax teira (Forsskål, 1775)	1
SIGANIDAE	
Siganus argenteus (Quoy & Gaimard, 1824)	2, 3, 4, 6, 7, 9, 10
S. luridus (Rüppell, 1829)	2, 4, 6, 7, 9, 10
S. stellatus (Forsskål, 1775)	2, 7, 9, 10
S. sutor (Valenciennes, 1835)	12
ZANCLIDAE	
Zanclus cornutus Linnaeus, 1758	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
ACANTHURIDAE	
Acanthurus dussumieri Valenciennes, 1835	2, 3, 4, 5, 6, 7, 10, 11
A. leucosternon Bennett, 1832	2, 4
A. lineatus (Linnaeus, 1758)	7, 10
A. mata (Cuvier, 1829)	2, 5, 6, 10
A. nigricaudus Duncker & Mohr, 1929	2, 3, 4, 6, 7, 8, 9, 10, 11
A. nigrofuscus (Forsskål, 1775)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
A. tennenti Günther, 1861	2, 4, 5, 10
A. thompsoni (Fowler, 1923)*	5, 8
A. triostegus (Linnaeus, 1758)	3, 4, 7, 8, 11
A. xanthopterus Valenciennes, 1835	11
Ctenochaetus binotatus Randall, 1955*	2, 3, 4, 5, 6, 7, 9, 10, 11
C. striatus (Quoy and Gaimard, 1824)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. truncatus Randall & Clements, 2001*	2, 3, 4, 5, 6, 7, 9, 10, 11
Naso brachycentron (Valenciennes, 1835)	2, 4
N. brevirostris (Valenciennes, 1835)	4, 5, 6, 7, 9
N. caeruleacauda Randall, 1994*	2, 5, 7, 8
N. elegans Rüppell, 1829	2, 4, 5, 6, 7, 9, 10, 11
N. hexacanthus (Bleeker, 1855)*	5
N. unicornis (Forsskål, 1775)	3, 5, 7
N. vlamingii (Valenciennes, 1835)	2, 4, 5, 7, 10
Zebrasoma desjardinii (Bennett, 1836)	2, 3, 4, 5, 6, 7, 10, 11
Z. scopas (Cuvier, 1829)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
SPHYRAENIDAE	
Sphyraena barracuda (Walbaum, 1792)	1
S. flavicauda Rüppell, 1838	2, 3, 11

S. qenie Klunzinger, 1870	5
BOTHIDAE	
B. pantherinus (Rüppell, 1830)	3
BALISTIDAE	
Abalistes stellatus (Lacepède, 1798)	8
Balistapus undulatus (Park, 1797)	2, 3, 4, 5, 6, 7, 9, 11
Balistoides conspicillum (Bloch & Schneider, 1801)	4, 5, 7, 9, 10
B. viridescens (Bloch & Schneider, 1801)	2, 3, 4, 5, 6, 7
Melichthys indicus Randall & Klausewitz, 1973	2, 4, 5
Odonus niger (Rüppell, 1836)	5
Pseudobalistes fuscus (Bloch & Schneider, 1801)	8
Rhinecanthus aculeatus (Linnaeus, 1758)	1
Rhinecanthus rectangulus (Bloch & Schneider, 1801)	8
Sufflamen bursa (Bloch & Schneider, 1801)	2, 4, 5, 6, 7
S. chrysoptera (Bloch & Schneider, 1801)	2, 4, 5, 6, 7, 8, 9, 10, 11
S. fraenatus (Latreille, 1804)	6
MONACANTHIDAE	
Amanses scopas (Cuvier, 1829)	2, 9, 10
Cantherines dumerilii (Hollard, 1854)*	2
C. pardalis (Rüppell, 1837)	4, 5, 6, 7, 9, 10
Paraluteres prionurus (Bleeker, 1851)*	4, 6, 7
Pervagor janthinosoma (Bleeker, 1854)	2
OSTRACIIDAE	
Lactoria cornuta (Linnaeus, 1758)	1, 2
Ostracion cubicus Linnaeus, 1758	2
O. meleagris Shaw, 1796	2, 3, 4, 7, 8, 10, 11
TETRAODONTIDAE	
Arothron hispidus (Linnaeus, 1758)	6, 7
A. immaculatus (Bloch & Schneider, 1801)	1
A. nigropunctatus (Bloch & Schneider, 1801)	2, 4, 5, 7
A. stellatus (Schneider, 1801)	1
Canthigaster bennetti (Bleeker, 1854)	2, 3, 4, 7, 8, 11
C. janthinoptera (Bleeker, 1855)	2, 4
C. smithae Allen & Randall	4
C. solandri (Richardson, 1844)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
C. valentini (Bleeker, 1853)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Torquigener flavomaculatus	1
DIODONTIDAE	
Diodon liturosus	1
Diodon hystrix Linnaeus, 1758	3

Site Records:

1 = BV Photo Library, 2 = Shark Alley, 3 = Coco Beach, 4 = Nosy Fasy, 5 = Andravamaike, 6 = THB, 7 = Valleys, 8 = Andavadoaka Rock, 9 = 007, 10 = Recruitment, 11 = Half Moon, 12 = Andavadoaka Lagoon (snorkel in seagrass bed), 13 = Laguna Blu (snorkel opposite resort).

APPENDIX 3

TAXONOMIC EVALUATION OF THE MARINE BIODIVERSITY AT ANDAVADOAKA MADAGASCAR: MOLLUSCS

November 2005

Mission Report for the Wildlife Conservation Society Marine Program, Madagascar and the Direction de la Préservation de la Biodiversité, Ministère de l'Environnement, des Eaux et Forêts, Madagascar (organisation of tutelage: Institut Halieutique et des Sciences Marines, IHSM)

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1) Methodology

The mission took place from the 25th to the 29th of november 2005 in Andavadoaka, along the coastline (between Antseranambe Point to the South and Andavadoaka Bay to the North), on the perimeter of the islands of Nosy Hao and Nosy Fasy, and on marine sites referenced by the NGO Blue Ventures.

Excursions by foot throughout the tidal zone and the mangroves were used to record the number of live mollusc species found in these areas, and the recently-deposited shells on the shore were recorded to give an estimate of the species found at depth. A methodology for a survey on the specific biodiversity of marine molluscs found in the intertidal zone was presented to the NGO Blue Ventures.

Several snorkelling transects were carried out in front of Andavadoaka Point, in the bay to the North of Antseranambe Point, and all around the islands of Nosy Hao and Nosy Fasy (R1, R2,etc.)

Several SCUBA-diving excursions were carried out on dive sites referenced by the NGO Blue Ventures (BV sites).

Micro-molluscs were not dealt with, nor were species living within the coral, to avoid destruction of coral colonies. On all surveys the species were identified, recorded and photographed; certain specimens were collected in order to further their identification and to photograph them in better conditions before being released (new 'no kill' methodology elaborated by ARVAM (Alain BARRERE and Jean Pascal QUOD, 2004), which allows the completion of the collection whilst preserving as much as possible the organisms). For each species, the abundance was recorded (+ : present , ++ several individuals, +++ : very abundant and ++++ : dominant).


