Coral reef management in the Maldives, with special reference to reef monitoring: The use of line transect method for monitoring coral reefs in the Maldives.

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Abstract:

This study attempts to ascertain aspects of coral reef management in the Maldives, with emphasis laid on reef monitoring. The patterns of exploitation of reefs are described. Threats to reefs, both man-made and natural, are reviewed. The major human impacts on reefs in the Maldives appear to be coral mining, dredging and reclamation, tourist related activities and pollution. *Acanthaster plancii* predation is a significant threat to coral reefs in some atolls of Maldives.

Aspects of coral reef monitoring are reviewed with emphasis on monitoring objectives, design and operation of monitoring programmes, and methods employed in reef monitoring. Transect methods, quadrat methods, photographic methods and visual surveys are reviewed.

A monitoring programme developed at the Marine Research Section of the Ministry of Fisheries and Agriculture, in Maldives is described. Data collected under this programme were analysed in chapter 4. This is a long-term monitoring scheme being developed to detect anthropogenic impacts on coral reefs. The problems and short comings of the data as well as their usefulness is discussed. It was concluded that the data collected under the monitoring programme can be put to management use only with further studies and refinements to the sampling procedures.

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1.1 Introduction

The Republic of Maldives form the central and the largest part of the Chagos-Laccadive Ridge, which extends from west of India into the Indian Ocean and consists of atolls and associated coral structures (Fig. 1.). The archipelago (07° 07'N to 00° 42'S and 72° 33'E to 73° 44'E), consists of about 1300 low-lying islands forming 21 natural atolls and represents one of the largest coral atoll groups of the world.

Although its territorial area is considerable (90,000km^2), a relatively small proportion of the total area (≅300km^2) is dry land. Of the 1300 or so islands only 202 are inhabited.

Being a country with more territorial sea than dry land, the Maldivians depend on resources almost entirely from the sea. The coral reefs which built the country play a vital role in the economic and social well-being of the country.

Fishing and tourism are the two main industries of Maldives. Both these industries are very healthy with good potential growth rates. They rely on healthy reefs for their existence. The majority of fish caught are tuna and tuna-related species. Other reef dependent species of fish and invertebrates are also exploited.

Like many developing nations, the population of the Maldives is increasing rapidly. From 1985-1990 it rose from 180,088 to 213,215 with more than 25% of the population living in the capital Male' (National Development Plan). This represents a growth of 18.9%, equivalent to an annual rate of growth of 3.4%.

Figure 1. Map of Maldives

The traditional life style of the people had almost negligible impact on the marine environment, but recent socio-economic developments have led to marked deterioration of the environment. With the increase in population growth and increased wealth from tourism and fishing, the pace of development have increased at a significant rate in the country, during the last two decades.

The need for land led to land reclamation programmes. Harbours are dredged to facilitate economic growth in islands. The demand for building materials in the form of coral nodules has increased steadily and coral mining has become a major environmental concern in the country. In addition to this the country is faced with localised environmental impacts as a result of tourism and waste discharges.

The fragile nature of the coral reefs, the biological diversity of its marine resources and the increased environmental problems have resulted in a demonstrated need for better environmental management and planning in the country. Recognising this, the government is taking measures to develop its management capabilities. Marine environmental research and management are given high priority. The key to environmentally sound development in the Maldives is the management of its marine resources including coral reefs on a sustainable basis.

1.2 Structure and diversity

The physical setting of the Maldivian atolls vary from open structures with numerous islands, faros (ring-shaped reefs) patches and knolls in the atoll lagoon and around the rim to almost closed structures with few lagoons, knolls and patches. Faros are ring shaped reefs emerging during tidal low water each with their own sandy lagoon and are separated by deep channels. They generally have a rim of living coral consisting of branched and massive types. Patches rise to 40 meters above the lagoon floor and are topped by robust wave-breaking corals. Knolls do not reach the surface and often support profuse coral growth, as do the reefs associated with many of the islands.

In geological time the filling up of the lagoons of faros by reef sediments has resulted in the formation of coral reef islands. The geomorphology of these islands varies tremendously in different atolls and it is influenced by a variety of factors such as location, climate, currents, tides, sea level change and also human factors. The islands are thought to be situated on top of layer of beach rock (about 1m thick), underlying the islands at about 30cm to 60m above present mean sea level (Preu & Engelbrecht 1991). At the edges of the islands the beach rock dips slightly seawards and forms a platform on which the beach sediments are seasonally transported around the islands.

Investigation of the coral reefs of Maldives probably date back to 1834 to 1836 (UNEP REPORT NO. 76.). The work carried out by Scheer (1971) and Davies *et al.* (1971) represent significant contributions to the knowledge of corals and coral reefs of Maldives. Pillai and Scheer (1976) described and summarised the geographical distributions of 143 species of hermatypic corals belonging to 49 genera and 4 ahermatypic corals belonging to 3 genera collected during their expedition to the Maldives (UNEP REPORT NO. 76). They listed a total of 241 species of corals belonging to 75 genera from the Maldives. A summary of coral genera collected by Scheer (1971) at various sites throughout the Maldives is given in Table 1.

Table 1. Coral genera collected in Maldives during the "Xarifa" Expedition in 1957-1958 (Scheer 1971).

ATOLL	NUMBER OF CORAL GENERA
Addu Atoll	42
Suvadiva Atoll	9
Ari Atoll	32
Rasdu Atoll	39
Gaa Faru	22
Faadhippolhu Atoll	26
Miladhunmadulu Atoll	5
Total genera from Maldives	51

1.3 Importance of coral reefs to Maldives

Maldives is a country virtually built by corals. Coral reefs continue to play an important role in everyday lives of the inhabitants.

Coral reefs in Maldives represent a strategic natural offshore sea-defence for the coral islands. They are also important as habitat for baitfish and are the primary source of building material. Coral rock has been historically used for buildings and many other constructions.

The tuna fishing industry, the backbone of the country's economy, relies on healthy reefs for the provision of bait for the tuna fishery. Any impact on bait fishing will have repercussions throughout the fishing industry.

Tourism, the second most important industry in the country also relies on healthy reefs for the well-being of the industry. A significant proportion of the visitors who come to Maldives do so to enjoy and admire the beauty of underwater gardens of corals and the colourful fishes and invertebrates which inhabit coral reefs. If the health of reefs decline through stress or other causes then the tourism industry will be affected adversely.

The islands of Maldives, being merely 1-2 meters above sea level, are prone to flooding and erosion by storms. The reefs provide physical protection to the islands by acting as natural barriers to storm surges and waves. Deterioration of reefs means loss of this barrier and could leave the islands prone to natural disasters.

The potentials of coral reefs as a resource are gradually becoming known to us. Specimens of sponge (*Cribrochalina* sp.) collected from the Maldives have provided a chemical with potential anti-cancer properites (Pettit *et al.*,1992).

Coral reef fish such as snappers (*Lutjanus bohar, Lutjanus gibbus*), emperors (*Lethrinus*), groupers (*Cephalopholis, Ephinephelus*) and jacks (*Caranx*), represent major contributions to the Maldivian reef fishery. Turtles, lobsters, (*Panulirus* sp) clams, (*Tridacna squamosa*) and sea cucumber are harvested from coral reefs along with many others. The coral reef fishery has great potential for expansion.

1.4 Patterns of exploitation

Being a country virtually built by corals, with thousands of coral reefs scattered around them, the Maldivians exploit the reefs extensively for many purposes.

Coral mining for building purposes is widespread. Large amounts of baitfish are caught off the rims of submerged reefs for the tuna fishing industry. Many reef dependant fish and invertebrates including giant clams, sea cucumber, lobsters and shrimps are exploited. The tourism industry uses the reefs for many activities ranging from SCUBA diving and snorkelling, to night fishing activities.

1.4.1 Coral mining

Coral mining is an important activity in Maldives having long lasting impacts on reefs. Coral is virtually the only building material available in the country and coral mining is widespread. The demand for coral has increased at an enormous rate during the last decade owing to increased development in the country. Recent studies had led to concerns over the sustainability of the reefs subject to coral mining activities (Brown and Dunne 1986, 1988; Brown *et al.* 1990).

Uses of corals

Corals are mainly exploited as a building material in Maldives. Massive coral boulders are collected from reefs, crushed by manual labour into small irregular pieces and lime, cement or concrete is used to bond the coral pieces together to form walls and other building structures.

Groynes, solid jetties, breakwaters and seawalls which are common features in many resort islands as well as in some local islands are also constructed from corals. Huge amounts of coral are used for the construction of these artificial maritime structures.

Another minor use of corals is in the making of lime. For many islanders it is cheaper to produce lime locally than buying imported cement. Coral and coral debris collected from the reefs are burned in a pit in the ground with locally available firewood. The coral rock is converted to lime by the high heat treatment and can then be used to bond coral pieces together to build houses and other constructions.

To a minor extent corals are used as ornaments and jewellery (black corals) and for decorative purposes.

Methods of Coral Mining

Mining methods and techniques are manual, crude and labour intensive. Having chosen a suitable reef the miners travel to the site on a dhony (a wooden boat). Mining starts from the inner edge of reefs. Massive corals are broken up with iron bars to manageable sizes. Some massive corals may be small enough to be mined without breaking up. The corals are lifted by hand on to the waiting boat and when the boat is full it is carried to the required destination. The coral lumps are left in the sun and rain for a period of time to dry out and clean by themselves.

Coral Mining Areas

Until quite recently corals were usually mined from the lagoon and reef flats of island 'house reefs' (the reefs around islands). In many islands the reef is reasonably close to the island and it is simply a matter of collecting and loading a small boat to carry the corals to the island. Current regulations do not allow coral mining on island house reefs.

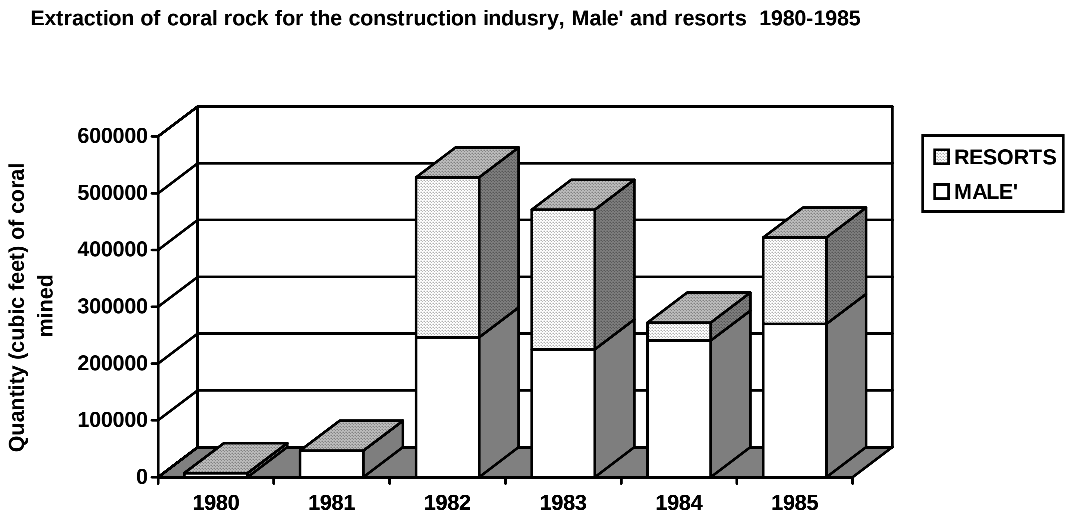
People who mine corals as an income generating activity choose shallow ring reefs (locally known as faros), of easy access to mine corals. Mining is carried out at the rims towards the inside of the reefs at a depth of 1-2 meters. In atolls with few ring reefs, it is more common to find mining carried out at the lagoon side of outer atoll rim reefs. The collection of living coral rock has in general extended to outer atoll faros. In some instances these are important for the protection of islands against storms.

Trends in Demand for Corals

With the increased pace of development in the country especially in Male' Atoll, the demand for coral rock for construction works is at its limit now. Demand has increased greatly during the last decade and is increasing.

Fig. 2 shows the quantities of corals mined in Male' Atoll in the period 1980-1985. Figures are not available for the whole country for the amounts of coral mined. Recent government regulations however require all islands in the country to keep records of the amounts of coral mined on a regular basis.

Figure 2. Quantities of coral mined in Male' Atoll in the period 1980-1985.

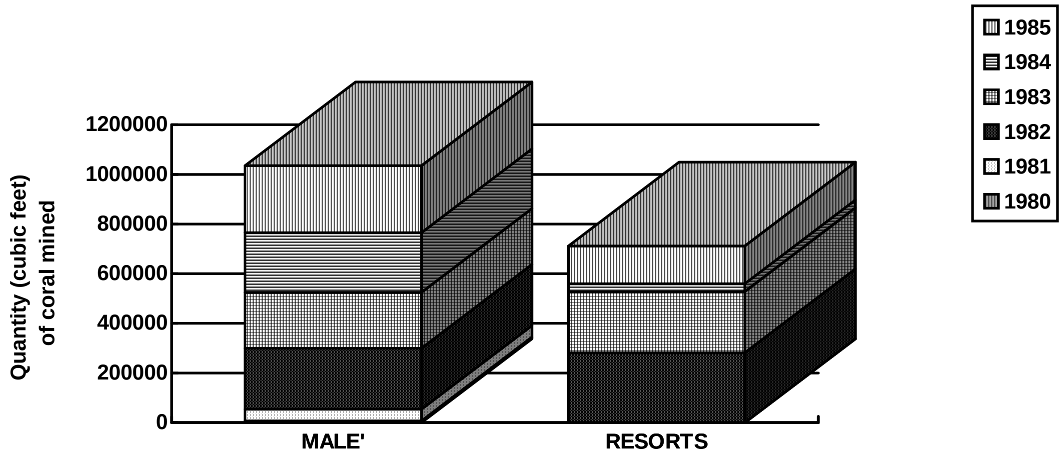


Reproduced from: Brown, B.E. & Dunne, R.P. (1986)

The extraction figures for coral mining given by Brown & Dunne (1986) showed that corals were been mined at the rate of 0.5 million cubic feet per year. This figure was based on quantities from only Male' Atoll and is likely to be much higher for the entire country. Approximately 1.8 million ft^3 of coral were mined in Male' Atoll in the period 1980-1985 (Figure. 3).

