Frontier-Tanzania Environmental Research

REPORT 112

Misali Island:

A Description of the Intertidal Regions

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Poonian, C.N.S., Fanning, E. & Jiddawi, N. (eds.)

Ministry of Agriculture, Natural Resources, Environment and Co-operatives
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FOR MORE INFORMATION

The Ministry of Agriculture, Natural Resources, Environment and Co-operatives
PO Box 159, Zanzibar, Tanzania
Tel: 255-24-223 2840
Fax: 255-24-223 0290
E-mail: manrec@zanlink.com

Frontier-Tanzania: Head Quarters
P.O. Box 9473, Dar es Salaam
Tel: 255-22- 2772077
E-mail: frontier@raha.com

Department for Commercial Crops Fruits and Forestry
PO Box 3526, Zanzibar, Tanzania
Tel: +255 24 223 8628
Fax: +255 24 223 6089
E-mail: dccff@zanlink.com

Society for Environmental Exploration
50-52 Rivington Street, London, EC2A 3QP. U.K.
Tel: +44 20 76 13 24 22
Fax: +44 20 76 13 29 92
E-mail: info@frontier.ac.uk
Internet: www.frontier.ac.uk

Dept. of Zoology & Marine Biology
University of Dar es Salaam
P.O. Box 35064, Dar es Salaam, Tanzania
Tel: 255-22-2410462
E-mail: zoology@udsm.ac.tz

Institute of Marine Science
PO Box 668, Zanzibar, Tanzania
Tel: 255-24-2230 741
Fax: 255-24-223 3050
Internet: www.ims.udsm.ac.tz

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MANREC (which includes DCCFF & Department for Fisheries and Marine Resources DFMR)

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Development Programme Manager:	Ms. Elizabeth Humphreys
Project Manager:	Ms. Nicola Beharrell
Operations Manager:	Mr. Matthew Willson

UNIVERSITY OF DAR ES SALAAM (UDSM) AND INSTITUTE OF MARINE SCIENCES (IMS)

FT Co-ordinators:	Dr. Masoud Muruke & Prof. K. M. Howell
Director of IMS:	Dr. Alfonse M. Dubi
Assistant Director of IMS:	Dr. Narriman Jiddawi
Lecturer, Marine Biology	Dr. Greg Wagner

FRONTIER-TANZANIA (FT)

Project & Research Co-ordinator:	Ms. Carol Daniels
Assistant Research Co-ordinators:	Ms. Ruth Mumby, Mr. David Redding, Ms. Beth Brierley, Mr. Angus McVean & Mr. Adam Pharaoh
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Research Assistants:	Expedition 023 (July-September 2002)

Andrew Ashton	Tim Myall	Philip Joseph	Iain Morrison
Adam Cooper	Matt Neale	Hakimu Matola (Tanzanian UDSM student)	Claudine Scholtus
Deborah Helsdon	Edward Reeves	Magreth Mchome (Tanzanian UDSM student)	Sarah Taylor
			David Wilby

CARE-International, Tanzania

MICP Research Co-ordinator, CARE:	Mr James Hutchins
Misali Ethics Conservation Programme Manager & Education Officer	Mr Ali Khamis Thani
Assistant Zanzibar Area Co-ordinator:	Mr Amour Bakar Omar

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FOREWORD

Tanzania is host to rich marine resources, which have supported coastal communities for generations. These resources are generated by the productive marine biotopes including coral reefs, mangroves, seagrass beds and estuaries located along the 850km coastline. As coastal populations have increased, so has the risk of over-exploitation and use of unsustainable and destructive fishing techniques, resulting in habitat destruction and loss of biodiversity (Mgaya 1988, Semesi et al. 1998). With the possible exceptions of the Mafia Island Marine Park, and Menai Bay, Chumbe Island and Misali Island conservation areas, there is currently little effective management to safeguard these resources. These problems have been recognised for some time (Ray 1968, Bryceson 1981) but many attempts to set up and implement management plans have failed because of a lack of finance, trained personnel and data to implement such schemes. During studies undertaken by the United Nations Environment Programme (UNEP) in 1987 one of the priority recommendations of the subsequently proposed action plan (UNEP 1989) was the quantification of coastal resources in Tanzania

The UNEP action plan (UNEP 1989) recognised that both Unguja and Pemba (the main islands that constitute the Zanzibar archipelago) possess a number of sites of regional and international importance for marine biodiversity. Pemba Island is renowned for its marine resources; however, there are few empirical studies to support this. This is of particular concern since short-term assessments and site visits have revealed that this region is increasingly threatened through resource use (Horrill et al. 1994). The island is also important with regard to the local fishing industry and contains extensive seagrass and mangrove stands. Unfortunately, most coastal management projects in Eastern Africa still focus on the conservation of biodiversity, often neglecting local community development (Moffat and Kyewalyanga 1998). In addition, the lack of biophysical information necessitated further research on which to base future management initiatives for the Pemba region.

Frontier-Tanzania Marine Research Programme (FT MRP) relocated to Tundaua, Pemba in February 2001, to assess the marine resources within the Misali Island Marine Conservation Area (MIMCA), and provide technical advice for management planning and decision-making. The work was carried out over ten-week field phases by Frontier-Tanzania scientists, local staff, short-term expatriate volunteer research assistants and advisors. Surveys have encompassed the marine environment of MIMCA including fish, benthic invertebrates and substrate, intertidal zone, mangrove stands, fisheries and marine mammals. Alongside baseline surveys, training was conducted for fisheries officers, Misali Island Conservation Project (MICP) personnel, local resource users, and students from UDSM, including the Institute of Marine Sciences (IMS). Additionally, the Project has worked with community representatives and teachers to increase environmental awareness among the coastal communities of Pemba.

Dr A. M. Dubi	Dr B.S. Asseid	Ms E. Fanning
Director, IMS	Director, DCCFF	Managing Director, SEE

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EXECUTIVE SUMMARY

Frontier-Tanzania Marine Research Programme worked on Misali Island between February 2001 and September 2003 at the request of the Ministry of Agriculture, Natural Resources, Environment and Co-operatives. Surveys of benthic substrata, commercial fish, reef-associated fish, benthic invertebrates, coral reef health, mangroves, intertidal areas, resource users and marine mammals were undertaken. This report details the findings of work involving the intertidal regions of Misali.

The intertidal zone is often a major impact area for human activities. Artisanal collection of octopus, sea cucumbers, shellfish and seashells are significant economic and subsistence activities for local fishermen on Misali Island. However, despite their importance, little is known about the status of these fisheries and their impacts on targeted stocks, other species and intertidal habitats.

Frontier-Tanzania Marine Research Programme surveyed the intertidal regions of Misali Island during early August 2002. This work aimed to describe the extent, substrate composition and species assemblages of the intertidal region and provide management recommendations. The limits of the intertidal zone were defined using hand-held GPS units. A species inventory was compiled through systematic observation. Intertidal substrate and assemblages of organisms were assessed by transects at five study sites, two on the east coast, one on the south, and two within the non-extraction zone on the west coast.

Mapping of the intertidal zone carried out during this study closely followed existing bathymetric maps. The non-extraction zone encompasses a large proportion of the intertidal regions on the south and west coasts. However intertidal collection continues on the extensive and accessible intertidal areas of the east coast. Ample seagrass beds in this area are important in the maintenance of other ecosystems on Misali and the future sustainability of its fisheries

Although some zonation of species was apparent, there were no clear patterns of distribution at the taxonomic levels investigated. Current non-extraction legislation appears to have had a positive effect on exploited species and continued and complete enforcement of the NEZ would be beneficial. However, owing to the unpredictable nature of patterns of species assemblages and exploitation, non-extractive management alone is unlikely to be completely effective in the maintenance of intertidal resources on Misali.

This study recommends stronger enforcement of the non-extraction zone and monitoring of intertidal exploitation, possibly through the involvement of local stakeholders. Seasonal controls on the octopus fishery would be easily enforced because of its international commercial interest, and would have knock-on benefits for other intertidal fisheries.

1. INTRODUCTION

1.1 Rationale

The intertidal zone is often a major impact area for human activities (Mlay et al. 2001). Human impacts on rocky shores include the harmful effects of exploitative activities such as shellfish collection (Duran et al. 1987; Castilla & Bustamente 1989; Lasiak & Dye 1989; Underwood 1993; Lasiak & Field 1995) and of trampling (Beauchamp & Gowing 1982). It has been demonstrated that anthropogenic influences can alter intertidal organism assemblages (Castilla 1993, Dye & Lasiak 1997, Hockley & Bosman 1986, Keough et al. 1993, Lasiak & Field 1995, Ortega 1987).

In addition to reductions in the population density of target species (Olive 1993, Beukema & Cadée 1996, Ferns et al. 2000), harvesting may also affect non-target species through cascading trophic interactions (Jackson & James 1979, Beukema & Cadée 1996, Brown & Wilson 1997, Hall & Harding 1997, Ferns et al. 2000). Furthermore, given that the manual harvesting of these organisms involves turning over sediments, major physical disturbances of the bottom habitat may occur (Anderson & Meyer 1986). Sandy and muddy shores, which often incorporate seagrass beds, are valuable, particularly in relation to fisheries, because many commercially important fishes spend at least their larval stages in these habitats (Fortes 1988).

Artisanal collection of octopus, sea cucumbers, shellfish and seashells are significant economic and subsistence activities for local fishermen on Misali Island. The catch may be destined for use as food, bait or curios. However, despite their importance, little is known about the status of these fisheries and their impacts on targeted stocks, other species and intertidal habitats.