in situ : Conus augur

in situ : Notodoris minor


collection : Cypraea isabella

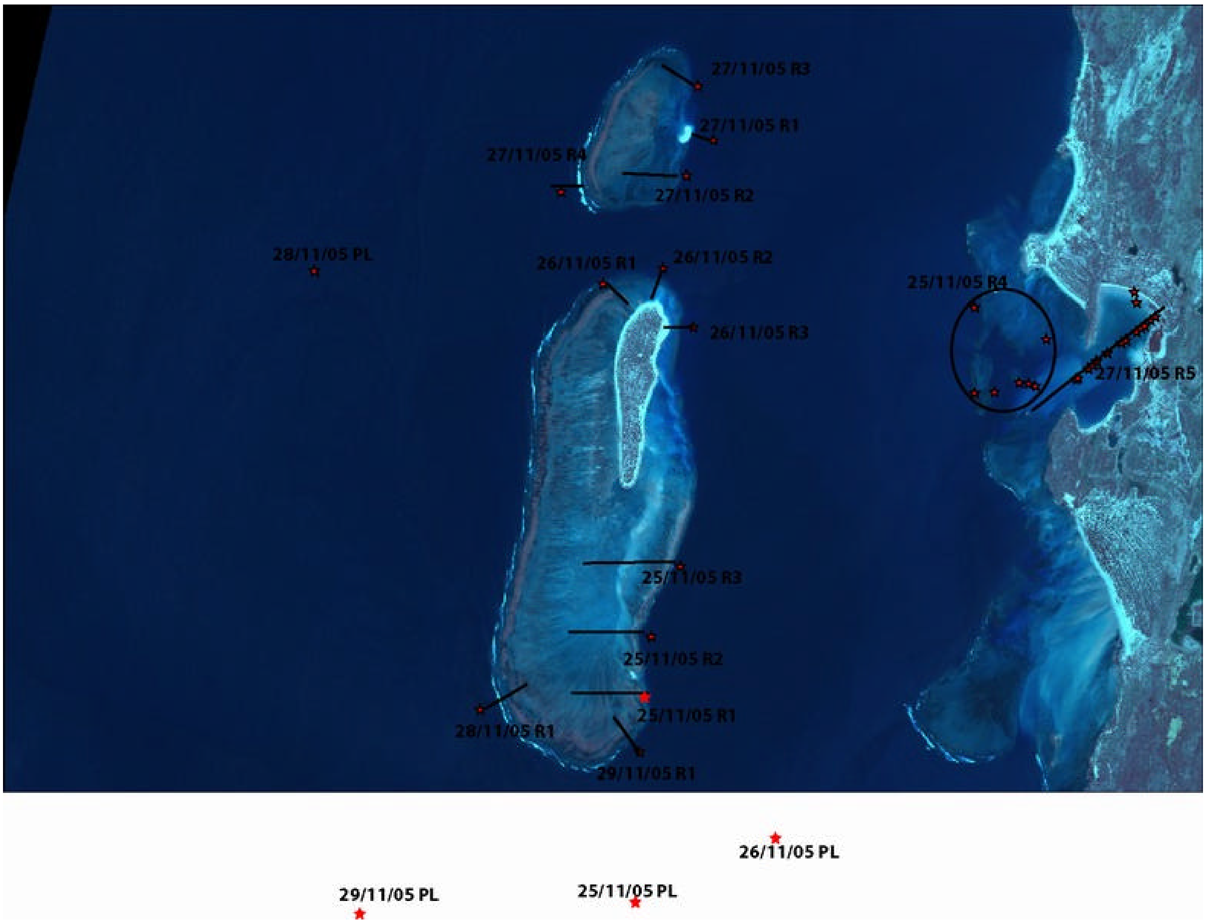

collection : Codakia tigerina

Photographs : Al. Barrère

Survey Plan :

Date	Stations	Depth	Type of Habitat
25/11/05	R1 Nosy Hao SE	0-5 m	Seagrass, algal reef flats
	R2 Nosy Hao SE	0-5 m	Seagrass, algal reef flats
	R3 Nosy Hao SE	0-5 m	Seagrass, algal reef flats
	Site BV1 (Betramosy)	32 m	External reef slope
	R4 Split Rock S	0-5 m	Detritic reef flat
26/11/05	R1 Nosy Hao N	0-5 m	Seagrass, algal reef flats
	R2 Nosy Hao N	0-5 m	Seagrass, algal reef flats
	R3 Nosy Hao N	0-5 m	Seagrass, algal reef flats
	SiteBV2 (Ambatobe)	20 m	External reef slope
27/11/05	R1 Nosy Fasy E	0-5 m	Seagrass, algal reef flats
	R2 Nosy Fasy S	0-5 m	Seagrass, algal reef flats
	R3 Nosy Fasy N	0-5 m	Seagrass, algal reef flats
	R4 Dive Nosy Fasy W	0-20 m	External reef slope
	R5 Andavadoaka-Antseranambe Bay	0-5 m	Sedimentary lagoon
	R6 Split Rock S cf R4	0-5 m	Detritic reef flat
28/11/05	R1 Nosy Hao S	0-5 m	Seagrass, algal reef flats
	Site BV3 (Andrivamaike)	30 m	External reef slope
29/11/05	Site BV4 Nosy Hao SW	30 m	External reef slope
	R2 Nosy Hao S	0-5 m	Seagrass, algal reef flats

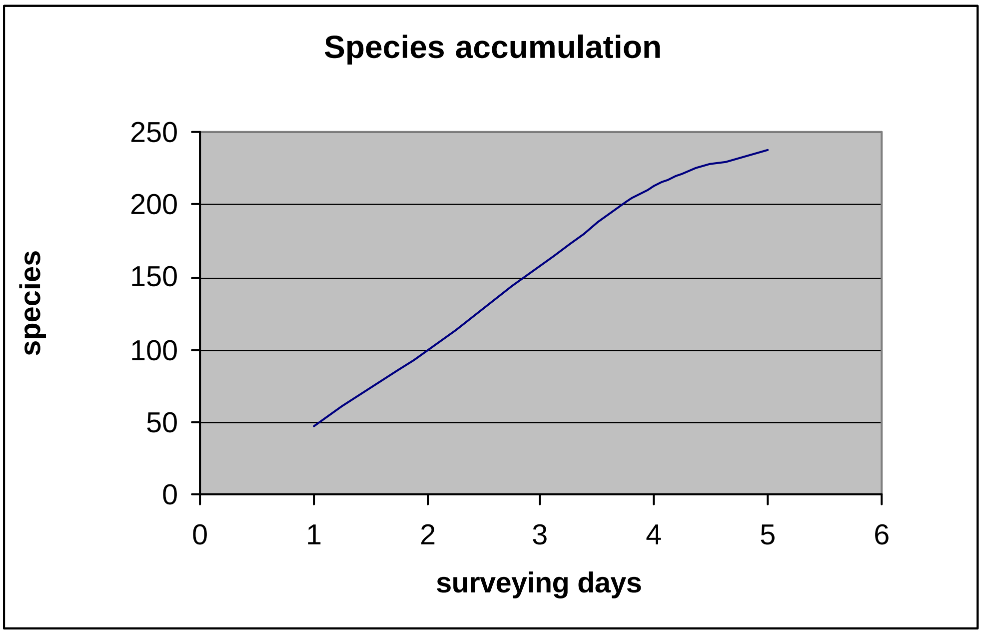
19 marine sites were studied, 14 by snorkelling transects (90 to 120mn per transect) and 5 SCUBA-dives to a maximum depth of 32m (average dive time of 40mn).



The previous figure (J.B. Nicet, ARVAM) shows the location of the snorkelling and dive transects carried out during this mission. All points on the photograph are georeferenced by Mapinfo from GPS coordinates, the 3 points underneath corresponding to dives have been placed approximatively (due to the distance separating them from the other sites they would have decreased the legibility of this document).

Evolution of the number of species found throughout the mission

Days	Number of species	Number of cumulative species
1	48	48
2	52	100
3	58	158
4	55	213
5	25	238



2) Results / Discussion

- 71 families, 112 genera, 238 species were found in the 5 days of surveying.

- The short duration of this mission allowed only a partial look at the molluscan fauna of Andavadoaka, but by extrapolating the results obtained, the number of species found in 15 surveying days would be of the order of 450-500 species, which correlates well with the results from previous missions:

  - 525 species found during the RAP mission of January 2002 (16 surveying days) in North-West Madagascar, Fred E. Wells (CI Marine RAP survey)
  - 294 species found during the Hibernia reef mission of 1993 (6 surveying days) by Willan (Western Australian Museum Survey)
  - 260 species found during the Rowley Shoals mission of 1986 (7 surveying days) Wells and Slack-Smith (Western Australian Museum Survey)

- The results are coherent with those obtained on the last mission in the North-West of Madagascar: RAP marine mission of January 2002, Fred E. Wells (CI Marine RAP survey)

Taxonomic composition of the Molluscs found in Andavadoaka

Class	Families	Genera	Species
Gastropoda	39	62	171
Opisthobranchia (sub-class)	7	11	15
Polyplacophora	1	1	1
Bivalvia	21	35	47
Cephalopoda	3	3	4
Total	**71**	**112**	**238**

Table comparing the relative quantity of species within the most well represented families:

Families	**North-west Madagascar January 2002 Fred E. Wells**	**Andavadoaka November 2005 A. Barrère**
Trochidae	1,7%	2,5%
Turbinidae	1%	2,5%
Neritidae	0,8%	1,7%
Cerithiidae	3,6%	3%
Strombidae	2,6%	4,6%
Cypraeidae	6%	11,3%
Naticidae	2%	2%
Cassidae	0,4%	1,7%
Cymatiidae	1,8%	2%
Muricidae	6%	2%
Buccinidae	2%	1,3%
Nassariidae	2%	1,7%
Fasciolariidae	2%	2%
Olividae	2,2%	1,7%
Mitridae	2%	3,4%
Costellariidae	4,5%	1,7%
Conidae	9%	12,6%
Terebridae	4,7%	2,5%
Chromodorididae	1,8%	2%
Phyllidiidae	1,5%	1,3%
Arcidae	1,3%	1,7%
Mytilidae	0,8%	2%
Pinnidae	0,8%	1,3%
Pteriidae	0,6%	1,3%
Pectinidae	4,5%	1,3%
Ostreidae	0,4%	0,8%
Lucinidae	0,6%	1,3%
Cardiidae	2,6%	1,7%
Tellinidae	2,5%	2%
Veneridae	3,8%	2%

The Conidae, Cypraeidae, Strombidae, Cerithiidae, Mitridae were the dominant families in terms of number of species present.
The area studied was rich in molluscs, the results show a high diversity, close to that found in the North-West of Madagascar. This may be due to the diversity of biotopes (sedimentary bay, isolated cay, biodetritic and coralline reef flat), the drop in ichthyologic predation (overfishing), and to the weak anthropogenic pressure exerted on deep marine sites (little SCUBA activity in the area). It should be noted that no Bursidae or Turridae were seen throughout this mission.