Figure 3. Total coral mined in Male' Atoll in the period 1980-1985

Extraction of coral rock for the construction indusry, Male' and resorts 1980-1985



Reproduced from: Brown, B.E. & Dunne, R.P. (1986)

There are many problems associated with the current mining practices. The demand is probably at its limit now and according to predictions made by Brown and Dunne (1986), the current methods of mining would exhaust the coral building materials in N. Male' Atoll within a maximum of 30 years.

Mining as a Commercial Activity

Coral mining is not a significant and widespread commercial activity except for one or two atolls in the country. Mining is carried out at a minor scale primarily for local needs in many of the atolls.

Large scale commercial mining is only practised in at one atoll just adjacent to Male' Atoll. In this atoll, (Ari Atoll) in two islands in particular (Fenfushi and Maamingilli), coral mining represents a major income generating activity. They work under contracts for the Male' construction industry, tourist resort islands and also for many other atolls country wide. Recent harbour improvement projects in many atolls of the country had led to an increase in the demand for corals for harbour wall constructions. Fenfushi and Maamingilli island miners work under contracts for these harbour improvement projects too.

In the early eighties the cost of coral rock varied between Maldivian Rufiyaa (Rf) 0.33-1.10 per cubic feet. A typical size dhony load is approximately 200 ft^3 and therefore would cost between Rf 66-220 (10Rf ≅ 1US$). A group of miners working 8 hours a day can mine 1-3 dhony loads of corals. This really depends on the availability of corals, the reef structure, the use for which the corals are mined for, and the distance of the reef to the construction area. They can in general earn up to Rf 20,000 for a month for a single group of miners. In most cases this figure can be still higher. The current prices of corals are much higher and varies between 500.00 - 600.00 Rf for 200 cubic feet.

Clearly coral mining forms an important source of income at least for a few atolls. The government is aware of the financial loss of income to these miners in attempts to seek for alternatives for coral mining and is at the same time concerned about the level of current increases in the scale of mining activities.

1.4.2 Reef fishing

Traditionally Maldives had been a tuna fishing nation. There is however some fishing of demersal reef associated fish. A reef fish resources survey carried out in the Maldives from 1986-1992 gave estimates of potential yields of reef fish from three major areas of the Maldivian atolls (Table 2). The total annual yield of commercially valuable reef fish species is estimated at roughly 30,000 ± 13,000t (Anderson *et al*. 1992). This estimate of potential yield is much greater than current catches of demersal reef fish (5,000-11,000 t per year) and the conclusion was therefore that the reef fish resources of the Maldives are underfished.

For the period 1983-1987 the annual catch reported as reef fishes in the Maldives ranged from 5,000-11,000 tonnes, constituting 5.7-9.4% of the total value of marine products exports (Brown *et al.* 1990). Reef fishing is a more significant activity in Male' Atoll due to availability of markets in the atoll (Male' market and tourist resorts).

Table 2. Estimates of potential yields of reef fish from three major areas of Maldivian atolls. (From Anderson *et al.* 1992)

	Estimates of annual maximum yield (t)		
	Mean	Lower	Upper
Atoll basins	24,000	13,500	36,000
Reef areas	5,250	3,500	7,000
Deep reef slopes	500	400	600
TOTAL	30,000	17,000	43,000

Apart from demersal reef fish, there are several other reef-associated resources that are exploited in the Maldives (Anderson *et al.* 1992). These include big eye scad (*Selar crumenophthalamus*), sharks (*Carcharhinus albimarginatus, C. amblyrhynchus, Loxodon macrorhinus, Stegosoma varium*), livebait (*Spratelloides,* Caesionidae, Apogonidae), aquarium fish, turtles.(green and hawksbill turtle), sea cucumber, giant clam (*Tridacna squamosa, Tridacna maxima*), lobster (*Panulirus* sp), black coral (*Antipathes*) and mother of pearl (*Pteria, Atrina*).

Widespread fishing of reef dependent species to large extents recently had led to concerns over the depletion of stocks. The giant clam (*Tridacna squamosa*) fishery which started in 1990 increased and spread rapidly through many atolls. A study of the fishery has led to concerns over the sustainability of the stocks. As a result of these concerns licences for the export of giant clam was terminated in 1991, effectively stopping the fishery (Anderson *et al.* 1992). Furthermore the practises of exploitation of some species in particular (giant clam, lobster, sea cucumber) indicate prominent ecological disturbances to reefs. Fishermen claim that baitfish become scarce in areas of sea cucumber fishing. This is apparently due to a toxin released by the animals (sea cucumbers) in the process of fishing which kills or disturbs the habitat of baitfish. The methods of fishing for lobsters and harvesting of giant clams can cause mechanical damage to reef corals.

1.4.3 Bait fishing

Baitfish caught for the tuna fishery, represent the only reef resource exploited on an comparatively large scale in the Maldives (Maniku *et al.* 1989). Baitfish are composed of reef associated species which are dependent on a thriving reef environment. They are collected at the reef edge and include species which require the intricate habitat provided by the coral reefs. Baitfishing methods were described by Maniku *et. al*. (1989).

The tuna fishing industry in Maldives depends on the availability of suitable bait which are collected in large quantities from shallow submerged reefs. The long term continuity of the tuna fishing industry thus depends on healthy reefs. The total annual catch of livebait may be of the order of 5000 tonnes (Anderson *et al.*, 1992). The main varieties of baitfish caught are silver sprat - *Spratelloides*, juvenile fusilier - Caesionidae, and cardinal fish - Apogonidae (Anderson, 1983,1984; Rasain Newsletter, No. 2).

The practices of bait fishing are not destructive to reefs (Maniku *et al.* 1989). There is an indication that bait fish abundance are low on disturbed or stressed reefs. Fishermen suggest that bait abundance, particularly that of *Spratelloides.gracilis*, has decreased over the years (Maniku *et al.* 1989). Reef fishing activities, long-term weather changes, collection of black corals and, more recently, the collection of sea cucumber has been suggested as the possible causes. Baitfish appear to be possible indicator species which can be employed in assessing reef conditions.

1.4.4 Tourism

Tourism started in the Maldives in 1972 and is now the largest industry in the Maldives. In 1972 only 1097 tourists visited Maldives. This figure has increased to over 200,000 by 1992 (Statistical reports from Ministry of Tourism). Except for two years (1983 and 1986) the rate of visitor arrivals have always increased steadily during the last 20 years. The number of resorts has also increased over the years and there are over 70 resort islands concentrated in two atolls. Tourism is a major source of revenue to the country. In 1991 revenue from tourism accounted for 26.2% of the country's total revenue for the year.

Tourism also represents the most important use of reefs in areas developed in the country for tourism. The major attraction of tourists to Maldives is undoubtedly the beautiful unspoilt underwater reefs with colour, vigour and activity and the crystal clear waters. Hence almost all entertainment in the resort islands is centred around the surrounding reefs and lagoons. Diving is the most important activity in any resort island. Visitors not fortunate enough to participate in diving activities enjoy underwater views by snorkelling over the reef flats and on the slopes. Many resorts also conduct guided night fishing (for reef fish) to various patch reefs. Healthy reefs with diverse life are essential for the well being of the tourism industry in the Maldives.

1.5 Impacts on reefs in Maldives

Coral reefs all over the world are undergoing varying degrees of changes due to increasing amounts of pressures on them. More and more people are depending on reefs for a living. Reef exploitation patterns are very varied. The external pressures on reefs fall under two categories: Natural and man-made. Natural events that have adverse impacts on reefs include coral bleaching, Crown-of-thorns starfish (*Acanthaster planci*) infestation and storms. Human impacts are more complex and widespread. Most human impacts on reefs represent chronic stresses and are more complicated than the episodic natural stresses. The major human impacts include organic and inorganic pollution (mainly from sewage), sedimentation and over-exploitation. Concern has also been raised about the potential effects of global warming and sea-level rise on coral reefs.

Not much quantitative information is available to assess the impacts on the reefs of Maldives. But much work has been carried out to determine the impacts of reef degradation, especially coral mining, on reef condition and reef associated fisheries (Brown and Dunne, 1986,1988; Brown *et al.* 1990) An account of potential sources of marine pollution in Maldives was given in UNEP REPORT No. 76. Shakeel *et al.* (1990) investigated pollution levels in Maldivian fishery harbours. The Marine Research Section of Maldives carried out many surveys to assess and monitor the extent of damage to reefs by *Acanthaster plancii* (COT Newsletters, Nos. 1-16). Studies and reports have been produced to highlight the possible consequences of global warming and sealevel rise (Edwards, 1989; Wells and Edwards, 1989; Small States Conference on Sealevel Rise, 1989). A study was conducted by the Environment Section of the Ministry of Planning and Environment to address the environmental concerns in the tourism sector (Environmental Protocol, 1992).

In order to draw management guidelines and strategies, it is necessary to determine the impacts on reefs. Practical research and continuous monitoring of reefs are urgently required for Maldives to establish the extent of human and natural disturbances to reefs in the country.

1.5.1 Man made

By far the greatest threat to reefs are man-made. Accounts of disturbance to reefs by human activities are reported widely (Brown & Holley, 1982; Brown and Dunne, 1988; Brown *et al.* 1990; Bak, 1978; Craik & Dutton, 1987; Grigg & Dollar, 1990; Loya, 1979; Pastorok & Bilyard, 1985; Shepherd *et al.* 1992; Tomascik & Saunder, 1987; Cortes and Risk, 1985; Loya, 1975; Maragos *et al*. 1985; Rogers, 1990; Supriharyono, 1985).

The coral reefs of the N. Male Atoll are affected by human interference in manifold ways (Preu & Engelbrect, 1991; Environmental Protocol, 1992). Corals are mined on reefs located close to Male' and resorts. Coral reefs fringing holiday resorts and local islands have been dredged to provide navigation channels and harbours (Preu & Engelbrecht, 1991). Damage to reefs also result from divers and from anchors of boats.

Sewage and water are discharged from Male and holiday resorts into the sea (Preu & Engelbrecht, 1991). The high concentration of shipping traffic around resorts has drastically increased the discharge of oil from boats. The consequent reduction of water quality may affect the growth rate of corals.

Man-made impacts on reefs are complex and widespread, of which some common aspects related to Maldives will be described in the following sections.

1.5.1.1 Coral mining

Coral mining represents the most important threat to the reefs in the Maldives. Population growth, and increased wealth from tourism and the fishing industries, has created a steadily increasing demand for building materials in the form of coral nodules and sand.

The biological and physical impacts of coral mining on reefs in Male' Atoll, Maldives were investigated by Brown and Dunne, (1986;1988). They reported that live coral cover on reefs subject to coral mining was very low compared to unmined reefs (Fig. 5). Response of reef associated fish to coral mining was reported by Shepherd *et al.* (1992) and Brown *et al* (1990). Fish community structure was compared on mined and non mined reef flats and their adjacent slopes. Abundance of reef fish was found to be low on mined reefs compared to non-mined reefs.

Biological surveys of mined sites, indicate that coral diversity and abundance were decreased dramatically. In addition to this, little recovery was seen at sites intensively mined over 16 years ago. Of particular concern is not only the apparent failure of mined reef flats to recover but the consequent loss of both coral and associated reef fish resources to the economy (Brown *et al.* 1990).

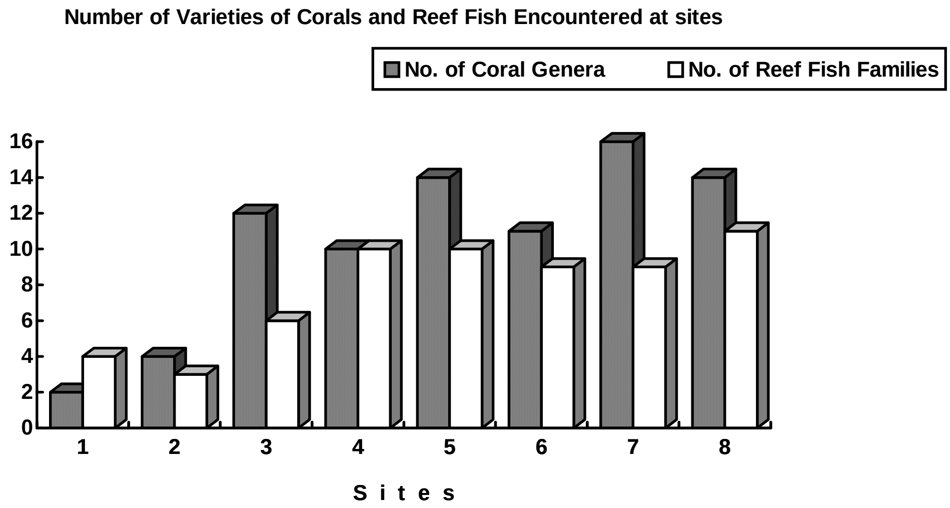
Coral mining is highly destructive and is carried out at a high cost to the reef environment with a very small return of corals as building material. It is estimated that 1 ha of reef flat corresponds to 3000m^3 of coral rock (Brown *et al*. 1990). Assuming that approximately 10m^3 of coral aggregate are required to build an average local house (20-30m^3 for two to three storey buildings), 80m^3 to construct 8 groynes of 10x1x1m each, at a tourist resort island, it is not difficult to estimate how much it takes to destroy 1 ha of reef flat. Coral jetties, groynes and seawalls are common structures in many resort islands as well as in local islands.