1.2 Aims and Objectives

Aim
To describe the extent, substrate composition and species assemblages of the intertidal regions of Misali and provide management recommendations

Objectives:

- To define the extent of the intertidal region using hand-held GPS
- To collate an intertidal species inventory by systematic observation
- To map substrate composition and species distribution through intertidal transects to elucidate zonation patterns

1.3 Misali Island

Misali (S05º15’, E039º36’) is a 0.9 km^2 Pleistocene coral island, situated off the west coast of Pemba, the northern island of the Zanzibar archipelago, Tanzania (Figure 1). The 21.6km^2 Misali Island Marine Conservation Area (MIMCA) was established in May 1998 and includes 2.84km^2 of intertidal areas (Richmond & Mohammed 2001). MIMCA incorporates a 1.4km^2 non-extraction zone (NEZ), where recreational activities, passage and scientific research are permitted, but depletion of natural resources is forbidden. There are no permanent inhabitants on the island, but MIMCA is enforced by a team of rangers, who live there on a rotational basis. Fishers also camp for approximately two weeks each month. The artisanal fishing industry dependent on the island's waters and intertidal region is sizeable relative to its area (Richmond & Mohammed 2001).

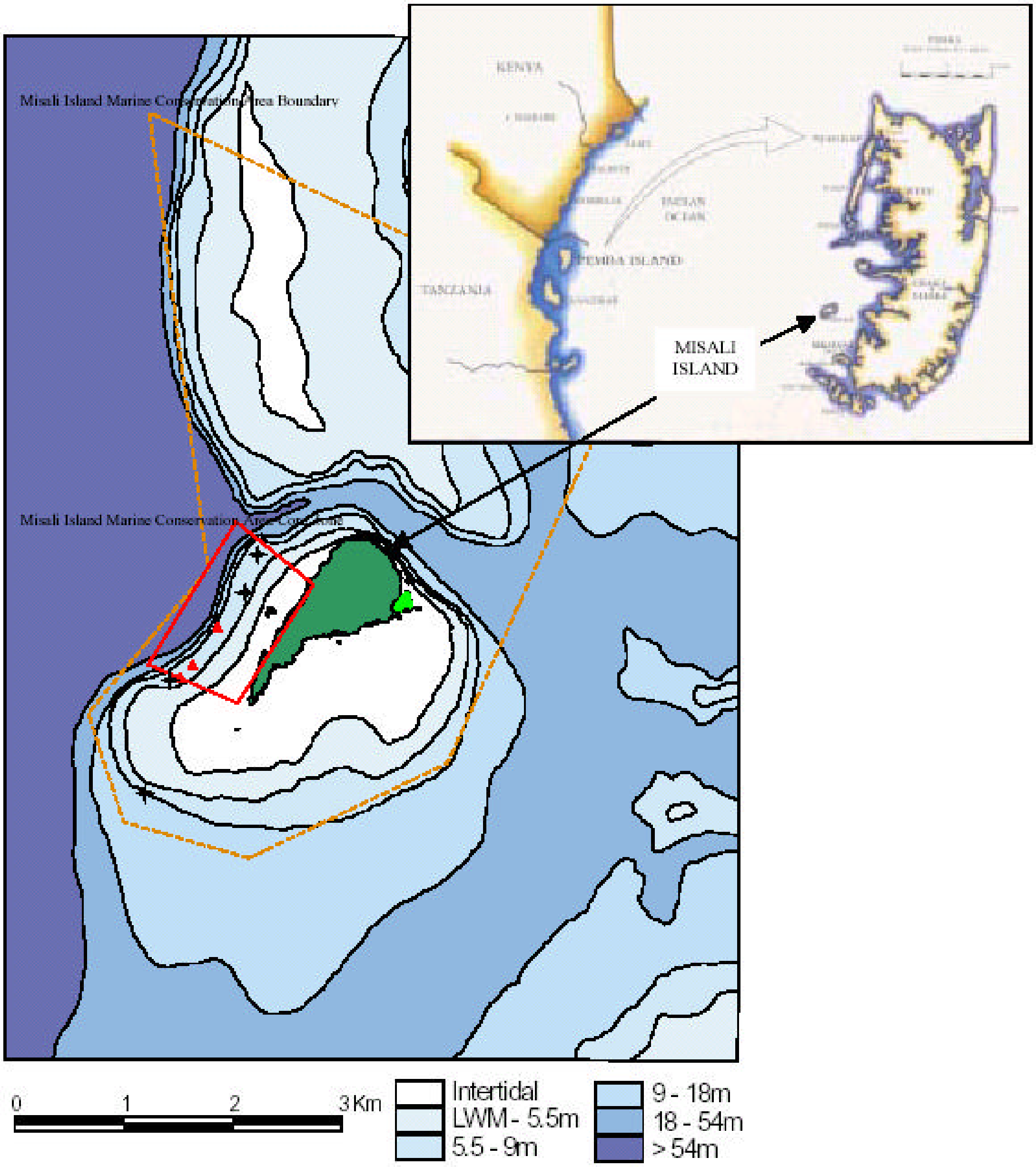


Figure 1. Misali Island Marine Conservation Area boundary with an inset of Pemba Island (adapted from Richmond and Mohammed 2001) (dashed orange line represents MIMCA boundary and red line represents non-extraction zone boundary)

1.4 Exploitation of Tanzanian Intertidal Resources

Food species collection

Intertidal species frequently collected on Misali include octopus, squid and a variety of bivalves. Other species are opportunistically exploited including moray eels, crocodilefish, stonefish, gastropod molluscs and seashells. These are usually gathered on foot during low spring tides by women, children and older men who cannot afford fishing vessels or gear (Jiddawi & Öhman 2002). Octopi, sea cucumbers and shells are collected by hand or with a stick *(kijiti).* In recent years, the octopus industry has switched from the domestic to international market. Octopi are now purchased by outside buyers for export to Europe, the Middle East and the Far East (Guard & Mgaya 2002; Jiddawi & Ohman 2002). Sea cucumbers are gutted, boiled and dried before being exported to the Far East; virtually none is locally consumed. (Jiddawi & Öhman 2002). Molluscs are smoked and consumed locally.

Shell collection

Collection of seashells, although discouraged by the authorities, still takes place. More than 150 species of seashells are collected by fishers in Tanzania for food and to be sold as curios (Jiddawi & Öhman 2002). At least 116 species have been recorded in markets in Dar es Salaam including 23 species of Conus, 19 species of Cypraea, 4 species of Lambis and 1 of Tridacna (Marshall et al. 2001). Harvesting of ornamental shells contributes to food and monetary resources of coastal communities, although a recent decline in exports because of environmental concerns (from 140t in 1990 to 30t in 1997 - Muhando & Jiddawi 1998) has reduced this fishery. Favoured shells are the trumpet shells, helmet shells and tiger cowries. The opercula of certain shells (e.g. *Chicoreus ramosus* and *Pleuroploca trapezium*) are exported to the Middle East. The shells of cockles are sometimes ground and used as a chicken feed supplement, or in lime manufacture, particularly in Zanzibar.

Management Considerations

Artisanal shellfish harvesting can be difficult to quantify because the harvesting is carried out by many individuals along long stretches of inaccessible coastline. Collectors return directly home with their catches and there are no landing or check points at which the catch can be assessed. As a result, little is known about the extent of harvesting and the effect such harvesting has on the stocks. From 20 – 100 fishers day^{-1} may hunt in the intertidal zone of Misali (MIMCA rangers pers. comm.). Octopus fishers number up to $44day^{-1}$; $mean=16.4day^{-1}$ (McVean & Fanning in prep.). The intertidal zone of the NEZ appears to be effectively closed to foot fishermen collecting octopus (Richmond & Mohammed 2001). Anecdotal details of the extent and financial significance of intertidal fisheries on Misali are given in Table 1.

Table 1. Collection rates and prices paid to artisanal fishers for their catch on Misali

Product	Collection rate / $fisher^{-1}$ day^{-1}	Price / TSh	Price / USD
Octopus	6.9 kg**	2000 / kg*	2.27*
Sea Cucumbers	Unknown	3000 / kg*	3.40*
Stick of 5-6 dried mussels	100 sticks*	100*	0.11*
Cowrie shells (small)	20-30*	40*	0.05*
Cowrie	Unknown	10*	0.01*

* MIMCA rangers pers. comm. (2001); **McVean & Fanning in prep.(2003)

The octopus fishery on Misali is currently showing elements of decline (McVean & Fanning in prep.). Sea cucumbers and shells are overexploited along the whole Tanzanian coast and the export of sea cucumbers has waned since 1991 (Jiddawi & Öhman 2002). However, if sustainably managed, the sea cucumber and shell trade could provide a useful source of income to Tanzanian coastal communities (Semesi *et al*. 1998).

1.5 Intertidal Zonation

A gradient of environmental conditions extends across the shore, mainly because of different durations of submergence at each level as a result of tidal cycles. This variation in conditions affects organism assemblages, since upper parts of the intertidal zone are immersed only during spring high tides, while lower areas are only exposed to air during spring low tides. The intertidal zone has been divided into three regions: the littoral fringe, eulittoral zone and sublittoral fringe (Stephenson & Stephenson 1974), characterized by their ecological communities, as shown in Figure 2. Species adapted to prolonged periods of exposure to the air are found in the upper regions, whereas those which can only tolerate brief periods of exposure are found in the lower parts. These fluctuating environmental conditions result in highly adapted organisms that can tolerate changes in temperature, salinity, oxygen levels and air exposure.