- The species distribution depends on the type of habitat: algal reef flats ; seagrass beds ; detritic reef flats ; external reef slop ; sedimentary lagoon :

    - Surrounding the islands of Nosy Hao and Nosy Fasy, the habitat is essentially algal-seagrass reef flat: the dominant species is *Cypraea annulus* (up to 50 individuals/m^2), other species are abundant : *Cerithium nodulosum*, *Tridacna sp* as well as some Strombrids and Vasids. The density of *Tridacna sp*, in certain areas (transects around Nosy Hao) is of the order of 10 individuals per 100 m^2. This species is protected (CITES and UNEP-WCMC lists), of high commercial interest and its abundance is remarkable: this site must be protected.
    - On the detritic reef flat zones, few molluscs were found, mostly Trochids and Turbinids.
    - The habitats on the outer reef slope make for a benthic fauna rich in hydrozoans, alcyonians and ascidians. The diversity of gastropods and bivalves is normal for this type of environment, however it should be noted that a relatively high abundance and diversity of opistobranch nudibranchs was present (between 5 and 10 individuals found on each dive, with on average 4 different per dive).
    - In the sedimentary lagoon (the bay between Andavadoaka and Antseranambe Point), the dominant species were *Anadara antiquata* and *Terebralia palustris* (within the mangrove), other species are abundant : *Donax sp, Terebra felina* and in places *Atrina vexillum.*
    - Within the intertidal zone, on the rocks and within the tide pools, the main species are *Nerita plicata* , *Clypeomorus batillariaeformis* and *Saccostrea cucullata.*

- The highest biomass was found on the transects carried out in the perimeter of the islands of Nosy Hao and Nosy Fasy, due to a high abundance of *Octopus cyanea* and *Tridacna sp*. (especially surrounding Nosy Hao for the latter species) and a high abundance of bivalves within the sedimentary lagoon (*Anadara sp, Donax sp*).

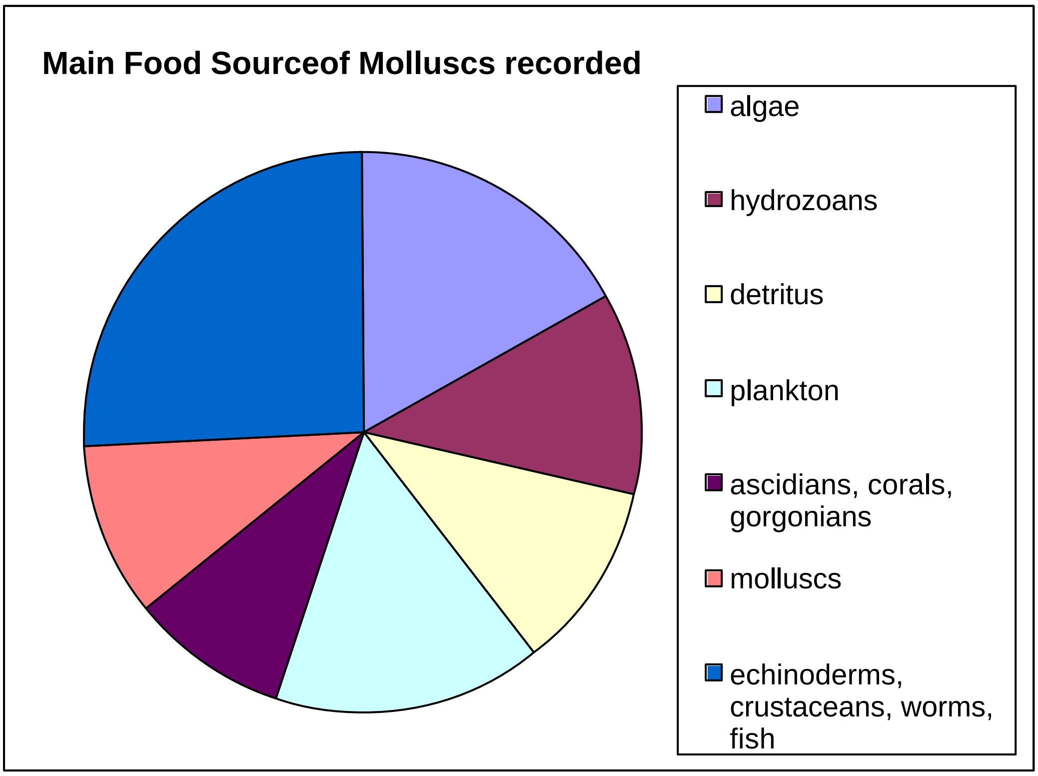
3) Trophic Guilds

The distribution of main sources of food divides the molluscan fauna into 3 main trophic guilds:

- Phytoplanktivores, particularly in the algal zones surrounding the isolated islands;
- Detritivores and filter feeders, particularly in the transport and sedimentation zones (back of the bay)
- Carnivores (predation) and benthic detritivores throughout the different zones.

It is worth noting the richness in predatory species.

Main food source	No. of Species
algae	50
hydrozoans	34
detritus	32
plankton	46
ascidians, corals, gorgonians	27
molluscs	30
echinoderms, crustaceans, worms, fish	76



4) Perspectives

The main issue facing the molluscs in the study zone is the octopus fishery, which needs to sustain the local Vezo population whilst preserving the stock of *Octopus cyanea*
Trial no-take-zones (NTZ's) with a regular re-opening are currently in place around the islands of Nosy Hao and Nosy Fasy. Continuing this work and drawing on recent experiments (cf for example the report on the *Octopus vulgaris* study on the north-west African coast IRD EDITIONS 2002) would be most valuable.
It is worth considering a permanent NTZ, which would act as a sanctuary and source for the surrounding area, and would allow the study of the distribution patterns of individuals over time .

The *Tridacna* sp. population around Nosy Hao must be protected.

A little-exploited source of animal protein in the area can be found in the bivalve population of the sedimentary lagoon, for example between Andavadoaka and Antseranambe Point. Its controlled use, with the careful conservation of a reproductive stock, could be of interest to the community of Andavadoaka.

In addition to octopus, certain other molluscs are exploited, such as certain cowries (*Cypraea annulus*) which serve to make cement for constructions, and certain species present a commercial interest (textile cone shells, some helmet shells). A Fasciolarid, *Pleuroploca trapezium* is often used as a decorative border to mark private property. A species of Mitridae *Mitra coffea* is sought after for its social importance (as jewellery).
It would be worth surveying these species in order to track any variations in population in order to evaluate the anthropogenic pressure exerted on them, and its consequences.

5) Bibliography

Abbott, R.T., Dance, S.P. 1990 Compendium of seashells. American malacologists, INC Melbourne, Florida

Angot, M. 1966 Bibliographie des travaux scientifiques marins intéressant Madagascar Centre ORSTOM Nosy bé, Imprimerie nationale Tananarive

Bidgrain, P. 2005 Nudibranches de l'ile de la Réunion. Vie Océane La Réunion : http://vieoceane.free.fr/runseaslug/f_intro.htm

BONS J., 1984 – Mollusques marins *de l'Océan Indien : Comores, Mascareignes, Seychelles*. Agence Coop.

Bourmaud, C. 2003 Inventaire de la Biodiversité marine récifale à La Réunion. Laboratoire d'Ecologie Marine-Université de la Réunion, ARVAM, Museum d'Histoire Naturelle de La Réunion

Caceres, S., 2003 Etude préalable pour le classement en Réserve Naturelle des Iles Eparses, Mémoire de DESS Sciences et Gestion de l'Environnement Tropical de l'Université de la Réunion, Laboratoire d'écologie marine, Université de la Réunion

Caverivière, A., Thiam, M., Jouffre, D. 2002 Le poulpe, *Octopus vulgaris*, Sénégal et côtes Nord-ouest Africaines IRD Editions collection colloques et séminaires, Paris

Coleman, N. 2001. 1001 nudibranchs. Catalogue of Indo-Pacific sea slugs. Springwood, Queensland: Neville Coleman.