Biological Impacts

Coral mining represents a questionable activity for the maintenance of the reef equilibrium. Brown and Dunne (1988) indicated clearly the high disturbances to the reef ecosystem. Even though the targeted species were usually massive corals, the process of mining disturbs many other coral species in the area primarily as a result of trampling and sedimentation. Mined areas of the reef are simply wiped out. However, it must be noted that the effects are very localised on the reef itself. Mining is carried out only at the reef flats and hence there is little effect at the slopes of such reefs.

Diversity of corals, live coral cover and resident reef fish abundance was very low at mined sites. The main coral species collected by miners consist of *Porites lutea*, *Goniastrea retiformis* and *Platygyra lamellina* (Brown & Dunne 1986). Fig. 4 shows the families of reef fish and numbers of coral genera encountered at 8 sites (Table 3) as observed by Brown and Dunne (1986).

Figure 4. Numbers of coral genera and reef fish families encountered at mined and non mined sites (From Brown and Dunne 1986).



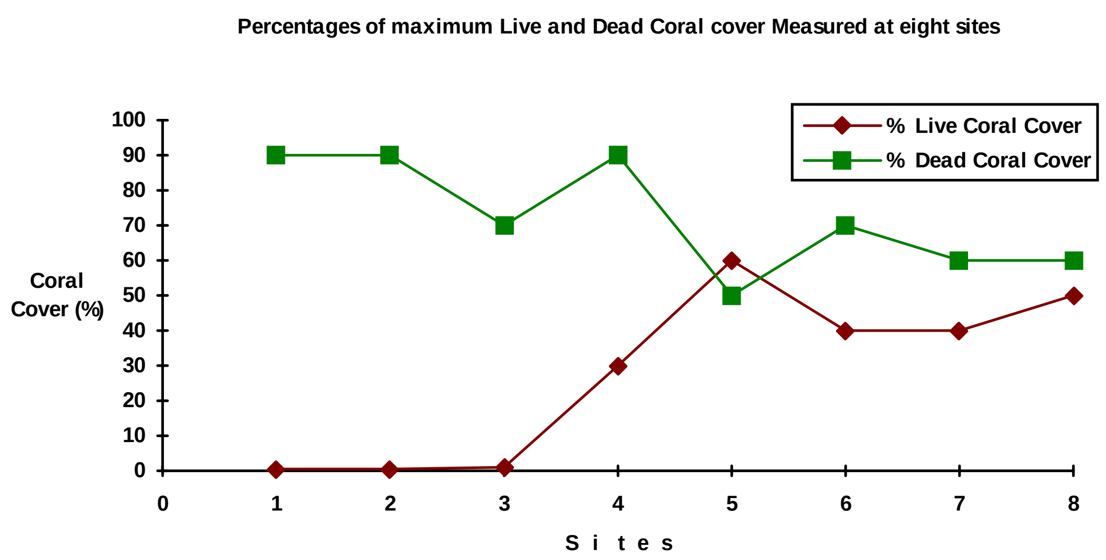
Rehabilitation and recovery of reefs subject to mining activity was found to be extremely low. The main reason for this was due to the chronic substrata disturbances which resulted from the mining procedures. Rubble mobility, mechanical abrasion and higher water-movement which result from the mining activities, limit successful larval settlement (Brown and Dunne, 1988). Sites, which have been mined at least 16 years ago, showed very low coral cover (approximately 0.5% total cover). A site which was mined 5 years ago showed very low coral cover (1%), as well. The indications are that mined reefs take a very long time to recover.

Table 3. Summary of the Histories of Sites Visited in North Male' Atoll. (From: Brown and Dunne, 1988)

Site No.	*Description*	*History*
1	Submerged reef N.Male' Atoll	Used for coral mining at least 16 years earlier
2	Submerged reef N.Male' Atoll, S.Kuda Bandos	Used for coral mining at least 10 years earlier
3	Submerged reef N.Male' Atoll, N. Villingili	Used for coral mining in recent years
4	Submerged reef N.Male' Atoll	Control: not used for coral mining
5	Submerged reef N.Male' Atoll	Control: not used for coral mining
6	Submerged reef N.Male' Atoll	Control: not used for coral mining
7	Submerged reef N.Male' Atoll	Control: not used for coral mining
8	Submerged reef S.Male' Atoll	Control: not used for coral mining

Live coral cover was greatly reduced at mined sites as observed by Brown and Dunne (1986). Fig. 5. shows the live and dead coral cover at 8 sites (Table 3) examined by Brown and Dunne (1988).

Figure 5. Percentage live and dead coral cover recorded at mined and non mined sites (From: Brown and Dunne, 1986).



It is known that the growth rate of massive corals such as *Porites*, is extremely low (Porter, 1974). Hence the removal of such corals will have long term consequences on the diversity of reefs with a long recovery time. There may be many factors affecting growth of corals on mined areas as a result of alterations in conditions such as light, sedimentation, wave energy, nutrients and degree of exposure.

Brown *et al* (1990) reported that mined reef flats had a significantly lower presence of fish. A visual census of mined and non-mined reef flats showed 60% reduction of fish species at mined sites. There was a positive correlation between rugosity index and diversity and biomass of fish. Coral mining on reef flats resulted in low rugosity (structural complexity) and, consequently, lower diversity and biomass of fish.

The effects were more evident for corallivores (*Oxymonacanthus longirostris, Chaetodon trifasciatus, Chaetodon triangulum*), and benthic herbivores and aquarium fish (*Acanthurus leucosternon, Oxymonacanthus. longirostris, Pygoplites diacanthus*).

The reduction of corallivorous species is explained by the destruction of corals, which are their primary food source and a retreat for them as well. Benthic herbivores use the reef structure in order to find shelter from predators. Common species of aquarium fish declined because of the loss of habitat. The abundance of bait fish *Chromis atripectoralis* was also reduced at the mined sites, possibly as a result of loss of shelter in the area and reduced abundance of zooplankton. It is thought that bait stocks, principally the baitfish *Chromis atripectoralis*, may be affected by habitat disturbance. The schools of bait fish live close to coral reefs, where they find food and protection against predators.

If livebait supply is reduced by habitat disturbances due to coral mining, the tuna fishery may be severely affected. The supply of bait fish is essential for the pole and line tuna fishery, which is important for the economic and social well being of Maldives.

Physical Impacts

Physical impact of coral mining depends on the type of reefs in question. No immediate effect may be observed with coral mining at an isolated ring reef. However if house reefs of islands are subject to mining activities there may be adverse effects. Island house reefs act as physical barriers, protecting the coral islands against wave action, by dissipating most of the energy in the incoming waves before they reach the beach line. Mining corals from the reef flats effectively remove this physical barrier and leave the islands prone to increased wave action, swells and storm surges and consequently beach erosion. The sediment dynamics of coral islands may be altered too as a result of altered flow regimes.

1.5.1.2 Dredging and reclamation

Dredging and reclamation work had been going on in the country for years. These activities have increased at a faster rate during the last decade. Harbours and port facilities had been proposed in all major atolls under a five year programme of development in the country. There are many on-going harbour projects in many atolls.

The islands where the shore line has undergone the greatest change in the country are perhaps Male' (the capital) and Hulhule (the airport). Reclamation in Male' and Hulhule began in as early as 1954 and 1968 respectively (Maniku, 1990). Dredging at various scales had been going on in Male' for almost a century (Maniku, 1990). Dredging of Male' lagoon using a mechanical grab mounted on a pontoon began on 14 March 1908 and this dredger, with modifications continued to work until the arrival of suction dredgers on the scene (Maniku, 1990).

The government in an attempt to enhance development in the country has identified approximately 75 islands whose harbours are in need of deepening. The government feels that in these islands development has been impeded because their shallow harbours makes it impossible for the local fishing boats and other vessels to enter the harbour basins and moor within them at all stages of the tide. Consequently fish spoilage and increased transport costs are a frequent occurrence. Safety of the boats are also considered to be of grave concern. The Deepening of Island Harbours Project was initiated on the 5th of May 1985. There are a number of projects ongoing in the country now on deepening of island harbours by dredging (Table 4). It has been estimated that it will take more than 18 years to complete the work.

Table 4. Dredging projects (completed and on-going) in the Maldives. (Source: Ministry of Public Works and Labour).

COMPLETED PROJECTS

ATOLL	ISLAND	METHOD EMPLOYED	STARTED	COMPLETED	AREA DREDGED (sq.ft.)
Haa Dhaal	Kulhuduffushi	Dredger/Excavator	5-Aug-1985	13-Apr-1990	629,000
Male'	Maafushi	Dredger/Excavator	1-Sep-1989	7-Jan-1990	46,400
Lhaviyani	Naifaru	Excavator	14-Feb-1990	31-Dec-1990	237,754
Gaaf Alif	Villingili	Excavator	29-Nov-1987	26-Mar-1991	175,000
Gaaf Dhaal	Thinadhoo	Dredger	26-Mar-1988	30-Jul-1991	251,182
Male'	Feydhoofinolhu	Excavator	21-Apr-1991	31-Dec-1991	-
Haa Alif	Ihavandhoo	Excavator	14-Apr-1990	2-Apr-1992	141,500
Lhaviyani	Hinnavaru	Excavator	17-Jan-1991	26-Jun-1992	181,500
Gaaf Dhaal	Gadhdhoo	Excavator	28-Mar-1991	5-Dec-1992	134,000
Laamu	Maabaidhoo	Excavator	24-Mar-1990	10-Jan-1992	112,000

Table 4, contd..
ON-GOING PROJECTS

ATOLL	ISLAND	METHOD EMPLOYED	STARTED	EST. DATE OF COMPLETION	AREA DREDGED (Sq.ft.)
Thaa	Thimarafushi	Excavator	10-Aug-1991	May-1993	150,000
Seenu	Hulhudhoo	Excavator	15-Aug-1991	July-1993	190,000
Kaafu	Himmafushi	Excavator	4-Jan-1992	June-1993	200,000
Laamu	Fonadhoo	Excavator	13-Jan-1992	Mar-1995	550,000
Noonu	Velidhoo	Excavator	2-May-1992	Apr-1994	275,000
Shaviyani	Komandoo	Excavator	3-May-1992	Jan-1994	175,000
Seenu	Hithadhoo	Dredger	3-June-1992	Mar-1994	850,000
Lhaviyani	Madivaru	Excavator	26-Oct-1992	Jul-1993	120,000
Gaaf Alif	Kolamaafushi	Excavator	6-Dec-1992	May-1994	240,000

The consequences of dredging and sedimentation on coral reefs were reported by many studies (Amerson and Shelton, 1976; Bak, 1978; Brown *et al.* 1990; Cortes and Risk, 1985; Craik and Dutton, 1987; Grigg and Dollar, 1990; Rogers, 1990; Sheppard, 1980).

Military occupation and construction for 40 years in Johnstone Atoll, (Central Pacific) so altered the physiography of the islands that little of the original habitat types remain (Amerson & Shelton, 1976). Dredging operations in 1964 destroyed over 1000 acres of reef. Dredging itself destroyed 700 acres of living coral. The reduction in % of living coral in these silty water areas varied from none to 40% with 10% being an average figure.

Cortes & Risk (1985) reported that the coral reef at Parque Nacional Cahuita, Costa Rica, showed low live coral coverage, species diversity and attributed this to sedimentation and siltation. They found that the amounts of suspended and re-suspended particulate matter was very high and large amounts of terrigenous material was found to be trapped inside massive corals. Coral growth rates were low and was inversely correlated with sediment suspension rates.

Bak (1978) observed that underwater light values at a depth of 12-13m were reduced from about 30% to less than 1% surface illumination in a dredging event on the south west coast of Curaçao. Colonies of coral species which are insufficient sediment rejecters (*Porites astreoides*) lost their zooxanthellae and died. Calcification rates in *Madracis mirabilis* and *Agaricia agaricites* were observed to be decreased by 33%.

Dredging possibly influenced the growth rates of corals in 3 ways (Bak, 1978):

a) Through decreased light values to marginal conditions.
b) Through stimulation of the energy consuming sediment rejection behaviour of the coral polyps.
c) Through the probably unfavourable influence of the suspended sediments and sediment rain on the planktonic food supply of corals.

A new development observed in Maldives, during the last few years has been an increase of dredging activities in tourist resort development. Dredging for harbours, beach nourishment and removal of seagrass in the lagoon are becoming increasingly common in many resort islands. No studies had been carried out to determine the extent on damage to reefs as a result of such activities.