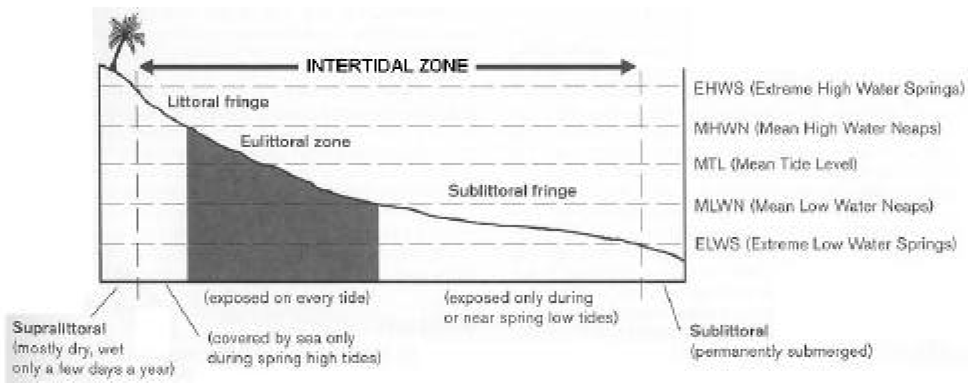


Figure 2. Profile of a shore showing the tidal zones (adapted from Richmond 1997)

2. METHODS

2.1 Demarcation of the Intertidal Zone

The low water line was marked every 30 paces (approximately 20m) by three surveyors, each using different GPS instruments. These co-ordinates were all taken within 40 minutes either side of low spring tide 0.09m at 1149 on 11th August 2002 and plotted onto a map using MapInfo Professional 5.0.

2.2 Intertidal Species Inventory

A limited inventory of species present in the intertidal zone of Misali Island was compiled through systematic observation and identification using Richmond 1997.

2.3 Intertidal Surveys

Five intertidal survey transects were located on Misali Island, two on the east coast (E1 and E2), two on the west (W1 and W2) and one on the south (S). The 10m wide transects started at a pre-determined point, located by GPS (Appendix 1), and were followed on a bearing seaward. All surveys were carried out during low spring tides (Appendix 2), extending to the ELWS mark and the end point of each transect was recorded by GPS (Appendix 1).

Substrate assessment
Six 1m^2 quadrats were randomly placed every 10m along the transect for assessment of substrate type. Cover of sand, rock, sand on rock, silt on rock and rubble in each quadrat were estimated using the P6 scale (English et al. 1997) (Table 2).

Species Assessment
Every 25m along the transect, ten 1m^2 quadrats were randomly positioned every 25m along the transect. Cover of sponges (Porifera), green algae (Chlorophyta), brown algae (Phaeophyta), red algae (Rhodophyta), blue-green algae (Cyanophyta), coralline algae (Corallinales) and seagrass in each quadrat were estimated using the P6 scale (English et al. 1997) (Table 2). Barnacles (Cirrepedia), limpets (Patellidae), chitons (Chitonidae), top shells (Trochidae), periwinkles (Littorinidae), nerites (Neritidae), cowries (Cypraeidae), vase shells (Vasidae), mussels, *Morula granulata* and oysters (Ostreidae) were counted.

Data analysis
Assuming a normal distribution of samples within each P6 category, the mean for each P6 range (Table 2) provided an equivalent value for percentage cover for each P6 category. Pooling of results from all quadrats taken each 50m along the transect resulted in 30 replicates for substrate data and 20 replicates for species data. Mean percentage cover and counts of substrate and species were assessed to identify zonation patterns and to compare sites.

Table 2. P6 scale and mean category values

P6 Category	Percentage Cover / %	Mean Percentage Cover / %
0	0	0
1	1-10	5.5
2	11-30	20.5
3	31-50	40.5
4	51-75	63
5	76-100	88

3. RESULTS

3.1 Demarcation of the Intertidal Zone

The location of the low water line around Misali Island was defined by the GPS coordinates given in Appendix 3 and is displayed in Figure 3. The shallow coastline of Misali Island is subject to a 4m tidal range, creating an extensive intertidal zone. Figure 3 shows that the zone is largest on the eastern coastline, with significant areas on the south and west. Conversely, the northern coast exhibited more restricted intertidal areas.

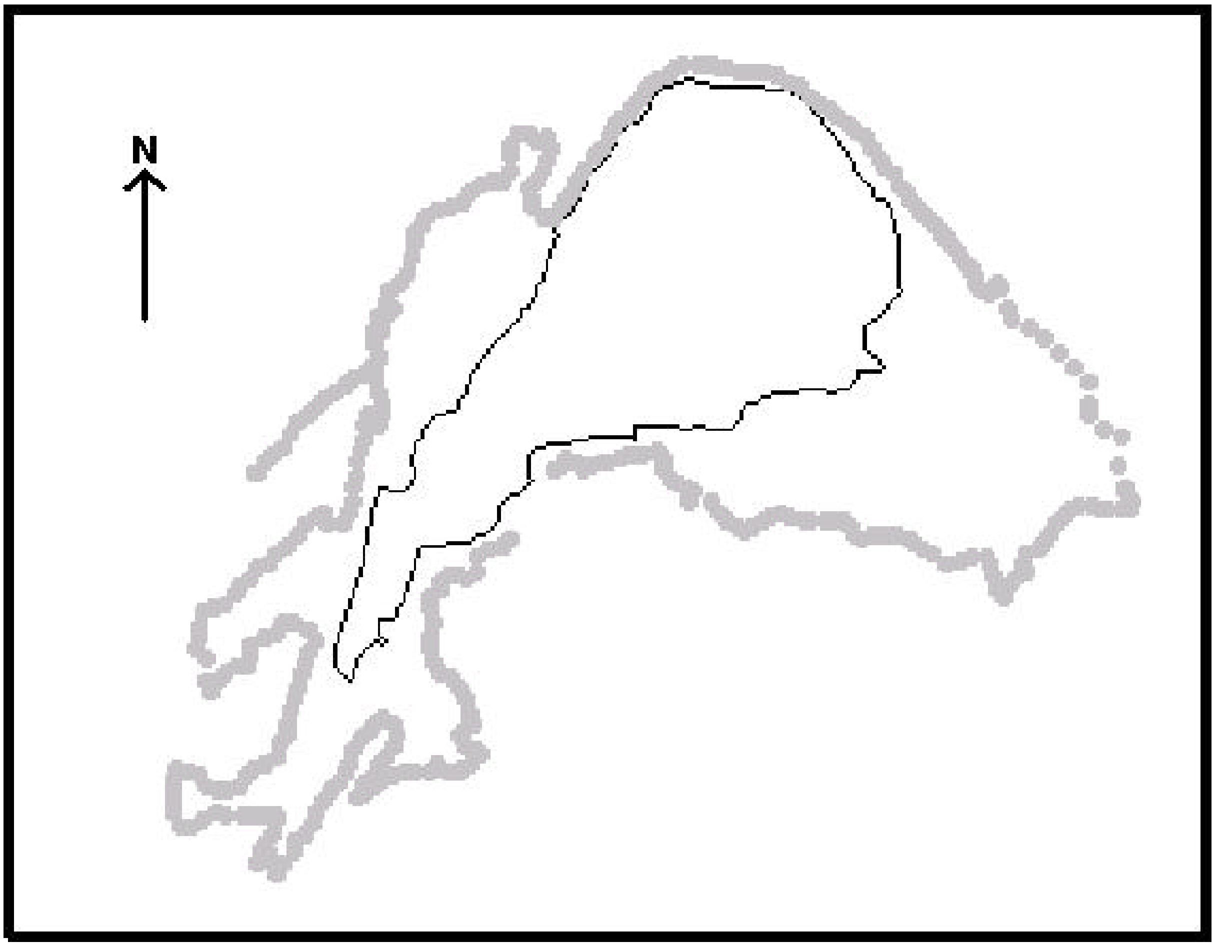


Figure 3. Misali low water line

3.2 Intertidal Species Inventory

A limited species inventory for Misali's intertidal regions is given in Table 3. Unfortunately, detailed species identification guides were unavailable, and this inventory was compiled using only Richmond 1997.

Table 3. Misali island intertidal species inventory

Group	Species	**Group**	Species
Green Algae	*Ulva pulchra*	**Corals**	*Porites sp.*
	Ulva pertusa		
	Ulva fasciata	**Polychaetes**	*Owenia fusiformis*
	Ulva reticulata		*Marphysa sp.*
	Cladophora sp.		
	Neomeris vanbossae	**Crustaceans**	*Balanus sp.*
	Dictyosphaeria cavernosa		*Chirona sp.*
	Codium geppii		*Gonodactylus sp.*
	Valonia fastigata		*Grapsus albolineatus*
	Enteromorpha ramulosa		*Macropthalmus boscii*
			Pilumnus verspertillo
Brown Algae	*Hydroclathrus clathrus*		*Menaethius monoceros*
	Turbinaria decurrans		*Geograpsus stormi*
	Dictyota humifusa		*Xantho hydrophilus*
	Stypopodium zonale		*Lydia annulipes*
	Colpomenia sinuosa		
	Padina boryana	**Molluscs**	*Acanthopleura gemmata*
	Sargassum sp.		*Acanthopleura brevispinosa*
			Trochus maculatus
Red Algae	*Ceratodictyon spongiosum*		*Trochus virgatus*
	Eucheuma sp.		*Nerita undata*
	Laurencia papillosa		*nerita albicilla*
	Gracilaria salicornia		*Cypraea moneta*
	Hypnea cornuta		*Cypraea annulus*
	Sarconem filiforme		*Vasus ceramicum*
	Acanthophora spicicfera		*Diala lauta*
			Tridacna maxima
Coralline Algae	*Lithophyllum kotschyanum*		*Pinna muricata*
	Hydrolithon rheinboldii		*Saccostrea cucullata*
	Mesophyllum funafutiense		*Semipallium tigris*
			Morula granulata
Blue-green Algae	*Lyngbya sp.*		*Cantharus fumosus*
	Oscillatoria sp.		*Drupella rugosa*
			Turbo argyrostomus
Sponges	*Spheciospongia florida*		*Conus sp.*
	Cinachyrella voeltzkowii		
	Sigmadocia amboinensis	**Echinoderms**	*Echinometra mathaei*
	Haliclona debilis		*Echinothrix diadema*
	Tedania anhalens		*Synapta maculata*
	Lissodendoryx monticularis		*Luidia maculata*
	Pseudosuberites andrewsi		*Astropecten mnacanthus*
			Dactyloaster cylindricus
Anemones	*Zoanthus natalensis*		*Ophiocoma sp.*
	Zoanthus sansibaricus		*Ophionereis sp.*
	Protopalythoa nelliae		