Cooke, A. In press. Marine and coastal ecosystems of Madagascar.

Dautzenberg, P. 1923. Liste préliminaire des mollusques marins de Madagascar et description de deux espèces nouvelles. Journal de Conchyliologie 67: 21-74.

Dautzenberg, P. 1929. Mollusques testacés marins de Madagascar.. Fauna des Colonies Francaises. Volume 3.

Dautzenberg, P. 1932. Mollusques testacés marins de Madagascar. Supplément. Journal de Conchyliologie 76: 5-119.

FAO (Food and Agriculture Organization of the United Nations). 1998. Aperçu sur les Zones de Pêche Traditionelle Maritime dans la Region de Toliara. Programme Sectiorel Pêche PNUD/FAO-MAG/92/004 – DT/10/98. 14 pp.

Gabrié, C (ed); Bossanyi-Johnson, I (trad) ; Ministry of Spatial Planning and Environment (ed); State Secretariat for Overseas Affairs (ed), 1998. State of coral reefs in French overseas départements and territories : New Caledonia, Wallis and Futuna, Fren,ch Polynesia, Clipperton, Guadeloupe, Martinique, Mayotte, La Réunion, Scattered Indian Ocean islands : 36 p.

Gabrié, C; Moyne Picard, M (collab) ; International Coral Reef Initiative (ed), 1998. L'état des récifs coralliens en France Outre-Mer : 90 p. multigr.

Gabrié, C., J. Maharavo, H. Randriamiarana, and E. Mara. 2000. The coral reefs of Madagascar. *In*: McClanahan, T. R., D. O. Obura, and C. R. C. Shepherd (eds.). Coral reefs of the West Indian Ocean. Oxford: Oxford University Press.

Gosliner, T., Behrens, D., Williams, G. 1996 Coral reef animals of the Indo-Pacific Sea Challengers, Monterey, California

Graham Oliver, P., 1992, Bivalved seashells of the Red Sea. Verlag Christa Hemmen, National Museum of Wales, Cardiff.

Hoffman, C. K. 1877. Recherches sur le faune de Madagascar et de ses dependances, d'après les découvertes de Dr Francois P.L. Pollen et D.C. van Dam. Leiden, The Netherlands: E. J. Brill.

Jay, M., Drivas, J. 1988 Coquillages de La Réunion et de l'Ile Maurice. Times Editions, Les éditions du Pacifique.

King, D., Fraser, V. 2002, More reef fishes and nudibranchs East and South coast of southern Africa Struik Publishers, Cape Town.

Lewis, A., et al., 2004, EUCARE & IH.SM. Collaborative Reef Research Expedition to Andavadoaka, South-west Madagascar. Edinburgh University Coral Awareness and Research Expeditions & Institut Halieutique et des Sciences Marines, Université de Toliara

Lindner, G. 2005 Guide des coquillages marins. Delachaux et Niestlé, Munich.

Odhner, N. J. 1919. Contribution a la faune malacologique de Madagascar. Arkiv för Zoologi utgifvet af K. Svenska Vetenskapsakademien 12(6): 1-52.

Quod, J.P., Barrère,A., Dinhut, V. 2005, Base de données Iles Eparses Françaises. ARVAM

Richmond, M. D. In press. The marine biodiversity of the Western Indian Ocean and its biogeography. How much do we know? *In*: Richmond, M. D. and J. Francis (eds). Proceedings of the Twentieth Anniversary Conference on Marine Science in Tanzania, June 2001. Western Indian Ocean Marine Science Association, Institute of Marine Sciences, Zanzibar, Tanzania.

Springsteen, F. J. and F. M. Leobrera. 1986. Shells of the Philippines. Manila, Philippines: Carfel Seashell Museum.

Thomassin, B. 1978. Les peuplements des sédiments coralliens de la région de Tuléar (SW de Madagascar). Leur insertion dans le contexte côtier indo-paci.que. Thèse Doct. Ès Sci., Univ. Aix Marseille.

Vergonzanne, G. 1977. Etude sur les mollusques et les échinodermes récifaux des îles Glorieuses (Nord Ouest de Madagascar). Thèse Doct. Es Sci., Univ Bretagne Occidentale

Wells, F. E. 2002. Molluscs of the Raja Ampat Islands, Papua Province, Indonesia. *In:* McKenna, S.A., G. R. Allen and S. Suryadi. 2002. A marine rapid assessment of the Raja Ampat Islands, Papua Province, Indonesia. RAP Bulletin of Biological Assessment 22. Washington, DC: Conservation International.

Wells, F.E. 2002. Molluscs of Northwestern Madagascar *In*: McKenna, S.A., G. R. Allen 2002. A marine rapid assessment of the Coral reefs of Northwest Madagascar. RAP Bulletin of Biological Assessment 31. Washington, DC: Conservation International.

Wells, F. E. and C. W. Bryce. 1997. A preliminary checklist of the marine macromolluscs of the Houtman Abrolhos Islands, Western Australia. *In:* Wells, F. E. (ed). Proceedings of the seventh international marine biological workshop: The marine flora and fauna of the Houtman Abrolhos Islands, Western Australia. Western Australian Museum, Perth. Pp. 362-384.

Annexe 1 List of Molluscs species identified at Andavadoaka

PHYLUM: MOLLUSCA	Abundance	Trophic Guild
Class: GASTROPODA		
Sub-Class: PROSOBRANCHIA (STREPTONEURA)		
Order: ARCHAEOGASTROPODA		
Super Family: PLEUROTOMARIACEA		
Family: Haliotidae		1
Haliotis ovina? Gmelin, 1791		
Haliotis varia Linné, 1758	+	
Super Family: PATELLACEA		
Family: Patellidae		1
cf Cellana radiata Born, 1778 *subsp enneagona* Reeve, 1854	+	
Patella barbara Linné, 1758		
Patella chapmani Tenison-Woods, 1876	+	
Patella flexuosa Quoy et Gaimard, 1834		
Family: Cocculinidae		
cf Cocculina Dall, 1882	+	
Super family: TROCHACEA		
Family: Trochidae		1,9
Clanculus flosculus Fischer, 1878	+	
Clanculus puniceus Philippi, 1846	+	
Tectus sp1	++	
Tectus virgatus Gmelin, 1791	+	
Trochus cariniferus Reeve, 1861	+	
Trochus radiatus Gmelin, 1791		
Trochus virgatus Gmelin, 1791	+	
Family: Turbinidae		1
Lunella coronata Gmelin, 1791	+	
Turbo argyrostomus Linné, 1758	++	
Turbo chrysostomus Linné, 1758	+	
Turbo imperialis Gmelin, 1791	+	
Turbo japonicus Reeve, 1848	+	
Turbo marmoratus Linné, 1758	+	
Family: Phasianellidae		
Phasianella variegata Lamarck, 1822	+	
Super Family: NERITACEA		
Family: Neritidae		1
Nerita textilis Gmelin, 1791	++	
Nerita albicilla Linné, 1758	+	

Nerita plicata Linné, 1758	+++	
cf Nerita undata Linné, 1758	+	
Order: CAENOGASTROPODA (MESOGASTROPODA)		
Super Family: LITTORINACEA		
Family: Littorinidae		
Littorina scabra Linné, 1758	++	
Super Family: CERITHIACEA		
Family: Vermetidae		9
Siphonium sp		
Spiroglyphus annulatus Daudin, 1800		
sp	++	
Family: Planaxidae		1
Planaxis sulcatus Born, 1778	++	
Family: Modulidae		1
Modulus tectum Gmelin, 1791	+	
Family: Potamididae		
Terebralia palustris Linné, 1758	+++	
Family: Cerithiidae		1,9
Cerithium alveolus Honbron et Jacquinot, 1854	+	
Cerithium caeruleum Sowerby, 1855	+	
Cerithium echinatum Lamarck, 1822	++	
Cerithium nodulosum Bruguière, 1792	++	
Clypeomorus concisus Hombron et Jacquinot, 1854		
Clypeomorus batillariaeformis Habe et Kosuge, 1966	+++	
Rhinoclavis aspera Linné, 1758	+	
Rhinoclavis articulata Adams et Reeve, 1850	+	
Super Family: STROMBACEA		
Family: Strombidae		1
Lambis chiragra arthritica Röding, 1798	++	
Lambis scorpius indomaris Abbott, 1961	+	
Lambis truncata Humphrey, 1786	++	
Strombus aurisdianae aurisdianae Linné, 1758	+	
Strombus decorus decorus Röding, 1798	++	
Strombus dentatus Linné, 1758		
Strombus gibberulus gibberulus Linné, 1758	+	
cf Strombus granulatus Swainson, 1822	+	
cf Strombus labiatus olydius Duclos, 1844	+	
Strombus lentiginosus Linné, 1758	+	
Strombus mutabilis Swainson, 1821	+	
Strombus ochroglottis Abbott, 1960	+	
Super Family: CALYPTRAEACEA		
Family: Calyptraeidae		3
Cheila equestris Linné, 1758	+	
Cheila tectumsinense Lamarck, 1822		