In order to establish the scale of disturbances to reefs in Maldives as a consequence of dredging and reclamation activities, urgent research and monitoring of specific sites are necessary. The widespread nature of dredging activities in the country is a consequence of lack of management guidelines and planning in such development activities. The environmental awareness created by coral mining studies (Brown and Dunne, 1986;1988) in the country is a clear example of how effective research can lead to corrective measures on environmental aspects.

Urgent practical research and revelations on the extent on damage resulting from dredging could perhaps lead to better management planning in the future.

1.5.1.3 Maritime structures

The building of artificial maritime structures such as jetties, groynes, seawalls and causeways all are known to have a bearing on the reef environment to such an extent that large scale coral deaths can result. Main islands of three atolls (Laamu, Gaaf Dhaal and Seenu) had been linked by solid causeways (Maniku, 1990). Three islands (Fonadhoo, Maandhoo and Kadhdhoo) in Laamu Atoll were linked by causeways in 1986. The islands, Fares and Maathodaa in Gaaf Dhaal Atoll were joined by causeways in 1981. The 20 year old causeways linking 5 islands of Seenu Atoll had received much concern recently. Recent surveys in Addu has shown severe deterioration of reef condition and erosion in the islands. Fishermen blame the causeways for the scarcity of tuna bait in Seenu Atoll. Although no quantitative biological observations had been made, it is well established that apart from visible erosion of beaches the reefs in the areas have deteriorated as a result of the construction of causeways.

Similar problems have been observed in islands where jetties, groynes and seawalls had been constructed. Again little information is available on the extent of impact on reefs. It is however well established that such structures if not designed properly could severely interfere with sediment flow regimes between island house reefs and beaches and also alter current and flow patterns in the areas.

Each holiday resort has a long jetty (upto 150m) to provide landing facilities for boats with significant draughts outside the 5m coral platform. These jetties are mainly concrete walls and have little or no flow through them. The same is true where groynes have been constructed to keep sand at deliberated locations on islands. Many holiday resorts in Maldives have constructed groynes to this effect.

1.5.1.4 Anchoring

Anchoring of boats on reefs pose a potential threat to coral reefs and is of great significance to a country such as the Maldives where the main mode of transport is by sea. The problem is more acute in tourist resorts where the diving school feels very strongly about the destruction of reefs around the island. Indiscriminate anchoring on reef areas is common and can destroy large areas of corals especially branching acroporids. Some resort islands have already provided mooring buoys to prevent anchoring on their island house reefs. Practical solutions such as this are not always easy options unless threats are seen and effects are acknowledged.

It must be recognised that anchoring must have had its impacts on reefs in all the atolls of the country for as long as the islands have been inhabited although the rate of damage may be increasing rapidly with the increase in the number of boats. The problem when looked at realistically depends on the type or formation of the island in question. Some islands have a deep and wide natural lagoon which is used as a natural harbour and in such cases there is no impact on the reef except perhaps from the occasional fisherman. On the other hand there are islands where there is no suitable lagoon for anchoring of boats and the only option is to drop anchor on a reef close by.

It is considered by virtually all the tourist resort dive operators in Maldives, that unrestricted anchoring damages the reef (COT Newsletter, No.13). Severe damage to coral communities were observed in Virgin Islands National Park as a result of anchor damage (Rogers, 1988). Continual anchoring overturned coral heads over an extensive area. Anchor damage is an important factor which causes reef damage in Thailand (Sudara and Nateekarnchanalap, 1988). They noted that coral damage by anchoring is the cause of reef destruction in many newly opened resorts.

1.5.1.5 Tourist activities

Tourism is a multi-faceted and rapidly developing activity in many parts of the world. Five broad sections of the tourist industry might be identified: attractions, transport, accommodation, supporting facilities and infrastructure (Pearce, 1985).

Tourism has developed in the world in a wide ranging environments from small tropical islands to vast mountain ranges, from rural communities to large urban areas. Many of the areas which appeal to the tourists are characterised by complex and often vulnerable environments such as coral reefs.

Factors which attract tourists to a given area are many and varied. Coral reefs in tropical areas appear to be a major attraction of tourists for many purposes. Transport, accommodation, supporting facilities and infrastructure development takes place at a rapid pace in such areas.

Taken together the relationships between tourism and the environment are usually rather complex and the implications are that tourism has the potential to give rise to a very wide range of environmental impacts. The importance of tourism and environmental research has been reviewed by Pearce (1985).

The building, management and everyday running of resorts in the Maldives is directly related to the reef around the island. The marine environmental problems associated with the resorts are very complicated indeed. Groynes are built to hold the beaches in front of the bungalows at the expense of erosion elsewhere along the coast of the island. Harbours are dredged and jetties and seawalls are built as associated facilities. The environment around the island is modified to varying extents depending on the type of island.

Diving, snorkelling and other recreational activities can have a bearing on the island house reef as well as on the reefs in the vicinity.

In most resorts solid and liquid wastes are disposed of at sea (Environmental Protocol). It is not uncommon to see the outlets from the septic tanks discharging on to the back reefs of the islands.

The long term survival of the tourism industry in the Maldives depends on healthy reefs. Long term monitoring and research can help us to determine the impacts on reefs as a result of tourist activities.

1.5.1.6 Pollution

Marine pollution is not a widespread problem in the Maldives. Pollution, mainly from sewage and disposal of solid wastes is highly localised in developed atolls. The impacts, if any, on coral reefs as a result of pollution events are not known. There are no chemical industries or other sources of industrial pollution. The major form of pollution is organic, mainly from discharge of untreated sewage. This is a problem mainly in Male', the capital, where a sewer had been built to collect wastewater centrally. In Male', there is no treatment of sewage. Sewage is directly discharged into the sea from 6 outfalls by 9 pumping stations (Sewage and solid waste treatment and disposal study.1990). Raw sewage is not discharged directly into the sea from any other island at least in a quantity to be concerned about. In most islands the common method of sewage disposal is via septic tanks. There is room for concern about wastewater disposal practices at some resort islands (Environmental Protocol, 1992). Apart from Male and resorts there are no islands or atolls where sewage is a major problem.

A study of pollution problems in Maldivian Fishery Harbours (Shakeel *et al.* 1991) concluded that Male' harbour was contaminated with coliform bacteria of human origin (Table 5). High BOD values were also observed in Male' harbour. Characteristics of seawater from Male' harbour are shown in Table 6.

Table 5. Coliform organisms per 100 ml of water sample taken from Male' harbour. TNTC = Too numerous to count. (From: Shakeel *et al.* 1991)

DATE	COLIFORM GROUPS	SAMPLE LOCATION			
		1	2	3	4
7-9-1991	Total	120	TNTC	TNTC	40
	Faecal	122	TNTC	TNTC	0
22-9-1991	Total	120	96	140	12
	Faecal	532	0	4	348

Marine investigations around Male' have identified two effects of the sewage discharges that cannot be regarded as insignificant (Sewage and Solid Waste Treatment and Disposal Study 1990). It was stated in the study that levels of *E. coli* bacteria at the reef edge down stream of the outfall exceeded current EEC standards. Ecological surveys reported in the same study indicated that the corals at the north coast of Male' were exposed to an increased siltation stress and attributed this partly to sewage outfalls around Male'. The sediment traps showed high organic content. It was also pointed out that a number of other sources can contribute to the observed sedimentation.

Table.6. Physical and chemical analysis of sea water samples from Male' harbour. (From: Shakeel *et al*. 1991)

Characteristics	Sample Location		
	1	2	3
Colour	-	-	-
Odour	-	-	-
Turbidity	Clear	Clear	Clear
Temperature, °C	26.0	26.0	20.0
PH	8.0	8.2	7.8
Dissolved oxygen, mg/L	5.0	5.2	5.0
BOD (5 days, 20 °C), mg/L	250.0	100.0	100.0
Settleable solids, mg/L	0.0	0.0	0.0
Total solids, mg/L	41322.0	41678.0	41351.0
Total dissolved solids, mg/L	41029.0	41447.0	40679.0
Suspended solids, mg/L	293.0	731.0	672.0

It must be noted that although untreated sewage is discharged over the reef in Male', the extent of damage to the reef around Male' cannot be solely attributed to sewage pollution because of other related impacts such as dredging and reclamation. Long term monitoring of selected reefs may give a clearer picture of the extent of organic pollution resulting from sewage discharges on reefs.

Many studies have demonstrated that adverse environmental conditions such as sewage and eutrophication may have a detrimental effect on coral growth. (Grigg and Dollar, 1990; Tomascik & Sander, 1987; Pastorok and Bilyard, 1985). It is suggested that reduction in reproductive activity may be attributed to turbidity associated with eutrophication processes (Tomascik & Sander, 1987). Turbidity may affect reproductive biology through reduced light levels, and hence a reduction of zooxanthellae, photosynthesis, and/or high suspended particulate matter concentrations, which will require additional energy expenditure for cleaning at the expense of growth of reproduction (Tomascik & Sander, 1987).

Sewage affects corals by nutrient enrichment, sedimentation and its toxicity (Pastorok and Bilyard, 1985). Some opportunistic algae are extremely sensitive to nutrient enrichment. Increase in algal cover leads to competition between corals and algae and ultimately large scale death of corals by smothering and overgrowth by algae.

Tomascik and Sander (1987) reported that coral colonies sampled from two polluted reefs contained lower numbers of larvae than colonies samples from a less polluted reef. They also stated that the sex ratio of 2:1 observed in a *Porites porites* sampled from a polluted reef may have resulted from rapid asexual reproduction (fragmentation), indicating that the mode of reproduction may be influenced by environmental stress conditions.

Such studies demonstrate the necessity to conduct physiological studies in order to understand causative factors behind reef deterioration.

1.5.2 Natural

Natural disturbances to coral reefs as a result of storms, hurricanes and *Acanthaster planci* predation and bleaching are well documented for many reefs world-wide (Brown and Suharsono, 1990; Brown, 1987; Glynn and D'Croz, 1990; Grigg and Dollar, 1990; Porter, 1972).

1.5.2.1 Storms

Storm frequency and severity is comparatively low in the Maldives and is of less significance in reef damage. Occasional surveys however do indicate storm disturbances. The low frequency and severity of storms in Maldives is due to its location. Tropical cyclones cannot form at latitudes less than 6-8° North or South of the equator.

Maniku (1990) reported on historical accounts of storms documented from the Maldives. In some instances islands have been evacuated as a result of severe damage. Natural disasters were quite common even before the Maldives started to be developed. Eight storms were reported including one in 1821 which washed away 2 islands and one in 1819 in which 12 islands had to be abandoned (Maniku, 1990).

More recent significant storms in the country were those in June 1987 and the storms which caused heavy damage in 1991 (COT Newsletter, No. 14).

Surveys carried out by the Marine Research Section indicated that some reefs in the northern atolls have been damaged by storms and supported little or no coral cover (COT Newsletter, Nos.11&13). It was also stated that storm damage was responsible for the demise of some table corals adopted by the Marine Research Section under a scheme to monitor reef health.

1.5.2.2 *Acanthaster plancii* predation

The Crown-of-thorns starfish (*Acanthaster plancii*) has been known from the eastern tropical Pacific since the early nineteenth century (Porter, 1972).

Acanthaster plancii outbreaks have been recorded as a major threat to reefs in the Maldives during the last decade. Quantitative information is available country-wide as to the extent of occurrence of Crown-of-thorns (Table 7 & 8). Quantitative information on the extent of damage is however not available in many areas. This is an area of ongoing research in the Maldives.

Table 7. Incidence of *Acanthaster plancii* for 111 sites examined in 1990. (Cot Newsletter No.12)

	NUMBER OF COTS SEEN				
ATOLL	0	1-9	10-99	>100	TOTAL
HAA ALIF	9	1			10
HAA DHAAL	3				3
SHAVIYANI	5				5
NOONU	3				3
RAA	6				6
BAA	5				5
LHAVIYANI	2				2
N.MALE'	8	5	1	1	15
S.MALE'	8	2			10
ALIFU	12	3			15
VAAVU	1	1			2
MEEMU	1				1
FAAFU	4	1			5
DHAALU	7				7
THAA	4				4
LAAMU	4				4
GAAF ALIF	2	4			6
GAAF DHAAL	-	5	1		6
SEENU	2				2

The first outbreak of Crown-of-thorns (COT) in Maldives was recorded in the 70's but soon died down (COT Newsletter, No.1). Severe outbreaks were again reported in the late 80's. Since then the Marine Research Section of the Ministry of Fisheries and Agriculture has monitored the situation closely. COT plagues of enormous proportions had been reported in COT Newsletter Issues. It appears that the problem is mainly concentrated in two atolls in particular (Male' and Ari Atoll) but there are also reports from other atolls. In some islands COT were collected in 1000's during the plagues (COT Newsletters). Reports indicated that most of the house reefs of the affected islands were killed and dead corals were covered in algae.

Table 8. Number of starfish collected at most affected resort islands. (Cot Newsletter, No.12)

ATOLL	RESORT	NUMBER OF COT
N.Male'	Ihuru	300
	Makunudhu	11400
	Nakatchafushi	18700
	Vabbinfaru	100

The reasons for COT outbreaks are not known. In some instances they have been connected to human actions such as sewage discharge and other forms of organic pollution (Birkeland, 1984). Most workers however believe that COT outbreaks are a natural phenomenon. An 11 year continuous observation of a reef in a resort island in the Maldives reported that the reef was severely degraded by COT in 1979. For the next 9 years until early 1988 there was no sign of COTS on the reef. In 1988 COTS were observed in plague proportions again (COT Newsletters). The fact that COT has been observed in atolls subject to relatively low levels of human impact may be further evidence that COT plagues are natural events.