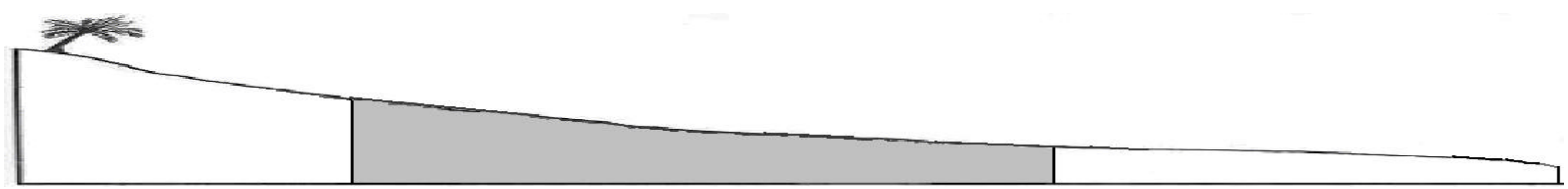
3.3 Intertidal Surveys

Dominant substrates, flora and fauna for each region of the intertidal zone for each transect are given in Table 4. More detailed figures showing the distribution of individual substrates and species are given in Appendix 4.

Table 4. Dominant substrates, flora and fauna of the intertidal zone at each transect on Misali Island in approximate order of prevalence

LITTORAL FRINGE			**EULITTORAL ZONE**			**SUBLITTORAL FRINGE**		
Substrates	**Flora**	**Fauna**	**Substrates**	**Flora**	**Fauna**	**Substrates**	**Flora**	**Fauna**
• Rock • Silt • Sand	• Green algae • Brown algae • Coralline algae	• Mussels* • *M. granulata* • Nerites • Vase Shells • Chitons	• Range of substrates	• Green algae*	• Oysters • Periwinkles • Topshells	• Sand*	• Seagrasses* • Green algae	• Sponges • Barnacles • Cowries • Topshells
• Rock • Sand	• Green algae • Brown algae • Coralline algae	• Periwinkles* • *M. granulata* • Sponges • Topshells • Chitons	• Silt on rock • Sand	• Green algae	• Mussels • Cowries	• Silt on rock • Sand	• Green algae • Brown algae • Coralline algae	• Cowries • Oysters • Topshells • Vase Shell
• Sand* • Rock • Sand on rock	• Green algae • Coralline algae • Brown algae	• *M. granulata* • Nerites • Periwinkles	• Sand on rock • Rock • Sand	• Green algae • Coralline algae • Brown algae • Blue-green algae	• Chitons	• Rock • Sand on rock • Sand	• Coralline algae • Brown algae • Green algae	• Mussels • Cowries • Chitons • Sponges
• Sand • Sand on rock	• Brown algae	• Periwinkles	• Rock • Silt on rock • Silt	• Green algae • Brown algae • Coralline algae	• *M.granulata* • Nerites • Chitons	• Rock • Sand • Rubble	• Brown algae • Coralline algae • Brown algae	• Mussels • Cowries
• Sand on rock • Sand • Rock • Rubble	• Green algae • Blue green algae	• *M. granulata* • Chitons • Nerites	• Sand on rock • Sand • Rock	• Coralline algae	• Mussels • Oysters • Sponges	• Rock • Sand on rock • Sand	• Coralline algae • Green algae • Brown algae	• Mussels • Cowries • Nerites • Chitons

**superabundant in this zone*



4. DISCUSSION

4.1 Demarcation of the Intertidal Zone

The low tide line plotted in this study (Figure 3) follows current bathymetric maps (e.g.: Richmond & Mohammed 2001 – Figure 1) but provides additional information on exact GPS fixes. The NEZ encompasses a large proportion of the intertidal regions of Misali, however significant areas still lie outside, particularly on the east coast. The east coast is probably the most frequently visited it is the closest to mainland Pemba, with sheltered and convenient locations for mooring boats and camping. The exposed northern coastline lacks any significant intertidal zone

4.2 Intertidal Species Inventory and Intertidal Surveys

4.2.1 Substrates

Substrate composition of intertidal areas is primarily determined by the level of exposure and wave action affecting the coastline and substrate grain size is an important factor in the determination of intertidal species assemblages. .

On the eastern shores of Misali, where wave intensity is moderate, large algae cover the shore and give shelter to small animals which cannot tolerate complete exposure to air and sun, such as coelenterates, sponges, bryozoans and small crustaceans. Finer particles are also allowed to settle, providing substrate for other plants such as seagrasses. However, sand and silt can also smother epibenthic organisms.

Stronger waves, as on the west and south coasts prevent the growth of plants, and the rock surfaces harbour periwinkles and nerites, or mussels at lower levels. Sand and finer substrates are removed by the persistent wave action. Rocks present a variety of habitable environments – exposed rock faces, sheltered overhangs, crevices, pools, silt within fissures or under boulders, in the shelter of algae or their ramifying holdfasts – each offering a domain which some species can occupy.

4.2.2 Flora

Green Algae (Chlorophyta)

Green algae were widespread throughout all sites and all intertidal zones. However, on other East African seashores, they are often restricted to the eulittoral and sublittoral zones, with individual species showing distinct zonation (Richmond 1997). Green algae were less widespread on the west coast, as a result of exposure to abrasive wave action.

Brown Algae (Phaeophyta)

Brown algae were present at most sites and intertidal zones, although they were less prevalent on the eastern transects. They generally occur in the lower eulittoral and sublittoral zones (Richmond 1997).

Red Algae (Rhidophyta)

Red algae are inhabitants of eulittoral and sublittoral although some species (e.g. *Gelidium pusillum*) are adapted to life in the upper shore (Richmond 1997). Species collected in Tanzania include *Peysonelia spp.*, *Halymenia spp., Euchema spp.* (cultivated in Zanzibar since 1989), *Champia spp.* and *Gracilaria spp.* (for agar production) (Richmond 1997). The scarcity of red algae on Misali shores may be a result of past overexploitation. However, seaweed is not currently harvested on Misali, apart for a small amount as bait for fish traps.

Blue-Green Algae

Blue-green algae normally dominate the littoral fringe on tropical rocky shores (Richmond 1997), but are generally widespread and may be found in most tropical coastal habitats. However, blue green algae were only positively identified on the S and W2 transects; this may have been because of the unavailability of suitable identification guides.

Coralline algae

Coralline algae were distributed throughout Misali's intertidal zone. They are an important component of reefs because of their ability to overgrow and stabilize fragmented, rubble substrates; and could be significant in the limitation of damage through trampling.

Seagrasses *(Mwani)*

The sublittoral fringe of E1 was an important habitat for seagrasses, owing to the sheltered conditions and soft substrates. Seagrass habitats are highly productive, and play an important ecological role as nursery grounds for fish and crustaceans, as a food source and shelter for many organisms, and in nutrient recycling. Thus conservation of this important habitat is vital in the maintenance of other ecosystems on Misali and the future sustainability of its fisheries. Although the seagrass beds are not exploited themselves, they are vulnerable to trampling during collection of other resources.

4.2.3 Fauna

Sponges

The eastern coastline of Misali appears most important for sponges. They are found throughout the intertidal zone, although most species inhabit the lower regions. They also provide habitats for a range of organisms including bacteria, fungi, crabs, barnacles, shrimps, nematodes, polychaetes, sea cucumbers, brittlestars, small fish and other sponges. Thus they play a role in the maintenance of some important fisheries.

Acorn Barnacles *(Makaya*)

Acorn barnacles are generally found on the upper eulittoral or lower eulittoral on exposed shores (Richmond 1997). They were not common on Misali, only being found in any number on rocks in the sublittoral fringe on the sheltered eastern shore at E1.

Limpets *(Kombe gwaa)*

Limpets usually occur on upper shores in East Africa, where they graze on microalgal film. However, they were rarely found on Misali.

Chitons ***(Nyamata)***
Chitons are found on the littoral fringe and upper eulittoral of East African seashores. They were a common component of the fauna in Misali's intertidal zone, and were more frequently found on the southern and western shores. This may be a result of increased collection rates outside the NEZ, or may simply be because of habitat preferences.

Topshells ***(Vipini, Zunguya)***
Topshells were found in the lower eulittoral and shallow sublittoral of the eastern shore of Misali, however they were absent on the exposed southern and western shores.

Periwinkles ***(Koamikoko)***
Periwinkles were common on rock and mangrove trees in the upper eulittoral zone around the entire Misali coastline, where they graze microalgae. They are too small to be of any commercial significance.

Nerites ***(Korogombwe, Kombe, Njagaisi)***
Nerites dominate the littoral fringe on tropical rocky shores (Richmond 1997), grazing microalgae on rock surfaces, and were found in this zone around the Misali coastline. They were also found in the rocky sublittoral fringe at W2.

Cowries ***(Macruru)***
Cowries were common in the lower eulittoral and subtidal zones at all sites, indicating that populations have survived exploitation because of their desirable shells. Misali is not easily accessible and shell collection is unlikely to develop into a primary industry on the island.

Vase Shells ***(Mbinu)***
Vase shells are normally found in the lower eulittoral zone, they are carnivorous, preying on polychaetes. They were only found in the intertidal zone of the eastern shore of Misali.