Super Family: TRIVIACEA		
family: Triviidae		15
Trivirostra exigua Gray, 1831	+	
Trivirostra oryza Lamarck, 1811	+	
Super Family: CYPRAEACEA		
family: Cypraeidae		1,3
Cypraea alisonae Burgess, 1983	+	
Cypraea annulus Linné, 1758	++++	
Cypraea arabica Linné, 1758	+	
Cypraea argus Linné, 1758	+	
Cypraea caputserpentis Linné, 1758	+	
Cypraea carneola Linné, 1758	+	
Cypraea caurica Linné, 1758	+	
Cypraea chinensis Gmelin, 1791	+	
Cypraea circercula Linné, 1758	+	
Cypraea erosa Linné, 1758	++	
Cypraea fimbriata Gmelin, 1791	+	
Cypraea helveola Linné, 1758	+	
Cypraea histrio Gmelin, 1791	++	
Cypraea isabella Linné, 1758	++	
Cypraea kieneri Hidalgo, 1906	+	
Cypraea lynx Linné, 1758	++	
Cypraea mappa Linné, 1758	+	
Cypraea minoridens Melvill, 1901	+	
Cypraea moneta Linné, 1758	+	
Cypraea nucleus Linné, 1758	+	
Cypraea owenii Sowerby, 1837	+	
Cypraea poraria Linné, 1758		
Cypraea scurra Gmelin, 1791	+	
Cypraea staphylaea Linné, 1758	+	
Cypraea talpa Linné, 1758	+	
Cypraea teres Gmelin, 1791	+	
Cypraea tigris Linné, 1758	+	
Cypraea vitellus Linné, 1758	+	
Cypraea sp		
Super Family: NATICACEA		
Family: Naticidae		12
Mamilla melanostoma Gmelin, 1791	+	
Mamilla simiae Deshayes, 1848	+	
cf Natica onca Röding, 1798	+	
Polinices flemingianus Recluz, 1844	+	
Polinices tumidus Swainson, 1840	+	
Super Family: TONNACEA		
Family: Cassidae		14
Casmaria erinaceus Linné, 1758	+	
Casmaria ponderosa Link, 1807	+	
Cassis cornuta Linné, 1758	+	

Cypraeacassis rufa Linné, 1758	+	
Family: Tonnidae		6,14
Malea pomum Linné, 1758	+	
Tonna canaliculata Linné, 1758	+	
Tonna perdix Linné, 1758	+	
Family: Cymatiidae		14
Charonia tritonis tritonis Linné, 1758	+	
cf Cymatium aquatile Reeve, 1844	+	
Cymatium hepaticum Röding, 1798	+	
Cymatium lotorium Linné, 1758	+	
Cymatium nicobaricum Röding, 1798		
Distorsio anus Linné, 1758	+	
Family: Bursidae		11
Bursa bubo Linné, 1758		
Bursa bufonia Gmelin, 1791		
Order: (NEOGASTROPODA)		
Super Family: MURICACEA		
Family: Coralliophilidae		13
Coralliophila neritoidea Lamarck, 1816	+	
Rapa incurvus Dunker, 1852	+	
Family: Muricidae		10
Chicoreus ramosus Linné, 1758	++	
Drupa lobata Blainville, 1832		
Drupa ricina albolabris Blainville, 1832	+	
Drupella cornus Röding, 1798		
Mancinella tuberosa Röding, 1798	+	
Morula granulata Duclos, 1832	+	
Morula uva Röding, 1798	+	
Naquetia triquetra Born, 1778		
Nassa francolina Bruguière, 1789		
Purpura persica Linné, 1758		
Thais aculeata Deshayes, 1844		
Super Family: BUCCINACEA		
Family: Buccinidae		9;10
Engina mendicaria unilineata Linné, 1758	+	
cf Phos cyanostoma Adams, 1850	+	
Prodotia crocata Reeve, 1846	+	
Family: Columbellidae		
Euplica turturina Lamarck, 1822	+	
Mitrella albina Kiener, 1841	+	
Pyrene flava Bruguière, 1789	+	
Family: Nassariidae		9;10
Nassarius albescens Dunker, 1846	+	
Nassarius albescens gemmuliferus Adams, 1852	+	
Nassarius arcularius plicatus Röding, 1798	++	
Nassarius margaritiferus Dunker, 1847		
Nassarius papillosus Linné, 1758	+	
Family: Fasciolariidae		10

Latirus craticulatus Gmelin, 1791	+	
cf Latirus turritus Gmelin, 1791	+	
Peristernia forskali Tapparone-Canefri, 1879	+	
Pleuroploca filamentosa Röding, 1798	+	
Pleuroploca trapezium Linné, 1758	+++	
Family: Melongenidae		
Volema pyrum Gmelin, 1791	+	
Super Family: VOLUTACEA		
Family: Olividae		9;10
Oliva annulata Gmelin, 1791	+	
cf Oliva caerulea Röding, 1798	+	
Oliva olympiadina Duclos, 1844		
Oliva sericea Röding, 1798	+	
Oliva tigrina Lamarck, 1811	+++	
Family: Vasidae		11,12
Vasum ceramicum Linné, 1758		
Vasum turbinellus Linné, 1758	+	
Family: Mitridae		9;10
Mitra coffea Schubert et Wagner, 1829	+	
Mitra cucumerina Lamarck, 1811	+	
cf Mitra fraga Quoy et Gaimard, 1833	+	
Mitra imperialis Röding, 1798	+	
Mitra litterata Lamarck, 1811		
Mitra mitra Linné, 1758		
Mitra paupercula Linné, 1758	+	
cf Mitra rubritincta Reeve, 1844	+	
Mitra stictica Linné, 1758		
Mitra tabanula Lamarck, 1811		
Pterygia crenulata Gmelin, 1791		
Pterygia nucea Gmelin, 1791		
Scabricola bicolor Swainson, 1824	+	
Family: Costellariidae		
Vexillum intermedium Kiener, 1838	+	
cf Vexillum modestum Reeve, 1845	+	
Vexillum osiridis Issel, 1869	+	
cf Vexillum unifascialis Lamarck, 1811	+	
Family: Harpidae		
Harpa amouretta Röding, 1758	+	
Harpa major Röding, 1798	+	
Family: Cancellariidae		
Scalptia scalata Sowerby, 1833	+	
Super Family: CONACEA		
Family: Turridae		10
Lophiotoma cingulifera Lamarck, 1822		
Family: Conidae		6,11,12
cf Conus caracteristicus Fischer, 1807		
Conus arenatus Hwass, 1792	++	
Conus augur Lightfood, 1786	+	
Conus aulicus Linné, 1758		

Conus auricomus Hwass, 1792	+	
Conus betulinus Linné, 1758		
Conus capitaneus Linné, 1758		
Conus catus Hwass, 1792	+	
Conus chaldeus Röding, 1798	+	
Conus circumclausus Fenaux, 1942	+	
cf Conus colubrinus Lamarck, 1810	+	
cf Conus convolutus Sowerby, 1857	+	
Conus coronatus Gmelin, 1791		
Conus ebraus Linné, 1758	++	
Conus episcopus Hwass, 1792		
Conus episcopus elongata Hwass, 1792		
Conus figulinus Linné, 1758	+	
Conus fuscatus Born, 1778		
Conus geographus Linné, 1758	+	
cf Conus generalis Linné, 1767	+	
Conus glaucus Linné, 1758		
Conus gubernator Hwass, 1792	+	
Conus leopardus Röding, 1798	+	
Conus litteratus Linné, 1758	+	
Conus lividus Hwass, 1792	+	
Conus maldivus Hwass, 1792	+	
Conus miles Linné, 1758	++	
Conus miliaris Hwass, 1792	+++	
Conus mitratus Hwass, 1792	+	
Conus nanus Broderip, 1833		
Conus nussatella Linné, 1758		
Conus parvatus Walls, 1979	+	
Conus quercinus Lightfoot, 1786	+	
Conus rattus Hwass, 1792		
cf Conus sponsalis Hwass, 1792	+	
Conus striatellus Link, 1807	++	
Conus striatus Linné, 1758	+	
Conus tenuistriatus Sowerby, 1857		
Conus terebra Born, 1778		
Conus tessulatus Born, 1778	++	
Conus textile Linné, 1758	++	
Conus tulipa Linné, 1758		
Conus verriculum Reeve, 1843	+	
cf Conus vexillum Gmelin, 1791	+	
Conus virgo Linné, 1758	+	
Family: Terebridae		10
cf Terebra affinis Gray, 1834	+	
Terebra areolata Link, 1758		
Terebra crenulata interlineata Deshayes, 1859	+	
cf Terebra dimidiata Linné, 1758	+	
Terebra felina Dillwyn, 1817	++	
Terebra maculata Linné, 1758	+	
Terebra subulata Linné, 1767	+	
Terenolla pygmea Hinds, 1844	+	