1.6 Management structure

Coral reef management had rapidly developed in Maldives during the last decade or so. Studies have been commissioned to assess the status of the marine environment in order to draw management guidelines and strategies (UNEP Report, 76; Kenchington, 1985; Brown and Dunne, 1986; Brown *et al*. 1990; Environmental Protocol, 1992). The extent of damage to reefs as a result of coral mining, dredging, *Acanthaster planci* predation, potential pollution and tourist related activities has been recognised and the government is committed to coral reef research and management. By practical research and monitoring of reefs we can determine the cause of reef decline. Such research will also help in the decision making process to safeguard the reefs against ever increasing pressures.

1.6.1 Institutional arrangements

There are many sectors of the government which have a role to play in the management of coral reefs. The Ministry of Fisheries and Agriculture represents a focal point for many marine and fisheries activities. In 1984 the Marine Research Section was established within the Ministry of Fisheries. The objectives were to develop and manage research activities on fisheries and coral reefs.

The formation of a separate Ministry of Planning Environment in 1988 emphasises the commitment of the government towards marine environmental management. Other sectors of the government involved in reef management aspects include, The Ministry of Public Works and Labour, Ministry of Tourism, Ministry of Home Affairs, Ministry of Transport and Shipping and Maldives Water and Sanitation Authority.

1.6.1.1 Marine Research Section

The Marine Research Section (MRS) is a branch of the Ministry of Fisheries and Agriculture. Its main fields of activity include biological sciences, coral reef ecology, marine fisheries, resource management and information services (Rasain Newsletter, 1).

MRS was established with a mandate to undertake research in marine biology and fisheries, particularly the study of population dynamics of commercial fish, with an emphasis on management of the fishery. Fisheries research in coastal marine waters and reef conservation research are the two main functions carried out at present. It had played a central role in coral reef research and management during the last 10 years. Many research projects both local and foreign funded have been carried out on reefs. It represents the major institution in the country responsible for managing and carrying out research work on coral reefs.

The stated specific objectives of the MRS are as follows: (Rasain Newsletter,No.1)

1. To Carry out research and investigations in the field of fisheries science, including marine biology where appropriate, with the objective of resolving problems confronting the fishing industry, and of compiling a 'bank' of scientific information and data which will facilitate the development and management of the fisheries resources of the Maldives.

2. To undertake, where feasible, further marine research which will assist in the conservation, management and if necessary the enhancement of the marine environment generally and for fisheries exploitation in particular.

3. In the process of achieving the foregoing objectives, undertake the systematic collection, identification, cataloguing and storage of samples of the marine flora and fauna of Maldives waters as a readily accessible reference collection for scientific and other purposes.

4. To advise the Government, through the Minister of Fisheries, and members of the public on the status of the marine resource, its stocks, its environment and its needs for proper conservation and management.

5. To train students in fisheries and related sciences, including the training of government staff in particular.

6. To liaise with fisheries professionals and scientists throughout the world.

Major activities to date include tuna surveys, baitfish research, collection and identification of economically important fish species, stock assessment, reef fish research, coral taxonomy, effects of reef degradation on local reef fisheries, impact of crown-of-thorns starfish on coral reefs and more recently reef monitoring and rehabilitation of reefs subject to coral mining activities.

1.6.1.2 Environmental Research Unit

This recently formed branch of the Environment Section of the Ministry of Planning and Environment is responsible for co-ordination of all environmental activities in the country (Figure 6, Organisation table). It plays a central role in all marine and terrestrial environmental management as well as setting environmental standards and guidelines.

The Environmental Research Unit (ERU) is entrusted with carrying out all research work relating to the environment, and making available all relevant data for programming, planning, enforcing and regulating environmental matters.

The aims and objectives of the ERU are:

- to establish environment research capability within the country.
- Carry out research in all environment related fields in the country.

Figure 6. The organisational structure of the Ministry of Planning and Environment, Maldives.

- make available all relevant data and information to provide for sound environmental management in the country.
- Develop and strengthen the technical know-how and manpower in the field of environmental research and management.
- Create sound environmental awareness and knowledge within the public and government administration.

The Environmental Research Unit has played a central role in the formulation of recent environmental legislation and regulations regarding coral mining.

1.6.1.3 Other Sectors

As mentioned above there are other institutions which play various roles in reef management. They represent reef users in one way or another and therefore need to be part of the institutional structure in the formulation of management strategies.

The Ministry of Public Works and Labour undertakes most major locally managed government projects; most significantly, dredging and harbour construction projects. There are many ongoing dredging projects throughout the country for which it is responsible. The Ministry also undertakes coral mining for various projects. It is therefore not difficult to see the extent to which the ministry must play a part in the management process.

All aspects of tourism in the country are the responsibility of the Ministry of Tourism. For most purposes it has its own regulations. Permission for activities such as dredging and the construction of artificial maritime structures are required from the Ministry.

Male' Municipality is responsible for the management of all solid wastes in Male'. It also therefore has a role to play in the management of reefs in terms of pollution aspects.

The management and discharge of sewage and wastewater is undertaken by the Maldives Water and Sanitation Authority.

1.6.2 Management strategies and legislation

The complexity of management of reefs in the Maldives is evident from the last section. The institution undertaking most research is MRS while the ERU / Environment Section of MPE deals with most management issues.

To minimise the adverse effects of environmental degradation, a number of activities were initiated by various sectoral agencies of the government. However, an integrated environmental management plan was felt necessary to allow for the co-ordination and implementation of such activities. With the assistance of the United Nations Environment Programme and the United Nations Development Programme, a National Environment Action Plan was drawn up in 1989 (National Environment Action Plan, 1989). This is a document aimed at environmental management and planning in the Maldives. The directive principles of the Action Plan are:

- The continuous assessment of the state of the environment within the country, including the impacts of man's activities on land, in freshwater, in lagoons, reefs and ocean and of the effects of these activities on the quality of the human environment.

- The development and implementation on management methods suited to the natural and social environment of the country, which will maintain or enhance environmental quality, while at the same time utilising resources on a sustainable basis.

- The preparation and implementation of comprehensive national environmental legislation and participation in international agreements to provide for responsible and effective management of the environment.

- The strengthening of national capabilities, institutional arrangements and financial support which will enable the Action Plan to be implemented in an efficient and economic manner.

Under the Action Plan, the following marine environmental problems have been designated for immediate consideration.

- Coral mining
- Sewage contamination of coastal waters
- Sea level rise
- solid waste management
- dredging

The environment was given priority in developmental strategies (National Development Plan). The National Development Plan identified the following priorities for the environment in its development strategies:

- To ensure that all development programmes and activities are fully consistent with sound and prudent management and conservation of the environment and natural resources.

- To ensure that environmental impact assessments are prepared for all major capital investment projects, in both the public and private sector.

- To monitor carefully both global warming and impending sea-level rise, and assess their implications for the future of Maldives.

In June 1988, the government announced a decision to make environmental impact assessments mandatory for all major development projects. The outcome was the recently drawn up environmental legislation (Appendix A).

Current regulations regarding coral mining

The government is concerned about the environmental implications of coral mining. Prior to 1992 there were very few regulations as to where people could or could not mine corals. It was then simply a matter of protecting properties such as islands belonging to individual owners.

In 1992 new regulations were introduced to combat uncontrolled mining activities. The following regulations are now in effect in the country.

1. Mining is not to be carried out on island house reefs.
2. Mining cannot be carried out on atoll rim reefs and common bait fishing reefs.
3. Applications are required to be submitted to the atoll offices through island offices by any one needing corals to build any structures and permissions need to be granted by the atoll office before any mining can be carried out.
4. The island office is required to estimate the quantity of corals required for the applied construction work and hence should ensure that only the required amount is granted.

5. Every island is required to keep a log book of the amount of corals mined.

1.7 Discussion

Coral reefs are used extensively for many purposes in the Maldives. The economic successes of the two major industries (tourism and fishing) depends of healthy reefs.

Impacts on reefs as a result of economic development are considerable. Coral mining, pollution and tourism are the main impacts. The study of impacts of coral mining on reefs and reef associated fisheries in Maldives (Brown *et al.* 1990) has created widespread awareness and concern over reef management at various levels of the government. This is a clear example of the need for more practical research on impacts on reefs.

Maldives appear to have the right institutional arrangements to undertake reef research and management. It has a planning and environment ministry to formulate management strategies and planning in line with the environment and a research institute to undertake reef research. Skilled manpower shortages is perhaps one of the main drawbacks of current management planning.

The recent formulation of environment legislation and regulations on coral mining are signs that the government is taking the right direction on environmental matters. There are however areas which need more attention, particularly activities such as dredging. Applied research can lead to more effective management policies and contribute to development or conservation of the reef environment.

What is needed most urgently is a well defined national monitoring scheme to detect marine environmental impacts and to feed information into the management cycle. Coral reef monitoring is an important component of any management package. Monitoring schemes would record changes and enable assessments to be made of potential impacts.

Chapter 2   Coral Reef Monitoring - A Review

2.1 Introduction

While preparing for the United Nations 1972 Stockholm conference on the Human Environment, many governments began to realise that their environmental data banks were inadequate (Munn, 1980). Many questions, queries and trends in the changes regarding the environmental systems were difficult to answer without data. The major outcome of the Stockholm Conference in 1972 was therefore, the establishment of Earthwatch, and its components GEMS (Global Environmental Monitoring System).

An intergovernmental meeting on environmental monitoring in 1971 (Geneva) recommended that a world monitoring system be established and agreed *inter alia* upon a definition of monitoring: a system of continued observation, measurement and evaluation for defined purposes (Munn, 1980). In a recently published report (Managing Troubled Waters, 1990) by the National Research Council of USA, marine environmental monitoring was defined as a continuing program of modelling, measurement, analysis and synthesis that predicts and quantifies environmental conditions or contaminants and incorporates that information effectively into decision making in environmental management

For convenience, large monitoring systems are frequently subdivided into smaller ones. This permits the sharing of operational responsibility. Such divisions according to Munn, (1980) are:

1. by geographic area or jurisdiction, e.g. by county, country, continent.
2. by medium, e.g. by air, ocean, freshwater, soil, vegetation, food, human beings.

3. by method of monitoring, e.g. by direct instrumental, sensing, indirect indicators (e.g. fossil-fuel consumption as an index of Co2 emission), questionnaires, diaries.
4. by strength of the effect/ process being monitored, e.g. impact monitoring, regional monitoring, baseline monitoring.
5. by type of impact e.g. geophysical, biological, human health, socio-economic, institutional (i.e. monitoring of governmental responses to environmental problems).
6. by objectives.

Most environmental problems are big and include several media, and are inter disciplinary. For example to monitor global warming and its consequences, it is necessary to monitor air pollution for greenhouse gases, monitor sealevel world-wide and study the ecological changes in marine and terrestrial ecosystems. Coral reefs represent just a fraction of such problems faced by many tropical countries.

Marine environmental monitoring has been successfully employed to protect public health through systematic measurement of microbial indicators of faecal pathogens in swimming and shellfish-growing areas, to validate water quality models, and to assess the effectiveness of pollution abatement in many countries of the world Monitoring is important to a wide range of interests (fishermen, dischargers, engineers, government environment managers, politicians, scientists and private citizens) and meets many needs (Managing Troubled Waters, 1990). Such needs are:

- monitoring provides the information needed to evaluate pollution abatement actions.

- monitoring information can provide and early warning system allowing for lower, cost solutions to environmental problems.

- monitoring contributes to the knowledge of marine ecosystems and how they are affected by human activity. Such knowledge allows for the establishment of priorities for environmental protection and for the assessments of status and trends.

- monitoring information helps answer such questions as "Is it safe to swim or eat fish and shell fish?

- monitoring information is essential to the construction, adjustment and verification of quantitative predictive models, which are an important basis for evaluating, developing and selecting environmental management strategies.

- monitoring information provide environmental managers the scientific rationale for setting environmental quality standards.

- monitoring determines compliance with conditions set forth in discharge permits.

For many reasons, there is increasing interest in the estimation of environmental trends. Baseline data are urgently needed in the first place. Mounting pressures on reefs had led to concerns at international levels. Monitoring had been on the agenda of many important meetings such as Symposia on coral reefs.

The need for information on the extent of natural and human disturbances on reefs is acknowledged now by many governments. Management schemes have been developed to provide decision makers who have responsibility for coral reefs, with the means to ensure that relevant issues are considered in the process of management and planning (Coral Reef Management Handbook, 1984; Kenchington, 1990). The need for reef monitoring is stressed in such schemes. Long term monitoring with well defined objectives can help us to establish the rates of changes on reefs and determine the causes of reef deterioration.

Coral reef monitoring studies can help to answer the following questions which are basic to environmental management planning (Dahl, 1977).

- What resources are present? A survey can give a systematised general description or characterisation of reef habitats and resources.

- Is the area particularly productive or useful? Certain signs of productivity and classes of resources of known importance (corals, baitfish, seagrass beds, trochus, high structural relief, local food items, etc.) can be measured in some rough quantitative fashion as part of the survey.

- Is the area "natural" or "disturbed"? This question cannot be answered categorically, but certain signs such as extensive dead but uneroded coral skeletons, and signs of man such as cans bottles, overturned rocks, or dynamited coral heads can provide evidence of recent disturbance.