Mussels ***(Vijyogoo)***
Mussels are most abundant of bivalve families, often forming a conspicuous zone in the eulittoral region (Richmond 1997). Many species are a source of food; however they do not appear to have suffered from overexploitation on Misali, since they are common even outside the non-extraction zone.

Morula granulata
Morula granulata were common amongst rocks in the eulittoral zone on all transects. This species is unlikely to be of commercial significance, but could be a useful zonation indicator species.

Oysters ***(Chaza, Makaya, Jeta)***
Oysters are edible and commercially important. They are generally found in the eulittoral, on rocks or mangrove trunks and roots. They were only found on two sites on Misali, and may have been overexploited in the past. Conservation of the remaining population within the NEZ is essential.

4.3 Management suggestions

Although some zonation of species was apparent, there were no clear patterns of distribution at the taxonomic levels investigated. Differences in exposure to wave action between each coastline of Misali result in considerable differences in substrate and thus species assemblages. There is also considerable spatial variation in collection effort owing to the fact that shellfish-gatherers go, at irregular intervals, to several different areas of shore during their search for food (Lasiak, 1993). Thus intertidal species assemblages are subject to a series of disturbances of variable intensity. The fact that such disturbances are neither temporally nor spatially sustained suggests that exploitation should be viewed as a repeated pulse disturbance rather than as a press disturbance, more commonly associated with anthropogenic impacts (Lasiak and Field 1995). As exploitation results in the removal of the larger individuals of several species of invertebrates the immediate response of the assemblage will be a decrease in the abundance of these species. While other species may be unaffected by such disturbances, those species, previously constrained by competition etc., may actually increase in abundance. While sustained anthropogenic disturbances, such as pollution, may lead to the eradication of species, there is no evidence to suggest that exploitation results in localized extinctions (Lasiak and Field 1995).

Unfortunately, current non-extraction legislation has been ignored to varying degrees by octopus fishers (McVean & Fanning, in prep). Enforcement of the current NEZ is vital for the successful management of Misali's intertidal resources. Commercially valuable species such as giant clams (*Tridacna* spp.) and Moray eels (*Morena* spp.) were noticeably common within the NEZ compared to the eastern and southern shores. This indicates that these species may already be re-establishing themselves since the establishment of the NEZ.

Owing to the variability of organism distribution and exploitation patterns, and enforcement difficulties, management of intertidal resources on Misali through non-extraction zones may not be the most effective option to ensure sustainability. Establishment of a monitoring programme for intertidal fisheries could be a valuable tool in ensuring sustainable exploitation of these resources. Although there is currently an attempt by the Department of Fisheries and Marine Resources to monitor octopus exploitation, this could be expanded to record all species exploited in the intertidal zone. In order to overcome the heterogeneous nature of intertidal resource exploitation and to combat deficiencies in monitoring capacity, local resource-users could be trained, possibly by the Misali Island Rangers. This approach has been used with success in Kwa-Zulu Natal, South Africa (Kyle et al. 1997), involving the local community and providing much-needed employment, improving living standards. It was also found to be an important step in enabling the local community to assume some responsibility for the resources in their area and develop a sense of ownership of these resources.

Since octopus collection is the primary fishing activity carried out in the intertidal zone, it is likely that the opportunistic collection of other resources is closely associated. Thus controls on the exploitation of octopus will probably have incidental benefits for other intertidal resources. Until the late 1990s, octopus collection did not occur between May and October, because the local octopus trader's boat was unable to reach Misali during this time. However, octopus collection now continues year round, potentially with serious repercussions for the octopus and associated fisheries on Misali (Misali Rangers pers. comm.).

5 CONCLUSIONS AND RECOMMENDATIONS

- Current non-extraction legislation appears to have had a positive effect on exploited species and continued and complete enforcement of the NEZ would be beneficial.

- However, owing to the unpredictable nature of patterns of species assemblages and exploitation, non-extractive management alone is unlikely to be completely effective in the maintenance of intertidal resources on Misali.

- Intertidal fisheries should be monitored, perhaps by involving local stakeholders in the programme. This would overcome difficulties in monitoring such an unpredictable fishery and would allow the local community to assume some responsibility for the resources in accordance with the underlying MIMCA philosophy.

- Seasonal controls on the octopus fishery would be easily enforced because of its international commercial interest, and would have knock-on benefits for other intertidal fisheries.

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Appendix 1. GPS locations of transects

SITE	DATE SURVEYED	Start	End
E1	10th August 2002	S05°14’18.6”;E39°36’32.0”	S05°14’33.7”;E39°36’46.2”
E2	10th August 2002	S05°14’22.3”;E39°36’24.9”	S05°14’32.8”;E39°36’27.1”
S	9th August 2002	S05°14’48.0”;E39°35’44.2”	S05°15’02.6”;E39°36’38.7”
W1	8th August 2002	S05°14’21.5”;E39°35’55.9”	S05°14’16.3”;E39°35’49.8”
W2	9th August 2002	S05°14’25.6”;E39°35’52.2”	S05°14’23.2”;E39°35’48.1”

Appendix 2. Times and heights of high and low waters during study period

	Time	**Height / m**
8th August 2002	0353	3.28
	0949	0.53
	1605	4.01
	2226	0.24
9th August 2002	0431	3.54
	1029	0.29
	1646	4.20
	2303	0.06
10th August 2002	0509	3.75
	1109	0.14
	1724	4.37
	2340	-0.04
11th August 2002	0548	3.89
	1149	0.09
	1804	4.21

Taken from the Tanzanian Ports Authority Tide Tables 2002

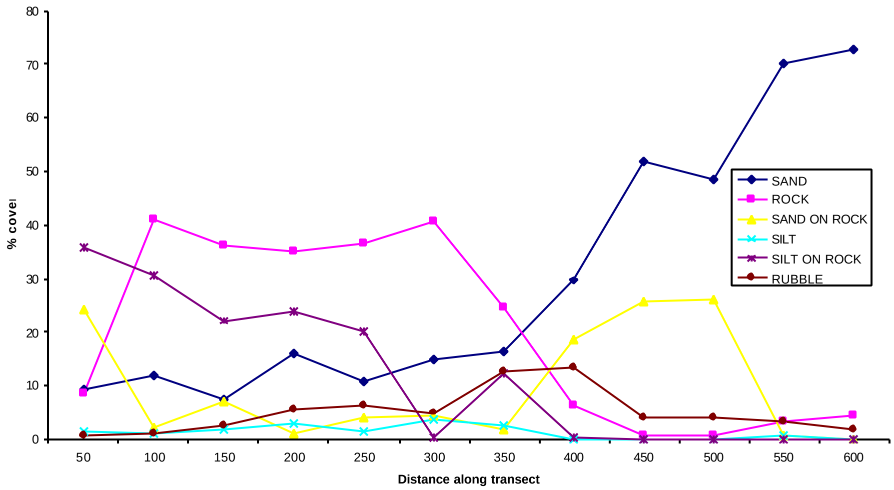
Appendix 3. Misali Island low tide line coordinates taken by GPS, heading clockwise from the western end of Misali Island