Order: (HETEROGASTROPODA)
Super Family: ARCHITECTONICACEA
Family: Janthinidae

Janthina balteata Reeve, 1858	+

Sub-Class: OPISTHOBRANCHIA

Sub-Order: BULLACEA

Family: Bullidae

Bulla ampulla Linné, 1758	++
Bulla vernicosa Gould, 1854	

Order: ANASPIDEA
Family: Aplysiidae

cf Aplysia dactylomela Rang, 1828	+
Dolabella auricularia Lightfoot, 1786	+

Order: NUDIBRANCHIA

Family: Aegiretidae	
Notodoris minor Eliot, 1904	+
Family: Chromodorididae	
Chromodoris africana Eliot, 1904	+
Chromodoris elizabethina Bergh, 1877	+
cf Chromodoris hamiltoni Rudmann, 1977	+
Hypselodoris bullocki Collingwood, 1881	+
cf Risbecia sp1	+
Family: Dorididae	
Halgerda toliara Fahey et Gosliner, 1999	+
cf Platydoris cruenta	+
Family: Phyllidiidae	
Phyllidiella meandrina Pruvot-Fol 1957	+
cf Phylidiella rosans Bergh, 1873	+
Phyllidia varicosa Lamarck, 1801	+

Ordre: SACOGLOSSA
Family: Plakobranchidae

cf Plakobranchus ocellatus Van Hasselt, 1824	+

Class: POLYPLACOPHORA

Order: (NEOLORICATA)
Family: Chitonidae

Sp1	+

Class: BIVALVIA

Sub-class: PTERIOMORPHA

Order: ARCOIDA

Family: Arcidae	
Anadara antiquata Linné, 1758	+++
Arca avellana Lamarck, 1819	+
Barbatia revelata Deshayes, 1863	+
Barbatia tenella Reeve, 1844	++
Family: Glycymerididae	
Tucetona audouini Matsukama, 1985	+
Order MYTILOIDA	
Super Family: MYTILACEA	
Family: Mytilidae	
Lithophaga teres Philippi, 1846	
Lithophaga sp	+
Modiolus auriculata Krauss, 1848	++
Modiolus sp	
Septifer bilocularis Linné, 1758	+
cf Septifer excisus Wiegmann, 1837	+
Sp1	+
Super Family: PINNACEA	
Family: Pinnidae	
Atrina vexillum Born, 1778	++
cf Pinna bicolor Gmelin, 1791	+
Pinna muricata Linné, 1758	++
Order PTERIOIDA	
Super Family: PTERIACEA	
Family: Pteriidae	
Pinctada margaritifera Linné, 1758	+
Pteria aegyptiaca Dillwyn, 1817	+
Pteria penguin lotorium Lamarck, 1819	
Pteria tortirostris Dunker, 1848	+
Family: Isognomonidae	
Isognomon isognomon Linné, 1758	
Super Family: PECTINACEA	
Family: Pectinidae	
Chlamys lemniscata Reeve, 1853	+
Excellichlamys spectabilis Reeve, 1853	+
Gloripallium pallium Linné, 1758	+
Sub-order: OSTREINA	
Super Family: OSTREACEA	
Family: Ostreidae	
Lopha cristagalli Linné, 1758	+
Pycnodonta hyotis Linné, 1758	

Saccostrea cucullata Born, 1778	++
Saccostrea sp	
Family: Spondylidae	
Spondylus sp	+
Super Family: LIMACEA	
Family: Limidae	
Ctenoides annulata Lamarck, 1819	+
Lima bullifera Deshayes, 1863	
Sub-class: HETERODONTA	
Order: VENEROIDA	
Super Family: ARCTICACEA	
Family: Trapeziidae	
Trapezium bicarinatum Schumacher, 1817	+
Super Family: LUCINACEA	
Family: Lucinidae	
Anodontia edentula Linné, 1758	
Codakia miniata Deshayes, 1863	+
Codakia punctata Linné, 1758	++
Codakia tigerina Linné, 1758	++
Divaricella daliana Vanatta, 1901	
Super Family: CARDITACEA	
Family: Carditidae	
Cardita variegata Bruguière, 1792	+
Super Family: CARDIACEA	
Family: Cardiidae	
Acrosterigma mauritianum Deshayes, 1863	+
Fragum fragum Linné, 1758	
Trachycardium elongatum Bruguière, 1789	+
Trachycardium flavum Linné, 1758	++
Trachycardium nebulosum Reeve, 1845	+
Super Family: GALEOMMATOIDEA	
sp 1	+
Super Family: TRIDACNACEA	
Family: Tridacnidae	
Tridacna maxima Röding, 1798	++
Tridacna squamosa Lamarck, 1819	+
Super Family: SOLENACEA	
Family: Solenidae	
sp1	+
Super Family: TELLINACEA	

Family: Tellinidae		
Quidnipagus palatam Iredale, 1929		
Scutarcopagia scobinata Linné, 1758	+	
Tellina crucigera Lamarck, 1818	+	
cf Tellina sulcata Wood, 1815	+	
Tellina virgata Linné, 1758	+	
Tellina sp1	+	
Family: Donacidae		
Donax faba Gmelin, 1791	++	
Family: Psammobiidae		
Asaphis violascens Förskal, 1775		
Super Family: VENERACEA		
Family: Veneridae		
Gafrarium pectinatum Linné, 1758	++	
Lioconcha castrensis Linné, 1758		
Lioconcha ornata Lamarck, 1817	+	
Lioconcha tigrina Lamarck, 1818		
Periglypta crispata Deshayes, 1853	++	
Pitar affinis Gmelin, 1791	+	
Sp1	+	
Class: CEPHALOPODA		
Sub-Class: TETRABRANCHIATA		
Family: Nautilidae		6
Nautilus sp		
Sub-Class: DIBRANCHIATA		
Ordre: TEUTHOIDEA		
Family: Loliginidae		6
cf Loligo sp	+	
cf Sepiotheutis sp		
Order: SEPIOIDEA		
Family: Spirulidae		
Spirula spirula Linné, 1758		
Family: Sepiidae		6
cf Sepia australis Linné, 1758	+	
cf Sepia papillata Quoy et Gaimard, 1832	+	
Order: OCTOPODA		

Super Family: OCTOPODOIDEA		
Family: Octopodidae		6,12
Octopus cyanea Gray, 1849	++	
	238	

Trophic guild code
1: herbivore (algae-grazer)
3: invertebrate sessile grazer
6: microcarnivore;piscivore
9: detritivore, saprophyte
10: microcarnivore
11: carnivore;wormivore
12: carnivore;malacophage
13: microcarnivore;alcyonians or madrepores
14: carnivore;echinoderms
15: filter-feeder
16: parasite

APPENDIX 4.