- Are changes taking place? Repeated surveys over a period of months or years in the same place will document gross changes in the parameters being observed, although care should be taken to distinguish random or seasonal variations. For this, living corals can be a particularly monitoring parameter, especially for showing the direction of change (degradation or recovery).

A number of reef monitoring programmes world wide were reported in the December Issue of Reef Encounter 10, 1991. Information was given on monitoring programmes in Florida, the Great Barrier Reef, Hawaii, St. Lucia, Caribbean, Jamaica, Indonesia, Singapore, Malaysia, Thailand, Philippines, Maldives and French Polynesia.

Reef monitoring projects range from the sophisticated SEAKLEY Automated Environmental Monitoring System (Forcucci *et al*. 1991) set up in Florida, to the simple procedures being used in St. Lucia that harness the diving community as a labour force (Reef encounter, 1991). The Florida Marine Research Institute set up five Long Term Ecological Research (LTER) stations at Fort Jefferson National Monument, Dry Tortugas in 1989 (Reef Encounter, 1991) Data for benthos were acquired from chain transects, quadrats, video transects, photogrammetry, recruitment setting plates and reef fish censuses.

Rogers (1988) described the US National Park Service coral reef assessment programme. The goal of the programme was to establish effective long term research and monitoring programmes at the four National Park Service units which have coral reef ecosystems. In addition establishment of monitoring sites, the objectives were to

1. develop and evaluate standardised methods for assessment of trends on coral reefs.
2. provide baseline data on reef fish and coral populations and environmental parameters.
3 determine natural rates of change.

Under the programme effects of Hurricane Hugo on reefs at Buck Island and the Virgin Island National Park have been quantified. A variety of methods including photographic techniques as well as quadrat and linear transect methods were used to monitor the reefs.

Hughes (1989) established permanent sites in 1977 in Discovery Bay Jamaica, which have been monitored annually using a variety of photographic, quadrat and transect techniques. During the 14 year course of assessments, hurricane effects, algal blooms following mortalities of *Diadema antillarum* and bleaching events were monitored.

Scientists from Indonesia, Singapore, Malaysia, Thailand, Philippines and Australia have agreed on a standard method for surveying and monitoring coral reefs in the ASEAN region. It is a semi-quantitative method which requires a minimum of taxonomic knowledge and yields data that are amenable to ecological analyses of coral reef assemblages. Reef monitoring methods used in Indonesia and Thailand were reported by Brown (1990).

A combination of line intercept chain transect and videographic methods were used in Hawaii to monitor reef health for disease (Reef Encounter, No. 10, 1991). The long term objective of these monitoring efforts were to investigate the temporal and spatial dynamics of coral community structures. The relative health of populations may be assessed through comparisons of net changes in living coral tissue cover through time.

In any management monitoring situation the ideal technique is one which is simple and quantitative and which is an indicator of conditions. When such a technique indicates departure from "normal" conditions more sophisticated techniques can be brought in to describe the situation in greater detail. Clearly defined objectives and a sound simplistic design approach are prerequisites for the long term success of reef monitoring schemes.

2.2 Aims and objectives

In any research activity we should consider what we are trying achieve. There should be a broadly agreed objective or objectives. In most general terms, the main goals in the environmental sciences are to describe, to explain, to predict and to manage (Munn, 1980). In each of these cases there is a monitoring component.

In considering objectives one must make a distinction between scientific objectives, and personal objectives or motivation as well as management objectives if any. The scientific objective is in most cases quite straight forward, i.e. to advance scientific knowledge. Very simply it is to gain sufficient understanding of a particular community with particular qualitative and quantitative characteristics. It is also essentially to seek an understanding of what's going on, what is now and has been affecting individuals and species. The greater the understanding of the processes and factors at work, the more accurately we can predict for similar or different circumstances elsewhere or in the future.

By far the most common objective of coral reef research is scientific, dealing with various aspects of coral reef ecology. The wealth and diversity of the fauna and flora in and around coral reefs makes these areas a fascinating subject for research amongst the scientific community. Considerable research had been carried out on coral reefs on coral morphology structure biotic distributions and physiology. Studies have been carried out to compare reefs from different areas or oceans with a view to understanding the overall functioning of reef ecosystems (Dahl *et al.* 1974; Davies *et al.* 1971; Scheer, 1971). The broad aim of such projects is to compile baseline data which can be used for other research programmes.

The recent degradation of the marine environment with increased human impacts on the ecosystems has resulted in the need for monitoring and surveillance of environmental systems. When we look at how pollution affects the marine environment at the level of organisms we find changes in the behaviour, in feeding or assimilation rates, in growth and maximum size, and in reproductive efficiency, all of which produce changes at population and community levels. Ecological consequences are often similar to those brought about by natural factors.

Today there is an urgency for more management oriented research in tropical reef areas. Protection of coral reefs is becoming increasingly difficult because the areas in which they are found particularly near the coasts, are used as sites for tourism, industry and resource exploitation. There is concern over the predictions of global warming and sea-level rise and the consequence of this for coral reefs. The changes which result from such impacts can only be observed by long-term monitoring of reefs. There is a need for urgent baseline information on reefs, changes in community structure and growth comparison. We can determine the real causes of reef deterioration and formulate management strategies by continuous monitoring and practical research on reef areas. Monitoring would become even more useful under a comprehensive national program for documenting environmental status and trends in coastal waters. Monitoring and baseline data would enable us to disentangle man-induced changes from natural ones.

The objectives of monitoring would include the following (Munn, 1980)

1. to determine present conditions.
2. to determine trends.
3. to understand phenomena.
4. to validate and / or calibrate environmental models.
5. to make short-term predictions
6. to made long-term assessments
7. to optimise the utility and / or cost effectiveness of any of the above.
8. to control (to detect illegal oil spills, violations in water or other quality standards).

Ideally any monitoring programme should have well defined scientific and management aims and objectives. If either of these objectives fail then the programme itself is quite unnecessary. The scientific objectives of a coral reef monitoring programme may be one of many.

1. Monitoring for changes in reef community structure.
2. Species composition and abundance.
3. Monitoring of health of reefs.
4. Monitoring a specific event e.g. dredging; pollution.
5. Changes in growth rate.
6. Monitoring recruitment.

In most cases depending on the primary aim of the project and its management objectives, there might be the necessity of other related monitoring research work of e.g. water quality, sea conditions, salinity, temperature, winds, currents and many others.

Scientific and management objectives come together in most monitoring programmes and have a common interest in being able to interpret ecological changes correctly and take appropriate measures to overcome it or reduce the resultant effects. If the objective of the monitoring scheme is purely management and is just a data collecting exercise, then the programme is more prone to be a failure due to lack of proper scientific directive and guidance. A more realistic approach would be to have both scientific and management objectives combined.

When managers demand quick instant action, practical science can do very little in most instances. It is perhaps not wrong to say therefore that motivation and personal scientific objectives must play a leading role in monitoring and survey work.

It is often essential to plan monitoring programmes which much broader objectives than just a sampling scheme. Many tropical areas lack baseline data on reef to start with and such factors should be born in mind in the planning stages of programme.

Without a proper understanding of causative mechanisms, it will be difficult in many cases to distinguish between the effects of human impacts and the natural variability of the reef ecosystem. Great fluctuations can occur naturally on coral reefs (Dahl, 1977). Widespread use of even the simplest monitoring systems will help to document the scale, extent, and duration of natural changes as well as those directly related to man's influence, and can thus help to lay the ground work for more thorough scientific studies of this problem.

2.3 Design of monitoring programmes

Having established the aims and objectives, by far the most important aspects of the monitoring programme will be its design an operation. Monitoring programs need to be well designed and methods appropriately applied if they are to meet the expectations of all those who call for them, implement them, and use or rely on the information that they can produce.

The optimum design of a monitoring system depends greatly on its objectives (Munn, 1980). Frequently a monitoring system may be designed to meet multiple objectives. Furthermore both the objectives and the measurement techniques may need degrees of refinement over the years. A monitoring system is usually designed to estimate change in both space and time. The design should reflect the levels of expertise available to carry out monitoring. In most cases monitoring several stations are established, each measuring the same elements at the same time.

The technical design of monitoring programs refers to the process of deciding what to measure; how, where, and when to take the measurements; and how to analyse and interpret the resulting data. When monitoring data have been analysed, they provide support for specific management actions.

A comprehensive account of the elements involved in the design and implementation of a general monitoring program were described in the book, Managing Troubled Waters, by the National Environment Council of USA (Figure 7). It provides a logical and scientifically based means of linking technical decisions about monitoring design to the information needs of the decision-making process. The methodology applies to most monitoring situations.

In reef monitoring, one should ideally be on the look out for abnormalities in either the structure or function of the reef system (Gomez and Helene, 1984). Monitoring may focus on any number of parameters in the biological components such as the more accessible reef organisms and more easily measurable physico-chemical factors such as water quality. The selection of physical and chemical factors to be monitored depends on the type of stress under consideration.

Figure 7. Elements involved in the design of a monitoring programme. (From: Managing Troubled Waters,1990)

The most common biological parameters measured are coral cover, species diversity, abundance. The extent of cover by coral and other benthic species of the available reef substrate and the range of species present are generally accepted as significant indicators of reef condition (Gomez and Helene, 1984). Changes in the behaviour or abundance of fish and other motile organisms can also be monitored. Use of butterflyfishes as indicators of reef condition was reported by Roberts *et al.* (1988).

The elements to be measured in a monitoring programme will be strongly influenced by the objective of the programme. If, for example, a monitoring programme was to be drawn up to investigate the effects of siltation on a particular reef area, it is first of all essential to design a survey in such a way as to isolate, define and analyse the effects of siltation on the reef (Craik & Dutton, 1987). If the objective is to consider the effects of sewage on a coral reef area the monitoring stations should be sited where the effect is largest and the variability smallest.

The need may also arise sometimes for complex physiological measurements of sediment rejection, reproductive rates, growth rates, water quality conditions, light conditions and many other parameters rather than just monitoring for coral cover or diversity. Methods will then need to be incorporated into the programme for determination of suspended particulate matter and sedimentation. Measurement of growth rates by methods such as radiography may become essential (Cortes & Risk, 1985). Study of growth banding in corals can reveal information about conditions in which the corals grew (Scoffin *et al*. 1989; Brown *et al*. 1986; Wellington and Glynn, 1983; Barnes and Devereux, 1988).

In order to determine the cause of deterioration in the health of reefs it is crucial to monitor as many environmental variables as possible. Tomascik and Sander (1987) measured 14 water quality parameters in their effort to investigate the effects of eutrophication on reef building corals.

1. dissolved oxygen
2. biological oxygen demand
3. percentage surface illumination
4. percentage of organic matter in sediments
5. suspended particulate matter
6. volatile particulate matter
7. downward flux of suspended particulate matter
8. chlorophyll a
9. inorganic phosphate
10. nitrate -nitrogen
11. nitrite
12. ammonia
13. temperature
14. salinity

All of these variables represent aspects of water quality and are essential components of a marine monitoring system designed to quantify environmental changes over time..

At the planning and design stages, it is important to address objectives precisely with operational definitions (Birkeland, 1984). Basic procedures and methods that are quite productive for one purpose can be counterproductive for another. For example, to monitor the environmental quality standards set by law, to do comparative surveys of temporal and spatial variations or to test hypotheses concerning questions such as causes of environmental degradation, standardised sampling methods must be designed to ensure the consistency of data acquisition within the studies. An over standardised approach can be detrimental to exploratory surveys for the assessment of latent resources or in searching for unknown causes of sporadic phenomena. There are many standard coral reef survey methods used widely in reef assessments (see next section).

The frequency at which recordings must be made should also be determined at the design stages of the monitoring programme. Monitoring should be conducted at appropriate intervals for the objectives (Gomez and Helene, 1984). Monthly monitoring is the limit for the detection of seasonal fluctuations. Where time or resources do not permit, quarterly or semi-annual monitoring may be the options.

Careful selection of sites and control sites is crucial in the case of monitoring reefs for health or to observe changes. The isolation of factors that may be affecting reefs in the event of reef deterioration may be very complex. The criteria for site selection would ultimately depend on the objectives of the monitoring programme. When criteria are set, surveys can be carried out at preliminary evaluation stages on reef areas to investigate their appropriateness in terms of the established criteria. Preliminary surveys and investigations may provide a basis for refinement of the survey design to suit the need of the programme.

Sheppard (1980) in his survey of the Diego Garcia lagoon made preliminary searches on the coral knolls which confirmed observations that coral knolls varied greatly within short distances with regard to coral cover and growth. Site selection and optimum design of surveys would be helped by such preliminary visual observations.

Site selection should reflect the objectives of the surveillance work. Sometimes it may be essential to find a pristine reef which is subject to little external stress as reported by Dahl *et al.* (1974). Their objective was to collect baseline data on selected reefs and make ecological comparisons between these research sites. The criteria by which sites are judged have a crucial bearing on the conclusions of the site analysis (Dahl *et al.* 1974). The criteria for site selection as reported by them were:

1. Ample development of all characteristic reef zones, from the reef flat to deep water communities in depths of 50-100 meters.
2. Vigorous reef growth where interactions with the surrounding water mass can be measured and with a good geological record of past development.
3. Unidirectional current flow periods long enough to permit cross reef metabolic studies.
4. No overriding unique characteristics with respect to the reefs in the same area.
5. Freedom from major terrestrial, human or natural catastrophic influences in the present or recent past.