	37M	UTM		37M	UTM		37M	UTM		37M	UTM
1	565892	9420327	*51*	566667	9421000	*101*	567636	9421059	*151*	567940	9420219
2	565893	9420326	*52*	566694	9421004	*102*	567653	9421039	*152*	567928	9420197
3	565919	9420352	*53*	566715	9421033	*103*	567671	9421025	*153*	567908	9420176
4	565937	9420374	*54*	566727	9421050	*104*	567682	9421013	*154*	567884	9420170
5	565963	9420390	*55*	566746	9421074	*105*	567694	9420999	*155*	567868	9420141
6	565986	9420425	*56*	566762	9421100	*106*	567710	9420981	*156*	567876	9420117
7	566008	9420455	*57*	566778	9421125	*107*	567720	9420967	*157*	567854	9420099
8	566038	9420479	*58*	566785	9431148	*108*	567740	9420946	*158*	567828	9420083
9	566060	9420500	*59*	566813	9421170	*109*	567755	9420920	*159*	567816	9420051
10	566080	9420519	*60*	566829	9421189	*110*	567773	9420900	*160*	567802	9420076
11	566103	9420538	*61*	566846	9421210	*111*	567783	9420882	*161*	567796	9420105
12	566135	9420558	*62*	566863	9421231	*112*	567784	9420862	*162*	567787	9420133
13	566156	9420575	*63*	566875	9421251	*113*	567804	9420846	*163*	567773	9420155
14	566184	9420586	*64*	566883	9421259	*114*	567816	9420837	*164*	567742	9420156
15	566205	9420600	*65*	566898	9421274	*115*	567648	9421045	*165*	567713	9420145
16	566224	9420626	*66*	566913	9421289	*116*	567670	9421024	*166*	567672	9420135
17	566219	9420663	*67*	566924	9421304	*117*	567698	9420985	*167*	567634	9420158
18	566222	9420699	*68*	566939	9421320	*118*	567724	9420962	*168*	567619	9420172
19	566227	9420724	*69*	566956	9421340	*119*	567727	9420952	*169*	567593	9420187
20	566241	9420746	*70*	566970	9421353	*120*	567751	9420925	*170*	567577	9420199
21	566253	9420771	*71*	566986	9421371	*121*	567778	9420886	*171*	567556	9420207
22	566264	9420805	*72*	567008	9421381	*122*	567794	9420853	*172*	567529	9420205
23	566289	9420820	*73*	567029	9421393	*123*	567841	9420859	*173*	567510	9420203
24	566310	9420852	*74*	567053	9421407	*124*	567845	9420852	*174*	567482	9420206
25	566325	9420891	*75*	567083	9421408	*125*	567861	9420800	*175*	567461	9420199
26	566331	9420929	*76*	567108	9421408	*126*	567871	9420770	*176*	567438	9420203
27	566335	9420954	*77*	567128	9421406	*127*	567917	9420751	*177*	567425	9420219
28	566351	9420973	*78*	567141	9421401	*128*	567954	9420725	*178*	567409	9420238
29	566365	9420998	*79*	567165	9421398	*129*	567990	9420684	*179*	567390	9420241
30	566398	9421018	*80*	567189	9421393	*130*	568028	9420655	*180*	567362	9420239
31	566430	9421020	*81*	567209	9421395	*131*	568030	9420654	*181*	567330	9420239
32	566464	9421032	*82*	567239	9421395	*132*	568063	9420617	*182*	567309	9420237
33	566482	9421058	*83*	567268	9421395	*133*	568065	9420559	*183*	567271	9420244
34	566510	9421084	*84*	567295	9421386	*134*	568062	9420532	*184*	567247	9420254
35	566545	9421090	*85*	567325	9421371	*135*	568095	9420493	*185*	567224	9420249
36	566573	9421093	*86*	567353	9421356	*136*	568139	9420473	*186*	567200	9420233
37	566594	9421126	*87*	567382	9421333	*137*	568132	9420400	*187*	567176	9420214
38	566595	9421159	*88*	567404	9421316	*138*	568142	9420345	*188*	567150	9420205
39	566596	9421192	*89*	567420	9421307	*139*	568143	9420342	*189*	567130	9420217
40	566610	9421220	*90*	567441	9421290	*140*	568149	9420337	*190*	567105	9420233
41	566642	9421215	*91*	567467	9421266	*141*	568161	9420306	*191*	567085	9420248
42	566659	9421200	*92*	567485	9421251	*142*	568157	9420289	*192*	567068	9420276
43	566691	9421209	*93*	567511	9421227	*143*	568132	9420290	*193*	567013	9420279
44	566696	9421184	*94*	567534	9421204	*144*	568097	9420289	*194*	567023	9420305
45	566682	9421151	*95*	567552	9421178	*145*	568073	9420284	*195*	567010	9420317
46	566677	9421121	*96*	567564	9421161	*146*	568054	9420298	*196*	566990	9420328
47	566655	9421093	*97*	567582	9421136	*147*	568020	9420294	*197*	566965	9420334
48	566638	9421075	*98*	567591	9421114	*148*	567999	9420287	*198*	566954	9420360
49	566640	9421051	*99*	567614	9421097	*149*	567979	9420269	*199*	566951	9420389
50	566647	9421025	*100*	567622	9421076	*150*	567957	9420244	*200*	566934	9420407

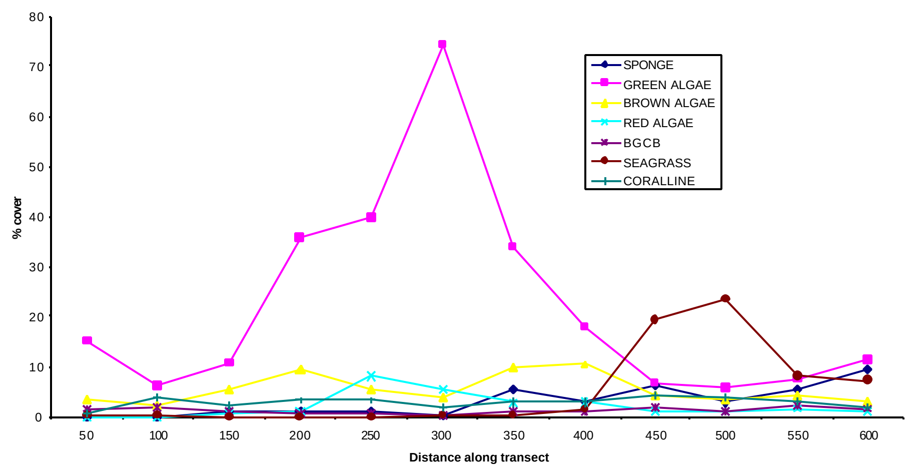
	37M	UTM		37M	UTM		37M	UTM		37M	UTM
201	566894	9420398	251	566134	9419502	301	565725	9419514	351	566107	9420198
202	566876	9420400	252	566115	9419492	302	565749	9419498	352	566128	9420224
203	566856	9420397	253	566134	9419526	303	565780	9419504	353	566139	9420254
204	566837	9420387	254	566162	9419550	304	565810	9419516	354	566145	9420288
205	566812	9420374	255	566179	9419574	305	565831	9419538	355	566152	9420322
206	566788	9420371	256	566194	9419600	306	565850	9419558	356	566159	9420354
207	566766	9420365	257	566212	9419624	307	565883	9419568	357	566170	9420386
208	566739	9420352	258	566229	9419652	308	565906	9419594	358	566181	9420418
209	566725	9420376	259	566217	9419678	309	565921	9419624	359	566183	9420450
210	566701	9420384	260	566192	9419696	310	565937	9419650	360	566192	9420482
211	566682	9420360	261	566167	9419684	311	565946	9419678	361	566208	9420478
212	566667	9420350	262	566151	9419660	312	565956	9419710	362	566205	9420452
213	566545	9420172	263	566128	9419638	313	565969	9419742	363	566213	9420450
214	566520	9420152	264	566113	9419610	314	565979	9419774	364	566214	9420450
215	566489	9420140	265	566097	9419580	315	565991	9419804	365	566223	9420480
216	566460	9420120	266	566085	9419552	316	566001	9419836	366	566226	9420512
217	566452	9420088	267	566068	9419528	317	566009	9419868	367	566225	9420542
218	566426	9420066	268	566048	9419504	318	566027	9419898	368	566214	9420572
219	566406	9420072	269	566048	9419504	319	566007	9419924	369	566216	9420604
220	566375	9420068	270	566028	9419476	320	565978	9419942	370	566221	9420636
221	566360	9420052	271	566011	9419448	321	565947	9419934	371	566220	9420666
222	566355	9420032	272	565993	9419424	322	565923	9419912	372	566225	9420692
223	566329	9420012	273	565976	9419398	323	565893	9419896	373	566229	9420720
224	566327	9419984	274	565951	9419372	324	565861	9419882	374	566231	9420736
225	566336	9419946	275	565944	9419350	325	565854	9419854	375	566239	9420726
226	566327	9419914	276	565919	9419320	326	565845	9419824	376	566237	9420700
227	566324	9419880	277	565897	9419290	327	565812	9419822	377	566252	9420732
228	566330	9419846	278	565892	9419320	328	565788	9419802	378	566264	9420758
229	566344	9419822	279	565877	9419340	329	565764	9419780	379	566265	9420758
230	566373	9419804	280	565852	9419318	330	565745	9419758			
231	566397	9419778	281	565858	9419354	331	565736	9419784			
232	566414	9419752	282	565871	9419362	332	565741	9419838			
233	566418	9419720	283	565890	9419390	333	565718	9419862			
234	566428	9419692	284	565899	9419430	334	565722	9419894			
235	566405	9419674	285	565905	9419436	335	565724	9419926			
236	566387	9419656	286	565871	9419434	336	565739	9419958			
237	566406	9419634	287	565847	9419436	337	565764	9419976			
238	566433	9419618	288	565814	9419432	338	565800	9419984			
239	566438	9419612	289	565773	9419436	339	565825	9420006			
240	566414	9419588	290	565746	9419440	340	565840	9420028			
241	566392	9419570	291	565715	9419426	341	565863	9420052			
242	566386	9419560	292	565685	9419408	342	565887	9420074			
243	566357	9419562	293	565650	9419406	343	565913	9420092			
244	566331	9419580	294	565641	9419440	344	565935	9420116			
245	566303	9419564	295	565637	9419474	345	565960	9420140			
246	566272	9419564	296	565637	9419494	346	565990	9420166			
247	566240	9419562	297	565640	9419526	347	566015	9420192			
248	566211	9419552	298	565648	9419556	348	566043	9420214			
249	566183	9419538	299	565679	9419550	349	566063	9420220			
250	566158	9419522	300	565710	9419538	350	566076	9420192			

Coordinates recorded on 11th August 2002, using three different GPS instruments, within 40mins either side of low tide every 30 paces, approximately 20m

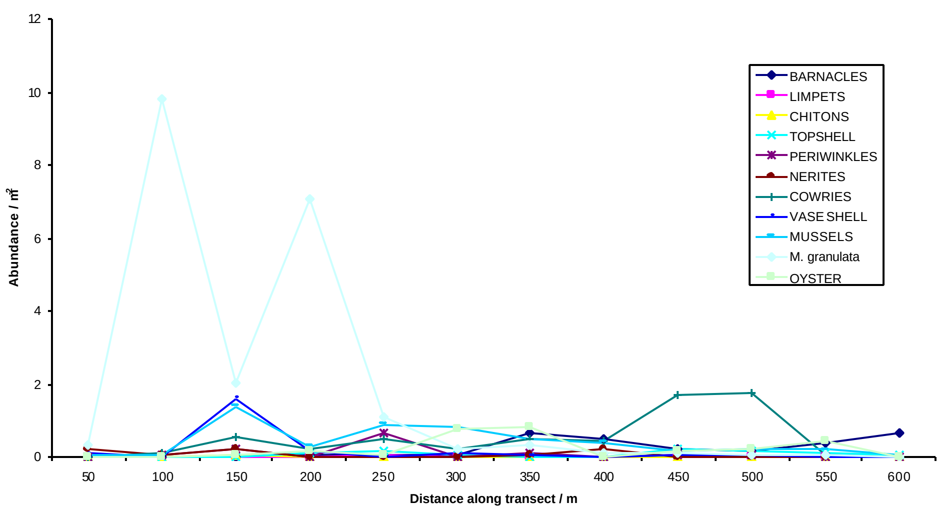
Appendix 4. Graphical Presentation of Intertidal Survey Results