Details of variables collected during monitoring surveys for Reef Fish, Macro-Invertebrates and Benthic Cover

4.1 Reef Fish

Reef Fish Families	Main Trophic Guilds	Size Classes (cm) recorded for each family
Serranidae	Piscivore/Invertivore	0-5
Lutjanidae	Piscivore/Invertivore	5-10
Lethrinidae	Piscivore/Invertivore	10-15
Haemulidae	Invertivore	15-20
Mullidae	Invertivore	20-25
Balistidae	Invertivore	25-30
Chaetodontidae	Corallivore/Omnivore	30-35
Scaridae	Herbivore	35-40
Acanthuridae	Herbivore	40-45
Siganidae	Herbivore	45-50
Pomacentridae	Herbivore/Planktivore	50-60
Caesionidae	Planktivore	60-70
Labridae	Carnivore/Omnivore	70-80
Pomacanthidae	Carnivore/Omnivore	80-90
Scombridae	Piscivore	90-100
Carangidae	Piscivore	

4.2 Macro-Invertebrates

Phyla	Category	Genus
Echinoderms	Urchins	Diadema
		Echinothrix
		Toxopneustes
		Tripneustes
		Echinometra
		Heterocentrotus
		Other
	Sea-stars	Acanthaster
		Linkia
		Culcita
		Nardoa
		Other
	Sea Cucumbers (Holothurians)	Actinopyga
		Bohadschia
		Holothuria
		Thelonata

Phyla	Category	Genus
Echinoderms	Sea Cucumbers (Holothurians)	Stichopus
		Pearsonothuria
		Other
Crustaceans	Lobsters	Any
	Mantis Shrimps	Any
Molluscs	Bivalves	Tridacna
		Hipoglossus
		Pinctada
		Lopha
		Atrina
		Spondilus
	Gastropods	Lambis
		Cypraea
		Cassis
		Charonia
	Cepahlopods	Octopus

4.3 Benthic Categories

Category	**HC Lifeform**	**Code (English)**	**Code (French)***
Sand		SD	SA
Silt		SI	BO
Rock		RC	RO
Rubble		RB	DEB
Dead Coral		DC	CX
Hard Coral		HC	CV
Acropora:	Branching	ACB	
	Digitate	ACD	
	Submassive	ACS	
	Tabulate	ACT	
	Encrusting	ACE	
Non-Acropora:	Branching	CB	
	Encrusting	CE	
	Foliose	CF	
	Massive	CM	
	Submassive	CS	
	Mushroom	CMU	CL
Soft Coral		SC	CMO
Sponge		SP	EP
Zooanthid		ZO	
Ascidian		AS	
Anemone		AN	
Giant Clam		GC	BE
Other Invertebrate		OT	
Halimeda		HA	
Calcified Algae		CA	AC
Macroalgae		MA	AD / AG
Turf Algae / Algal Assemblage		TA / AA	
Blue-Green Algae		BGA	CYA
Seagrass		SG	HE

* where different from the code in English

APPENDIX 5

Environmental Parameters for coral reef sites surveyed.

Date	Dive #	Time	Location	Depth (m)	SST (°C)	Sea State	Wind Direction	Cloud Cover
26/11/06	1	10:53	Shark Alley	10-12	28	2	NW	2
27/11/06	2	09:57	Nosy Fasy	8-10	28	3	NW	2
"	3	15:08	"	10-12	28	3	NW	3
28/11/06	4	09:51	Andravamaike	20-22	28	3	SW	3
"	5	13:18	Shark Alley	8-10	28	4	SW	4
29/11/06	6	08:24	'THB'	10-12	28	3	SW	2
"	7	11:38	"	10-14	28.5	3	SW	2
30/11/06	8	09:08	Valleys	6-10	28	3	N	2
"	9	12:23	"	7-10	28	3-4	N	2
02/12/06	10	09:24	Coco Beach	5-8	28	3	SW	3
"	11	12:19	"	6-9	28	3	SW	3
03/12/06	12	09:17	Andavadoaka Rock	5-8	28.5	2	SW	2
"	13	11:54	"	"	28.5	2	SW	2
04/12/06	14	09:25	'007'	8-10	28	4	SW	2
"	15	11:19	"	"	28	4	SW	2
05/12/06	16	08:37	Recruitment	11-13	28	3	N	4
"	17	10:50	"	"	28	4	N	3
06/12/06	18	08:10	Half Moon	6-10	28	3	N	4
"	19	10:42	"	"	28.5	4	N	4

APPENDIX 6.

Benthic Composition at 10 coral reef sites in the Andavadoaka region.
(Mean Percentage Cover)

Benthic Category	**Shark Alley**	**Nosy Fasy**	**Valleys**	**THB**	**007**	**Recruitment**	**Coco Beach**	**Andavadoaka Rock**	**Half Moon**	**Andravamaike**
N =	8	8	8	8	6	6	8	8	8	4
Sand	2.5	4	2.5	0.25	0	0.33	0	6.5	1.25	14
Silt	0	0	0	0	0	0	0.5	4.5	0.5	0
Rock	4	2	1.5	0.5	0.67	0.33	2.5	0.75	0.25	6
Rubble	2.25	3.5	4.25	0.5	1	0.67	0	7.75	6.25	3
Dead Coral	0	0.25	0	0	0	0	0	0	0	0
Abiotic	**8.75**	**9.75**	**8.25**	**1.25**	**1.67**	**1.33**	**3**	**19.5**	**8.25**	**23**
ACB	0	0	0.25	0.5	1.67	1.67	0	0	0	0
ACD	0	0	0	1.75	0.33	0	0	0	0	0.5
ACS	0	0	0.5	1.5	3.67	4.33	0	0	0.25	0
ACT	0	0	0	5	0.33	4.67	0	0	0	1.5
ACE	0.25	0.75	0.5	0.5	0	0	0	0	0	1
Acropora	**0.25**	**0.75**	**1.25**	**9.25**	**6**	**10.67**	**0**	**0**	**0.25**	**3**
CB	0	0	0	5.25	3.33	0.67	0	0	0.25	0
CE	7.75	5	3.25	17.25	12	28.67	4.5	2.75	0.75	6.5
CF	0	0	0	0.25	21.67	1	0	0	0	0
CM	10.75	7	5.75	4	0	1.33	0	3.25	2.25	6
CS	3.25	4.5	3.5	4.25	6.67	3.67	27.5	2	0.5	0.5
CMU	0.5	0	0	0	0	0	0.25	0.75	0	0
Non-Acropora	**22.25**	**16.5**	**12.5**	**31**	**43.67**	**35.33**	**32.25**	**8.75**	**3.75**	**13**
Hard Coral	**22.5**	**17.25**	**13.75**	**40.25**	**49.67**	**46**	**32.25**	**8.75**	**4.**	**16**
Soft Coral	**9**	**6.5**	**0.5**	**10.25**	**4.33**	**5.67**	**2.25**	**4.75**	**10.5**	**20.5**
Sponges	0.25	0.75	1.75	0.75	1.33	1	0.25	1.25	1.5	7
Zooanthids	0	0	0	1.75	0.67	0.67	0	0.25	0	0
Anemones	0	0	0	0.75	1.33	0	0	0	0	0
Other Invertebrates	0.75	0.75	0	0.5	0	0.33	0	0.5	0.25	0.5
Invertebrates	**1**	**1.5**	**1.75**	**3.75**	**3.33**	**2**	**0.25**	**2**	**1.75**	**7.5**
Halimeda	0	0	0.25	0	0	0	0.25	0	0	0
Calcified Algae	18	27.5	27.25	17.25	10.67	15	11.25	8.5	12.75	16
All Calcified Algae	**18**	**27.5**	**27.5**	**17.25**	**10.67**	**15**	**11.5**	**8.5**	**12.75**	**16**
Macroalgae	7.25	7	8.25	2.5	4.33	5.67	7.25	5.5	8.75	0
Turf Algae / AA	33.5	30.5	40	24.75	25.67	24.33	44	50.5	49.75	17
Blue-green Algae	0	0	0	0	0.33	0	0	0.5	4.25	0
Non Calcified Algae	**40.75**	**37.5**	**48.25**	**27.25**	**30**	**30**	**50.75**	**56**	**58.5**	**17**
All Algae	**58.75**	**65**	**75.5**	**44.5**	**40.67**	**45**	**62.5**	**64.5**	**75**	**33**

APPENDIX 7.

Mean Percent Cover of Hard Coral Genera at 10 Andavadoaka coral reef sites.