Some practical criteria behind site selection identified by Dahl *et al.* (1974) were:

1. Sufficient accessibility to meet the needs of a large program.
2. A harbour and accommodation and facilities or the possibility of developing these at reasonable cost.
3. Availability of research vessel support.
4. Probability of a stable government with a favourable attitude towards the program.
5. Suitability for research needs such as multiple sampling, monitoring with shore based instrumentation, drilling for geological samples etc.

The practical and cost problem involved in research programmes must be taken into account in the early design of the study. When the area to be monitored in large the preferred sampling strategy depends on:

1. The funds available and the cost of equipping and operating stations.
2. The objective.
3. The complexity of the field being monitored.

In considering the proper sampling techniques for studies of coral reef communities, one has always to bear in mind the practical difficulties involved, i.e. the physiological and physical limitations dictated by the aquatic environment (Jones 1971, in: Holme and Mcintyre) Any underwater study is several time more complicated, tedious, time consuming and expensive than a comparable operation in a terrestrial evvironment.

It is necessary to determine how much information is needed and what degree of accuracy it is reasonable to aim for. It may often be too difficult, too time consuming to undertake a study at which point we need to consider designing the study at a simpler level. We have to be reasonable in our ecological targets in setting out scientific objectives.

Any survey or monitoring system, if it is to be useful under conditions where scientific resources are limited, (as it is in many tropical reef areas) must meet the following requirements: (Dahl, 1977).

- Rapidity of surveys
- Simplicity of methods
- Repeatability of techniques

Environmental signals are always noisy and hence trends and changes cannot be accurately interpreted unless monitoring systems are designed with a particular objective in mind. Events such as bleaching, disease, death of large areas of reef, human impacts and cause-effect relationships can only be studied with carefully designed monitoring schemes.

2.4 Methods employed in reef assessment

A variety of methods employed in reef assessments are widely reported. Broadly these fall into three categories:

1. Transect methods
2. Quadrat methods
3. Photographic methods

The method used in any monitoring situation will depend on the primary objective of the programme, and the resources available. Methods will also depend on site characteristics, sea conditions, manpower capability and infrastructure. Most quantitative methods employed in reef assessment are modified terrestrial methods used for plants (Loya, 1978).

The basic methodological dilemma of all ecological surveys is striking a balance between extensive/ qualitative and intensive/quantitative work (Lewis, 1974). When a choice is necessary the rule must surely be for extensive work to be followed by the intensive, when the broader background has been established and one is indeed starting to look into more specific problems. If we are starting afresh, the basic tool should be a general survey which is essentially descriptive. Descriptive surveys are short, but understanding requires time. The more we know generally, about any habitat or community, the less the scientific need for quick descriptive studies. In order to understand and consolidate, descriptive surveys must be succeeded by quantitative long term studies.

2.4.1 Line transect method

Most of the invertebrate communities of coral reefs are sessile or limited in their mobility. In this sense there is a great similarity between coral reef invertebrate communities and terrestrial plant communities. Methods and concepts used by plant ecologists are thus also used for the study of benthic communities of coral reefs. Loya (1978) reviewed line transect methods used by ecologists and discussed their possible applications for quantitative studies of coral communities. Although line transects had been used before in various studies, they were only used as a reference line for the establishment of quadrats or as a belt transect with specified length and width, all individuals within it being measured (Loya,1978).

Plotless line transect methods where the line transect has specified length but no breadth were first used by Loya (1972) and Loya and Slobodkin (1972). The line transect methods basically involve the recording of the length covered by an object along the transect. The method is most popular in the study of coral community structure in terms of species composition, zonation and diversity.

Line transects has been used extensively in many reef assessment studies (Brown and Holley, 1982; Brown *et al.* 1990; De Silva, 1984; Cortes and Risk, 1985; Loya, 1972,1976,1978; Loya and Slobodkin, 1971). Loya (1976) described community structure of hermatypic corals off the west coast of Puerto Rico quantitatively in terms of species composition and diversity patterns, using line transects from 8-20m depths.

Line transects can be run basically at any depth. The necessary sample size (length of transect) should be determined in a preliminary study of the area investigated. In vegetation studies it has been found that as the area sampled increased the number of unrecorded species added decreased, a concept referred to as the species-area curve which has often been used in plant ecology. The point where the species-area curve starts to level off is usually considered an adequate sample size. The same considerations may apply to the species versus transect length curve (Loya, 1978). This approach is commonly used to determine the appropriate transect length in studies of community structure of hermatypic corals (Fig.8.).

Figure 8. The species area curve are used to determine the length of transects for line transect studies on coral reefs. The adequate length for a transect is the point where the curves level off. (From: Loya, 1978).

The transect length should therefore depend on the biological diversity of the site in question. Loya (1971) found that a 10m line transect proved to be an adequate sample size for a quantitative study of hermatypic corals in different reefs investigated in Eilat, Red Sea. However, on a study on the reef flat of Heron Island, Great Barrier Reef, Australia, the species versus transect length curve started levelling off only at 30m of a line.

The methods of recording along a transect involve recording any coral species which underlie the line and its projected length which intercept the line is measured to the nearest cm (Fig. 9). Transects can be run along depth contours parallel to the shore and parallel to each other at fixed intervals on the reef flat and along the fore reef (Loya, 1978).

Figure 9. Line transect method for quantitative studies of corals. A,B,C, and D represents the measurements made along the transect. (From: Loya, 1978)

There are two principal line transects methods employed in reef surveys: (Loya, 1978)

Recording under equally spaced points along a transect

In this method a line transect is divided into contiguous units of equal size. Each block is divided by a fixed number of equally spaced points (Fig. 10). The frequency in each block is determined by summing the presence of each species from all the points within the block. In this way a series of contiguous frequency records may be obtained for each species. It is worthwhile to note that this is essentially a method to determine species abundance and diversity of an area. It does not provide a mean of determining coral cover on the transect. The method is sometimes called the point transect method.

Figure 10. The point transect method. The species under the points are recorded to determine species composition. (From: Sukarno, 1984)

Continuous transect recording

This is probably the oldest transect method used mainly by plant ecologists for recording frequency and coverage of vegetation. Any individual that is intercepted by the line is recorded and the portion of the line being intercepted by the line is measured (Fig. 9). According to Loya (1978) although the line transect itself has practically no breath, measurements of the coverage of individual species along its length are possible, since they would be proportional to the areas covered by the species concerned. The method is based on the expectation that total transect length/total population area = total transect length intercepted /total area of living population.

De Silva (1984) reviewed the reef assessment methods used in Malaysia. He also described a modified transect method for quick assessment of coral reefs especially where time, money and personnel are major constraints.

In the method, a nylon rope marked at intervals of one metre is placed over the reef. It is laid perpendicular to the shore, starting from the most leeward side coral colony and extending to the seaward edge of the reef. The approximate position and proportionate length of live corals, dead corals, soft corals, other macro-organisms and sand or rock which fall directly under the transect line are marked on lines drawn on an underwater slate to represent each metre along the transect line. (Figure 11 and Figure 12).

Figure 11 Diagrammatic sketch of a transect line marked at intervals of 1 meter passing over a coral reef. (From: De Silva, 1984)

The recordings on the underwater slate will be as in figure 12.

Figure 12 The scoring based on Figure 11 on lines drawn on an underwater slate to represent every meter along the length of the transect line laid over a reef.(From: De Silva, 1984)

Porter, (1972a,b,) employed a modified transect method called the chain transect method to determine coral species diversity. His method involved placing chains 10m long with links of 1.3cm, laid down parallel to the depth contours at one meter intervals from the top to the bottom of the reef. The number of links covering each species of coral were counted and used to compute the species diversity of living coral under each transect chain.

The study of species diversity is sometimes an important element of monitoring schemes. The precise treatment of species diversity requires terms representing both number of species and their relative abundance. Corals pose special problems in the quantification of both of these (Porter, 1972). Morphological similarities between species and the presence of a variety of growth forms in the same species (Veron 1986; Wood, 1983) present special problems of species identification. Corals also pose special problems in measuring species abundance. While one could count each coral colony as one individual, this definition of individuality, however, has proven unsatisfactory for abundance studies. Some colonies of *Montastrea annularis* for example, reach dimensions of 8m in diameter (Porter, 1972). This is $25m^2$ of living tissue and cannot be evaluated in the same sense as a colony with and area of only $5cm^2$. Porter (1972) used the total length of transect line covering living tissue of each species to measure the abundance of each species.

Diversity was then defined by the Shannon formula as

$$H' = \sum p_i \log_2 p_i$$

where $p_i = Ni/N$ and N is the total number of chain links covering all species of living coral and Ni is the number of chain links covering the ith species of coral.

These studies are carried out with clear scientific objectives i.e. to determine the species diversity of a given reef but the methods are widely employed in monitoring work as well.

2.4.2. Quadrat method

Quadrat methods had been used widely for assessing coral reefs in many studies (Babcock, 1984; Davies *et al.* 1971; Scheer, 1971; Gomez and Alcala, 1982; Gomez and Helene, 1984; Robson *et al.* 1993). The method is derived from terrestrial plant ecology. The use of random quadrats as applied in terrestrial ecology and in the study of inter tidal areas is problematic for underwater sampling of reefs. Hence quadrat sampling is most commonly used along transect lines for studying reef areas.

Quantification of data using the quadrat method has two components: the number of individuals of a species and the cover or extent of this species (Scheer, 1978).

Hence we can determine the individual coral cover and total cover of all species in the area together with species diversity of the reef.

Scheer (1978) reported on the application of the quadrat method to the investigation of coral reefs in the Maldives. Before setting out to work with the quadrats its essential to obtain a general view of the area of the investigation by swimming over it and diving with or without SCUBA This will indicate differences in coral community in different parts of the reef (reef flat, reef margin, reef edge, reef front, reef slope). Attention can then be directed to typical areas for special studies such as community structure species or monitoring studies.

The right choice of a sample plot is of great importance because all conclusions depend on the result of the record made there. According to Scheer (1978), the sample plot has to fulfil three conditions. It must be large enough to ensure that it contains nearly all species ranging regularly in the coral community, be homogenous and not dominated in different parts by different species and reflect the uniform conditions of the location for example, uniform water movement, inclination, lighting conditions etc.

Size of the sample plot is very important in the application of the quadrat method. The bigger the coralla and the richer the reef is in species the larger the sample plot has to be (Scheer, 1978). He indicates that the plot has to be large enough to contain the greater part that is one half to two thirds of the coral species of the reef area under examination. The necessary size may be found by counting the number of species first on a small plot, for e.g. $0.1m^2$. Then the area is progressively enlarged for instance to $0.25m^2$, $0.5m^2$, $1m^2$, then to 2, 4, 10, 25, 50, 72, and $100m^2$. The respective newly occurring species are noted. If the number of coral species found in the different samples are recorded graphically the result is the species number area curve, which first increases rapidly then always more slowly.

Scheer (1971) investigated reefs in the Maldives using the quadrat method. The species area curve reached 38 species at $100m^2$. The minimum size of the sample plot is obtained where the curve begins to level off (Fig. 13). An approximate value of this size was determined by taking 2/3 to 3/4 of the asymptotically reached final value of the species number (Scheer, 1978).

Figure 13. The species-number-area curve for the evaluation on the sample size of plots in quadrat sampling on coral reefs. (From: Scheer, 1978)

Davies *et al.* (1971) investigated reef forms of Addu Atoll, Maldives by using quadrat transects and visual observations. They selected two sites at the lagoon reef of Gan Island, as typifying the main features of coral distribution after a reconnaissance of the whole reef.

Their method involved placing a survey chain, with tags at intervals of 10ft (3.05m), across the reef at each transect site, from the shore to the reef edge and from the reef edge to the base of the reef slope. A wooden quadrat of 10ft side (area 100ft^2 or 9.29m^2) was laid down successively along the chain to give a continuous series of quadrats. In each quadrat one specimen of each coral and algal species was collected and notes were made on the nature of the substrate, percentage cover by living coral, the dominant coral species and other salient observations.

Gomez and Alcala (1982) reported on the use of a quadrat method in Philippines. They used a 1x1m quadrat divided into 16 squares of 25x25cm each to sample along a 300m transect line (Fig.14). Quadrats were placed regularly at 20m intervals along the transect. At each sampling point the number of squares covering live coral, soft coral, dead coral, rocks, sand, sponges and algae were recorded. The data were entered into a reef survey data sheet for each site (Table 9). The percentage cover of various types was computed from the data sheets.

Figure 14 The quadrat sampling method along transect. (From: Sukarno, 1984)

Table 9 Reef survey data sheet used in Philippines to enter quadrat data. (From: Gomez and Alcala, 1984)

Babcock (1984) studied the spatial distribution of *Goniastrea* by the quadrat method. He placed three 30m belts of contiguous 1m^2 quadrats laid parallel to the reef front. The area of sites where transects were laid was the area of greatest abundance of *Goniastrea aspera*. In each quadrat the abundance and size of colony was measured.

2.4.3. Photographic methods

Photographic surveys are essentially qualitative and the techniques correspond closely to visual assessments. They also have the advantage of giving reliable visual comparisons in time and space. Photographic surveys are generally carried out along line transects, with pre-determined quadrats being photographed along the transects. In some cases when transects are photographed continually at regular intervals, reliable quantitative data can be obtained from the photographs. Stereo photographic methods can also be employed.