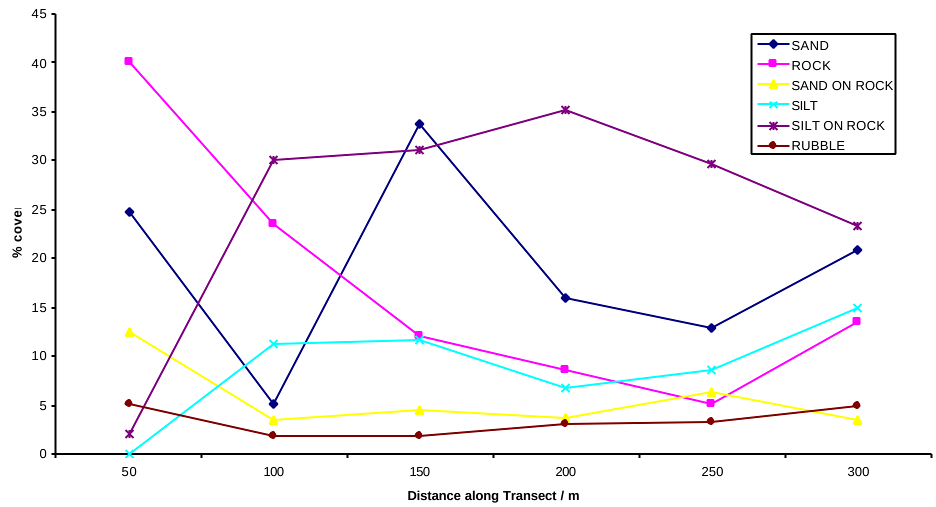
% cover of substrates along transect E1



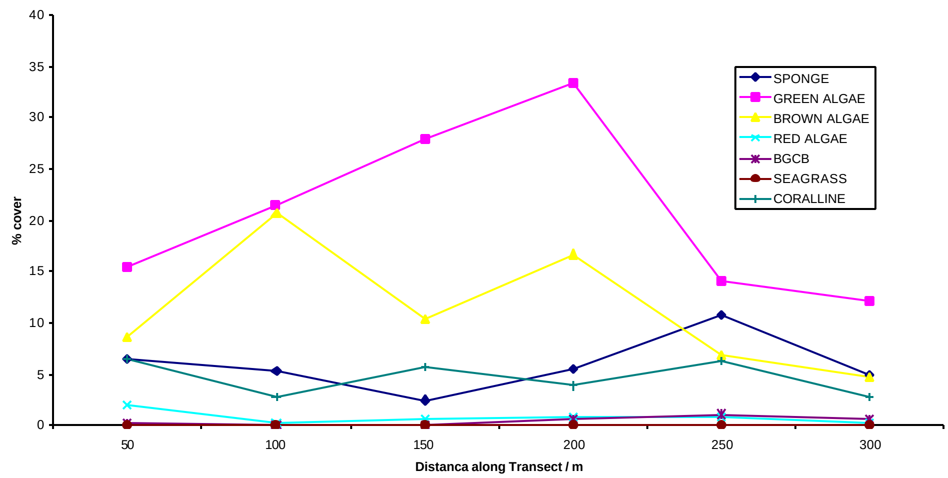
% cover of species along transect E1



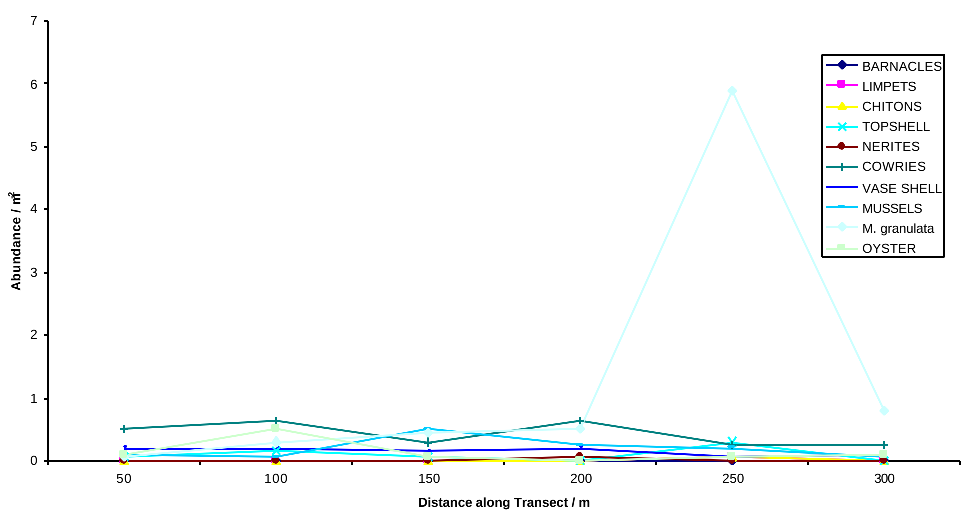
Abundance of species along transect E1



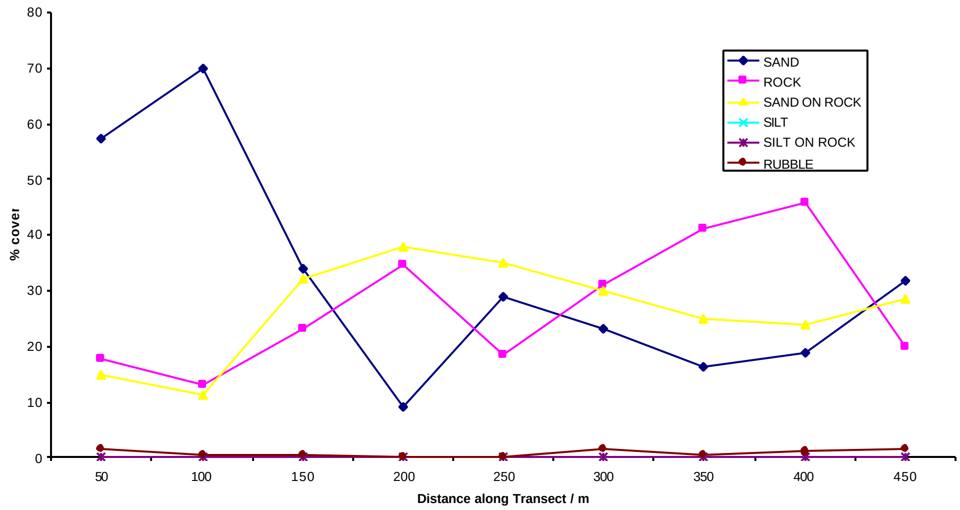
% cover of substrates along transect E2



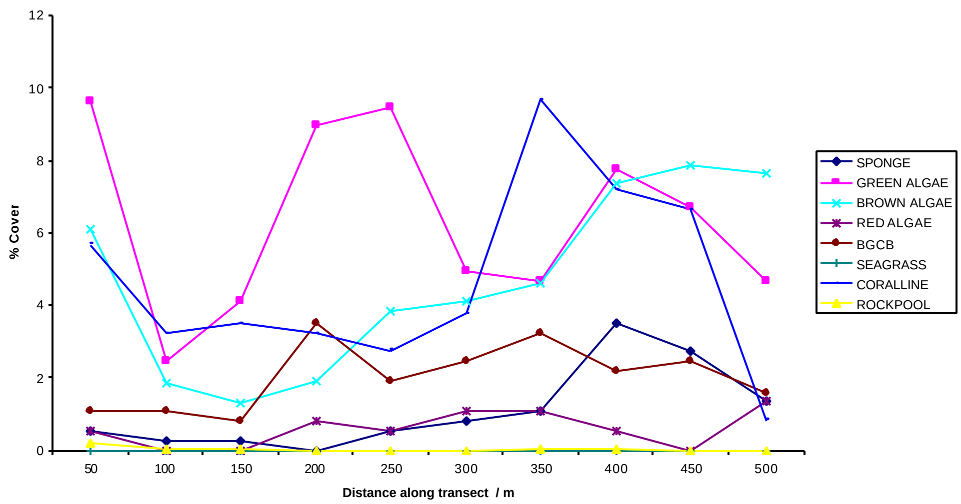
% cover of species along transect E2



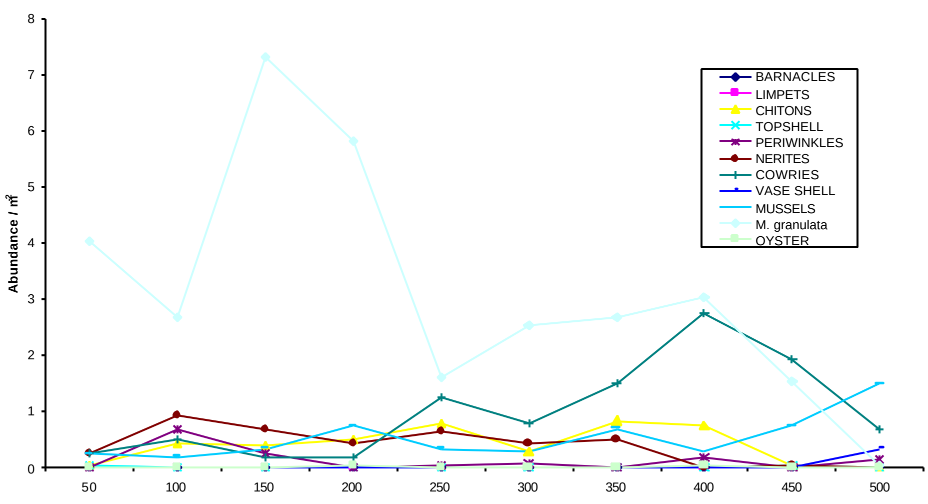
Abundance of species along transect E2



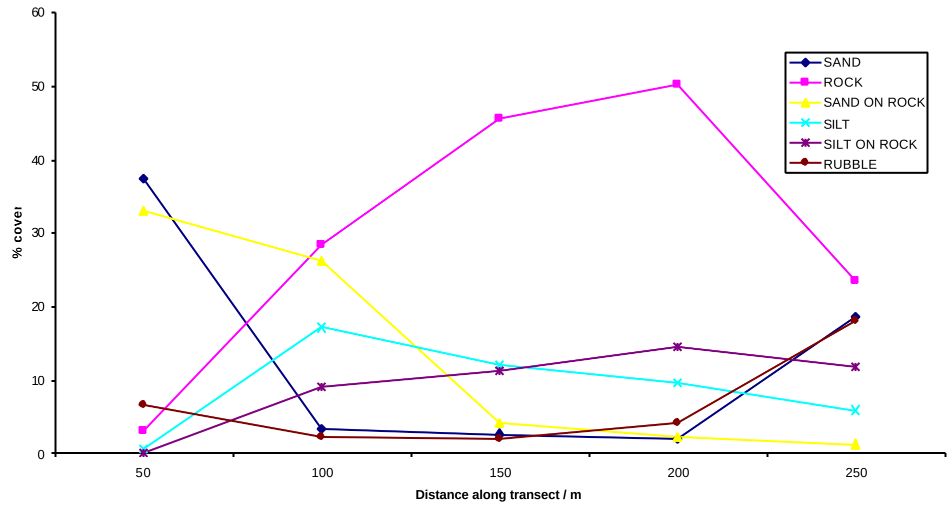