Benthic Category	Shark Alley	Nosy Fasy	Valleys	THB	007	Recruitment	Coco Beach	Andavadoaka Rock	Half Moon	Andravamaike
N =	8	8	8	8	6	6	8	8	8	4
Acanthastrea	0.25	0.25	0.25	0	0	0	0	0	0	0
Acropora	0.25	0.75	1.25	9.25	6.33	10.67	0	0	0.25	3
Cyphastrea	0.25	0.25	0	0	0	0	0	0	0	0
Echinopora	0.25	0.5	0.25	8.5	4.67	15.33	0	0	0	2.5
Favia	2.5	1	1.75	1.5	0	0	0	1.5	0.75	0
Favites	0.5	1.5	0.75	0	0	0.33	0.25	0	0.25	0
Fungia	0.25	0	0	0	0	0	0.25	0.25	0	0
Galaxea	0	0	0.5	0.5	0.33	0.33	0.75	0.25	1	0
Goniastrea	0.25	0	0.25	0.75	0	0.33	0	0	0	0
Herpolitha	0	0	0	0	0	0	0	0.5	0	0
Hydnophora	0	0.5	0.25	0.25	0	0	0	0.25	0	0
Leptastrea	0.25	0	0	0	0	0	0	0	0	0
Lobophyllia	0.25	0	0	0.25	0	0	0	0	0	0
Millepora	0.75	0.25	0	0	0	0.67	0	0	0	4
Montipora	0.25	0	0	1.75	23.33	3.67	0	0	0	0
Mycedium	0	0	0	0.25	0	0	0	0.25	0	0
Oxypora	0	0	0	0	0	1	0	0	0	0
Pachyseris	0	0	0	0	0	0.33	0	0	0.25	0
Pavona	0	0	0.5	2.5	1.33	1.33	27.25	0	0	0
Platygyra	1	0.25	0.5	0.75	0	0.33	0	0.5	0.25	1
Pocillopora	2.75	4.75	3.5	0.75	4	1.33	0.25	2.25	0.25	0.5
Porites branching	0	0	0	4	3.33	0	0	0	0	0
Porites massive	8.25	5.25	3.25	2.25	0	1.33	0	1.75	0.75	4
Porites	1.25	0.25	0.25	2	2.67	3	0.25	1	0	0
Psammacora	0	0	0	0	0	0	0.25	0	0	0
Seriatopora	0	0	0	1	0	0.33	0	0	0.25	0
Stylophora	0	0	0	0.5	0	0.33	0.25	0	0	0
Turbinaria	0.25	0.25	0	0.5	3	1.67	0.25	0	0	0

APPENDIX 8.

Reef Fish biomass for 14 fish families at nine sites and three reef types at Andavadoaka.
(Mean Values and Standard Error)

8.a Mean Values

Family / Site:	Nosy Fasy	Shark Alley	Valleys	THB	Recruitment	007	Coco Beach	Andava' Rock	Half Moon	Barrier	Patch	Fringing
N:	3	3	3	2	3	2	3	3	2	9	7	8
Acanthuridae	248.83	137.81	159.38	212.22	132.94	166.54	29.79	109.82	0.70	182.01	176.51	52.53
Balistidae	23.88	2.75	2.44	5.50	5.48	14.78	0.00	8.53	0.00	9.69	8.14	3.20
Caesionidae	0.00	14.26	184.53	53.91	0.00	20.22	205.48	68.74	0.00	66.26	28.88	102.83
Chaetodontidae	6.56	6.52	1.96	5.30	23.70	8.62	6.44	11.90	0.00	5.01	11.51	6.88
Haemulidae	0.00	1.73	0.00	0.00	33.62	12.17	30.53	8.11	0.00	0.58	13.08	14.49
Labridae	47.71	47.18	22.93	32.11	34.04	21.03	51.65	77.78	17.17	39.28	29.50	52.83
Lethrinidae	0.00	6.24	0.00	244.31	9.82	0.00	0.82	0.00	0.00	2.08	107.51	0.31
Lutjanidae	0.00	13.19	1.47	56.41	218.71	7.40	81.12	0.00	1.10	4.88	88.78	30.69
Mullidae	28.35	3.12	1.32	9.33	1.97	0.00	0.12	1.32	1.97	10.93	4.56	1.03
Pomacanthidae	36.94	0.00	2.17	6.40	9.96	13.04	1.35	1.23	0.18	13.04	9.32	1.01
Pomacentridae	11.15	10.02	8.88	10.59	11.79	33.83	43.62	26.97	31.28	10.01	17.57	34.29
Scaridae	0.00	31.24	39.46	20.61	23.69	40.17	12.85	47.89	0.13	23.57	27.08	22.81
Serranidae	0.00	26.58	0.00	1.25	8.10	13.71	0.00	33.76	0.00	8.86	6.76	12.66
Siganidae	0.00	2.32	1.16	2.32	0.00	0.00	0.00	0.00	0.00	1.16	1.00	0.00
Total	**403.42**	**302.95**	**425.68**	**660.27**	**513.83**	**351.50**	**463.77**	**396.06**	**52.53**	**377.35**	**530.21**	**335.57**

8.b Standard Error

Family / Site:	Nosy Fasy	Shark Alley	Valleys	THB	Recruitment	007	Coco Beach	Andava' Rock	Half Moon	Barrier	Patch	Fringing
N:	3	3	3	2	2	3	3	3	2	9	7	8
Acanthuridae	109.35	57.10	22.31	95.59	2.33	43.64	28.91	47.63	0.99	36.15	35.85	24.41
Balistidae	3.52	1.69	1.49	6.73	2.58	4.95	0.00	2.98	0.00	3.91	3.05	1.87
Caesionidae	0.00	11.16	88.46	66.03	0.00	0.00	146.48	59.08	0.00	38.54	24.23	56.43
Chaetodontidae	1.15	7.24	1.05	4.40	25.57	5.79	5.72	9.70	0.00	2.02	5.76	3.72
Haemulidae	0.00	2.12	0.00	0.00	47.55	17.21	24.08	9.93	0.00	0.61	10.43	9.07
Labridae	0.34	8.01	4.12	8.45	10.55	4.15	18.94	67.71	3.93	4.88	4.15	22.22
Lethrinidae	0.00	4.95	0.00	274.14	13.89	0.00	1.00	0.00	0.00	1.66	105.30	0.33
Lutjanidae	0.00	12.34	0.90	13.40	118.24	7.36	93.05	0.00	1.55	3.80	42.46	30.92
Mullidae	20.42	1.73	1.61	1.54	2.79	0.00	0.15	1.61	2.79	6.92	1.98	0.68
Pomacanthidae	15.89	0.00	1.56	7.84	13.59	11.22	1.65	1.51	0.25	7.50	4.12	0.67
Pomacentridae	1.20	2.76	2.29	1.63	7.53	28.75	12.98	9.30	3.07	1.01	6.74	5.48
Scaridae	0.00	11.06	12.07	12.13	10.40	34.07	15.09	31.89	0.19	7.57	8.08	12.93
Serranidae	0.00	12.72	0.00	1.53	11.45	8.81	0.00	31.95	0.00	5.67	3.37	11.27
Siganidae	0.00	2.85	1.42	2.85	0.00	0.00	0.00	0.00	0.00	0.87	1.08	0.00
Total	**104.91**	**64.89**	**76.05**	**446.17**	**70.95**	**144.47**	**288.78**	**242.16**	**3.14**	**41.39**	**161.36**	**126.87**

APPENDIX 9.

Mean densities of selected macro-invertebrates for nine sites at Andavadoaka.

(No. of individuals / hectare)

Invertebrate Category	Nosy Fasy	Shark Alley	Valleys	THB	Recruitment	007	Coco Beach	Andavadoaka Rock	Half Moon
N:	3	3	3	2	2	3	3	3	2
Diadema	0	0	93.33	173.33	0	1600.00	0	0	1160.00
Echinothrix	0	0	0	0	0	100.00	0	640.00	1600.00
Echinometra	0	0	906.67	266.67	0	0	0	40.00	0
Acanthaster plancii	0	0	0	0	0	0	0	0	0
Linkia	120.00	0.00	80.00	0.00	20.00	220.00	306.67	893.33	100.00
Culcita	0	0	0	0	0	0	0	0	20.00
Nardoa	13.33	0	0	13.33	0	0	0	0	20.00
Choriaster	0	0	0	0	0	0	0	13.33	0
Protoreaster	0	0	0	0	0	20.00	0	13.33	0
Total Asteroidea	133.33	0	80.00	13.33	20.00	240.00	306.67	920.00	140.00
Pearsonothuria graeffei	40.00	13.33	13.33	66.67	80.00	80.00	53.33	13.33	0
Holothuria atra	40.00	13.33	0	0	0	0	0	0	0
Other Holothurians	0	0	13.33	13.33	0	0	0	13.33	0
Total Holothurians	80.00	26.67	26.67	66.67	80.00	80.00	53.33	26.67	0
Lobster	0	0	0	0	0	0	0	0	0
Anemone	0	0	0	1506.67	0	0	0	40.00	40.00
Tridacna	93.33	40.00	26.67	26.67	0.00	0.00	13.33	53.33	0
Octopus	13.33	0	0	0	0	0	0	0	0
Charonia tritonis	0	0	0	0	0	0	0	0	0
Cassis cornuta	0	0	0	0	0	0	0	0	0
Lambis.	26.67	13.33	0	13.33	0	0	0	26.67	0
Cypraeidae	120.00	13.33	53.33	26.67	0	0	13.33	0	0