% cover of substrates along transect S



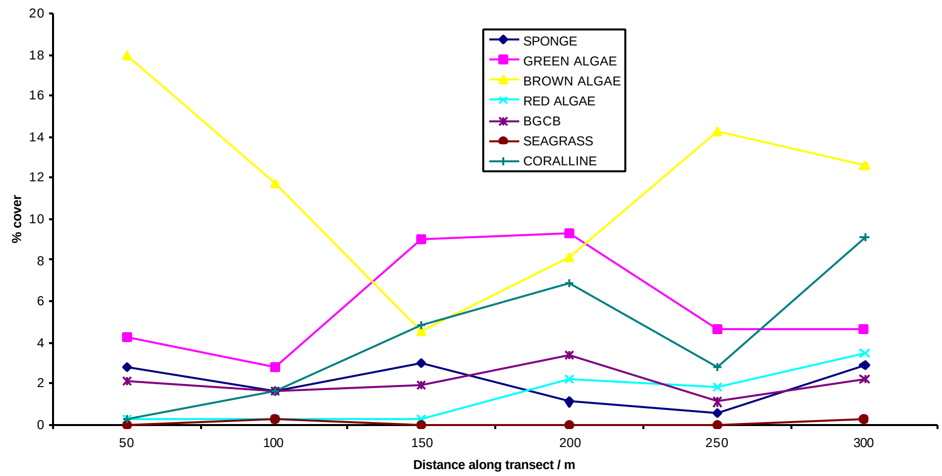
% cover of species along transect S



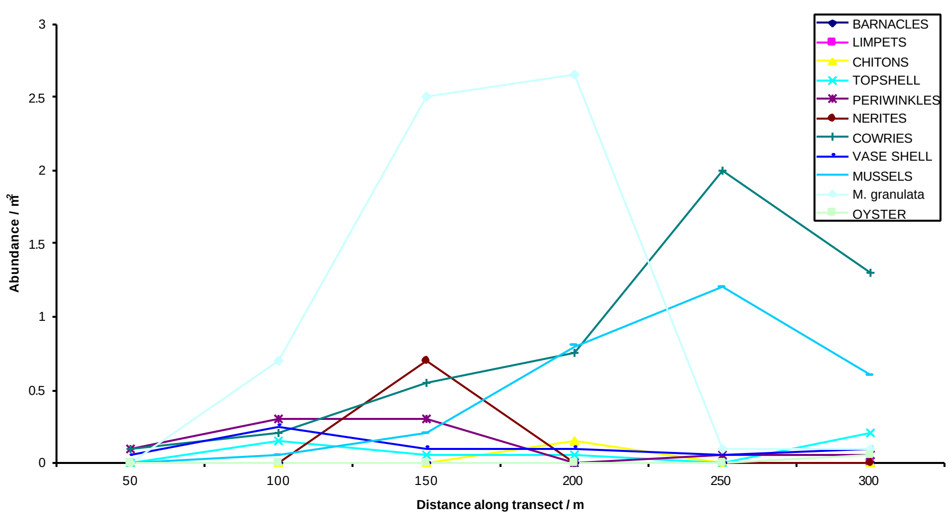
Abundance of species along transect S



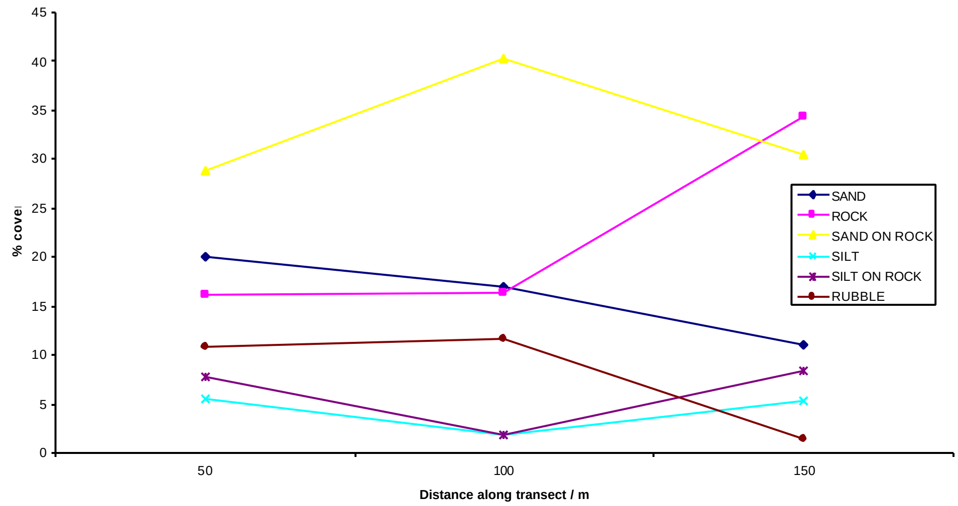
% cover of substrates along transect W1



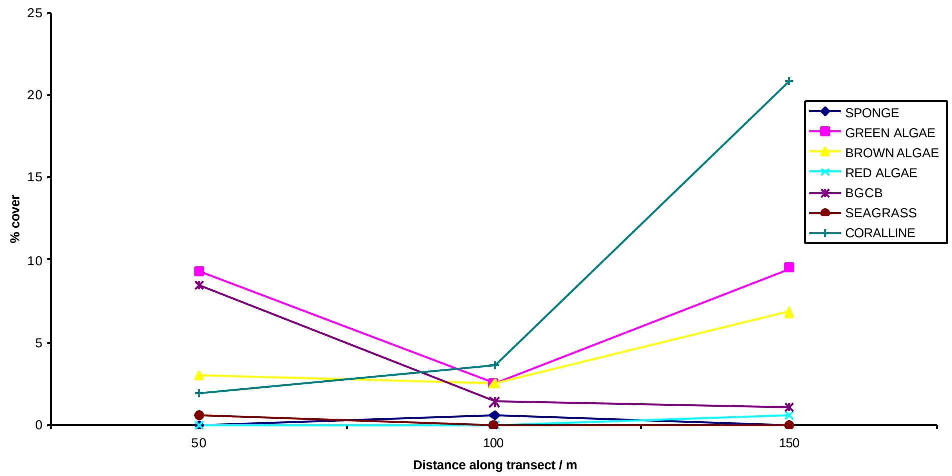
% cover of species along transect W1



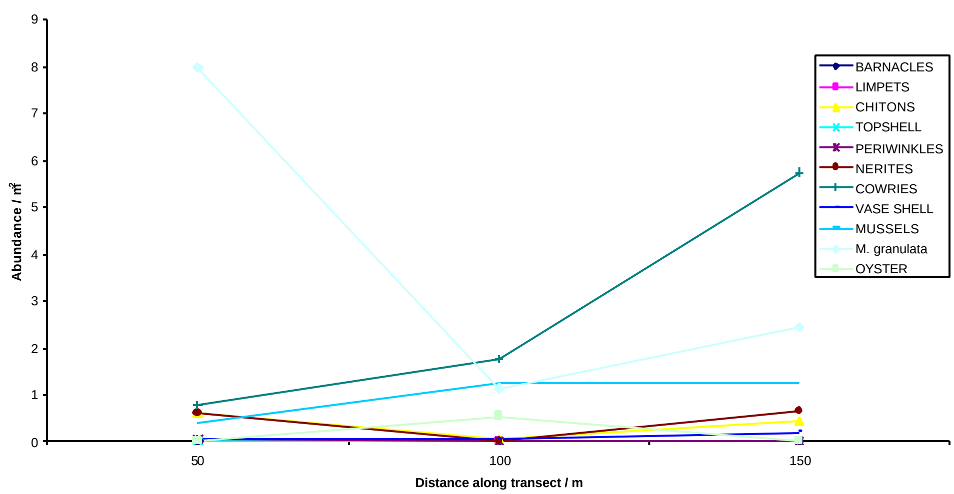
Abundance of species along transect W1



% cover of substrates along transect W2



% cover of species along transect W2



Abundance of species along transect W2