Photographic techniques were adopted in assessing coral cover on areas of a number of reefs in the central region of the Great Barrier Reef by Endean and Stablum (1973).

They reported on a standardised photographic quadrat method designed to estimate percentage cover of sedentary reef organisms.

First they identified three complex types of reef areas from visual inspections:

1. reef top
2. reef slope
3. vertical reef areas

To sample these areas quadrats were taken in a variety of ways. A one meter square quadrat proved to be the largest size that could be handled easily in the water. The organisms enclosed within the quadrat were recorded photographically. A Nikonos 35 mm underwater camera with a 28 mm wide angle lens gave a negative in which the quadrat area filled the majority of the frame when used from a distance of 1.83m (6ft) perpendicularly above the quadrat. The qualities of the photographs vary depending on the type of film used. Scienta 50 B 65 (50-80 ASA) and Ilford FP4 125 (ASA) gave good results (Laxton & Stablum, 1974).

The most serious drawback of this method was that many of the reef tops did not have the required 6ft of water over them at times other than spring tides. Oblique photographs could not be used for accurate results. This was overcome by dividing quadrats into quarters and photographing each quarter separately at a distance of 3ft.

Two 10 cm square prints were made from each negative which was considered to be the smallest photograph in which organisms could be identified with certainty. Each organism was carefully cut out and each piece weighed. These weights were expressed as percentage of total weight of the whole photograph. This gave the percentage area occupied by each colony. Since each weight is in direct proportion to the area of the colony, photographs can be analysed to determine the percentage area occupied by many objects such as corals, soft corals, substrate types.

Apart from yielding accurate values of percentage cover of sedentary organisms on coral reefs, this photographic technique has the following advantages.

1. The method is rapid and cheap.
2. Time spent in the field is minimal.
3. An exact record of size, number of colonies and their spatial arrangement for a given instant in time is obtained.
4. By periodically re-photographing transects relative growth data can be obtained.

Chansang (1984) reported on a similar photographic method used in the Andaman Sea.

A method developed and used for the Great Barrier Reef Marine Park Authority, used an underwater camera rig to take stereo photographic pairs of sample locations. The advantages of the method is that the photographs can be taken by a trained diving technician and that they provide a permanent three dimensional record of conditions at that time. By recording at the same site at regular intervals, a record of change with time, can be achieved (Kenchington, 1984).

Photographic methods appear to be the best method in continuous permanent surveys if the same quadrats can be located readily. However, this depends on the objectives, staff and resource availability. Although photographs represent permanent visual records, they can pose special problems in species identification and detailed analysis.

2.4.4. Video methods

Video survey methods for the study of coral reef benthos were described and compared with manual methods by Buchan, (1992). Two methods were illustrated:

- Video quadrat method.
- Video transect method.

In the video quadrat method, a video camera within a waterproof housing was used to film random quadrats along a transect line. The camera was mounted on a quadrapod constructed from Schedule 40 & 80, 0.5" diameter P.V.C. piping (Figure 15). It was constructed so that the video camera within its housing could be mounted 75cm above the reef, at which distance the quadrat base was equal to the camera field of view. The centre of the left hand edge of the quadrat base was lined up against a random point on the transect line and the reef within the quadrat base was filmed (Figure 16). Adobe Photoshop digitising software was used to enhance the filmed frames. The software allowed each coral colony to be outlined and enabled the colony size to be measured. Percentage cover for each species was based on the ratio of the selected species to the total species area sampled.

The video transect method involves a diver swimming at constant height above the length of the transect line and filming the substrate below. The video tape is then analysed by identifying and counting all colonies which appear in the field of view when replayed on a television monitor.

The major advantage of video methods are their quickness, coverage of a large area in any one observation and the production of a permanent record of the site. The main limitation seems to be the difficulty in identifying species confidently. When filming transects, the difficulty to keep a constant height above the reef is a also a disadvantage.

Figure 15. Illustration of the video quadrapod used for mounting the camera to film quadrats. (From: Buchan, 1992)

Figure 16. Illustration of site layout and positioning of the video quadrapod in relation to the transect lines. (From: Buchan, 1992)

2.4.5 Visual surveys

While it is necessary to compile quantitative data to make statistical comparisons spatially and temporally, visual surveys of large areas can be very useful under certain circumstances. They are rapid and cost effective. Furthermore, in some instances, (e.g. in cases where decision-makers often demand instant action on environmental issues), qualitative assessments may be the only viable option. Visual surveys have been carried out to monitor the effects of *Acanthaster plancii* predation as well as the rapid assessments of reefs.

Baseline data on coral fauna was collected for Diego Garcia lagoon following harbour construction by Sheppard (1980). In the Diego Garcia lagoon the sole impact is that of the building and clearing operations (Sheppard, 1980). His study attempted to ascertain any gross effects that building, clearing and harbour construction may have had on the coral fauna.

The method used by Sheppard (1980) involved recording coral species onto a writing board or collecting in the case of difficult species for later identification. Estimation by eye were made simultaneously of coral cover, sedimentation, substrate slope, cover of sand and other loose substrate, and cover by other forms of biota. Each of 6 sites was examined between its uppermost limit and its lower limit, from 1-25m respectively. Thirty to forty-five minutes were spent at each of the six sites and each search was ended only after no additional species had been recognised for 10 minutes.

This method may be particularly useful when large areas are to be surveyed within a limited time frame. Another point to note is that the observer in such studies must me very experienced at identification and the conduct of such surveys. Only crude estimations of coral cover can be made.

Having said this it must be recognised that such rapid qualitative and semi-quantitative assessments can sometimes produce significant results. Incidence of sedimentation and mechanical damage on reef areas can be readily observed.

The main disadvantage of visual methods are that they depend on the experience and judgement of the observer. Important observations can be missed because of the indirected method of approach and observations are usually restricted to the more obvious reef features and gross zonation patterns, ignoring smaller and cryptic forms (Davies, 1971). On the other hand much larger areas can be covered and better impressions gained of local variations in reefs than if efforts are concentrated on the detailed analysis of particular reef segments. Within the limits imposed by water turbulence and accessibility, logistic problems are not significant controls of direct observation methods (Davies, 1971). Visual methods are also subjective.

2.5 Discussion

The goals of reef monitoring in most cases appear to be trend analysis. Efforts have been concentrated on establishing natural and human induced disturbances. When changes are detected the need arises of detecting the cause of changes.

Most monitoring schemes have a management objective behind them. Impacts are quantified, assessed and fed in to the management cycle. Governments sometimes expect to have a complete monitoring programme in place on the first day of management, recording baseline conditions and thus ready to record change. This is rarely possible. Development of methods and refinement of design may take time, but is a more practical means of developing a monitoring programme.

The long-term success of a monitoring programme depends on its design and continued operation. Careful consideration should be given to design in relation to predetermined objectives. The design of a monitoring programme involves five basic elements: what to measure, how to measure it, where to measure, when to measure and the production of standardised sets of data over time. Production of useful information is the key to successful monitoring and standardised data sheets should be prepared. Each of these elements should be given careful consideration at the planning stage.

There are many methods in use in monitoring programmes. Line transect methods, quadrat methods, photographic methods and video methods are commonly used. The methods should be weighed against logistic and technical know-how available. They should be simple, repeatable and cost-effective.

The effectiveness of a monitoring programme depends on repeated use of appropriate methods for data collection. The main reasons for the limited amount of reef monitoring in developing nations are lack of expertise and the promotion of methods that could only be applied by experts and which are not specifically designed for monitoring. Almost all of what has been labelled as monitoring methodology has been copied with little or no change from methods originally designed for studies of species interactions, successions, diversity, population dynamics and productivity. These methods often require far more time, resources and expertise than are available for a monitoring programme. Local technical staff often have neither the time nor the inclination to spend hours measuring and identifying reef species underwater, and the methods cannot be applied by staff with lower levels of experise.

Monitoring changes in reef community structure is complex but can be greatly simplified using photography. This has the advantage that expertise in identifying species is only needed at the outset, when a permanent station is established. With a suitable frame for mounting the camera, any competent diver can re-photograph the permanent quadrats and the photographs can be analysed elsewhere.

A good example of a survey framework for monitoring coral reefs is provided by the Coral Reef Monitoring Handbook (Dahl, 1981) published by the South Pacific Commission. The handbook was prepared by 15 participants, each with a particular expertise on coral reefs or monitoring. Thus it represents the product of a multi-disciplinary effort. While recognising the complexities of coral reef ecosystems, the book attempts to establish comparatively simple indicators and to develop a basic approach to coral reef surveys which might be used both by scientists and others without a scientific background but with some initial guidance and training. The data sheets included in the handbook, for example provide for information on site characteristics, percentage cover of different types of sediments, corals, sponges and algae. The practical format of the handbook is such that it lends itself to widespread and regular use in monitoring reef changes.

Transect sampling proved to be very efficient in information gained per time spent underwater and also in avoiding problems of bottom topography (Loya & Slobodkin,1971; Loya, 1972; Loya, 1978). Thus, a line may be put along depth contours, while quadrat sampling is much more complicated to interpret due to topographical complexity, subjective recording and handle underwater. The amount of information derived from line transects is for many purposes more useful than that derived from quadrat sampling techniques. Due to efficiency limitations of quadrat sampling a much smaller dimension of the reef can be covered when compared to line transect techniques in terms of results obtained per equal labour time (Loya, 1978). Laxton and Stablum (1974) stated that transects and quadrat methods, while all have virtue are uneconomical of field time.

The chain transect method has the advantage of determining the structural complexity of the reef as well as its accuracy in placement in the case of permanent transects. The disadvantages may be the laboriousness and difficulty in manipulating chains under adverse conditions. Chains due to their weight will also make variations less likely to occur due to sea conditions.

The advantages of quantitative methods such as the quadrat method are, first that they yield results which can be compared with those from other reefs (Davies *et al.* 1971; Robson *et al*. 1993). Secondly, the process of quadrat surveying directs attention to the details of the reef, and thus leads to the discovery and recording of features which might otherwise be overlooked. It is hence difficult to compare directly the results of quadrat or other quantitative surveys with those of direct observation and subjective descriptions.

The immediate criticism of quadrat or transect works is that it concentrates attention on a segment of the reef which maybe unrepresentative. This can be avoided to some extent by locating transect sites subjectively by a preliminary survey.

Davies *et al.* (1971) reported considerable difficulties in field recording in quadrat and transect surveys. While it is relatively simple to establish the number of species per quadrat, the number of colonies and percent cover are difficult to determine. Colony definition varies with species and growth form. Estimation of percent cover are also subject to considerable variation, particularly in areas of irregular topography. Furthermore, since colony counts and cover estimates are often obtained from quadrat records rather than directly in the field, two additional sources of error arise: one, the error inherent in the recording process, and two, the error involved in the transferral of complex 3-D distributions to a 2-D plane, particularly where the reef surface itself is not horizontal.

Visual surveys are subjective and limited in use (De Silva, 1984). It is however a useful technique as a preliminary survey to obtain an idea of the reef under study.

The long term success of a reef monitoring programme rests on the production of data useful for decision making purposes. It is the ultimate goal of a management monitoring programme. In order to fulfil this the scheme should be planned and developed with repeatable and simple methodology. Problems and causes of reef decline, if any, should be identifiable from the programme. Sites should be selected with a clear objective in mind. Reef monitoring projects, if well planned and designed, represent an important aspect of reef management. It is also an important step to advancing our knowledge and understanding of the variability and susceptibility in coral reef ecosystems.

Chapter 3. The ICOD Reef Monitoring Programme at MRS

3.1 Introduction

The reef monitoring programme described in this chapter is a component of the project, "Establishment of a Coral Reef Research Unit - Maldives", funded by the International Centre For Ocean Development (ICOD), Canada. The ICOD reef monitoring programme in Maldives began in 1990. The project terminated in 1992 but the programme was to be continued using local expertise afterwards. The main objective of the programme was to provide training on reef survey methods and water quality testing methods for Maldivian counterparts, while at the same time compiling quantitative baseline data on reefs of Maldives.

The general objective of the project was to provide assistance to the formation of a Coral Reef Research Unit within the Marine Research Section of the Ministry of Fisheries and Agriculture, in Maldives, to monitor and recommend action to maintain and protect the marine ecosystem in the atolls of Maldives.

The project, "Establishment of a Coral Reef Research Unit - Maldives", was the result of a request by the Marine Research Section of Ministry of Fisheries of Maldives to ICOD. The project was managed and executed by McMaster University of Canada and was carried out initially from 1989-1990. The project was extended for a further period in 1990 to end in 1992.

A specific component of the project, reef monitoring, will be described in the following sections. The monitoring component of the project represented the single most important part of the project framework and formed the basis for the establishment of a Coral Reef Research Unit in the Marine Research Section. The broad expectation of the project was to have a self-contained unit within the Marine Research Section trained to undertake coral reef research work especially on reef monitoring and be able to identify and report on the status of coral reefs in the country.

3.2 Aims and objectives of the ICOD project

The specific objectives of the project initially for the period 1989-1990 were to:-

1. Assist in the formation of a coral reef research unit by the provision of expertise and training to assess the marine environmental concerns in the Maldives.

2. Map the NE Male' Reef.

3. Investigate the extent of reef cracking along the NE. Male reef.

4. Establish baseline data on the status of marine ecosystems and an ongoing monitoring system for Maldivian counterparts.

5. Develop an information brochure and a questionnaire to enlist sport divers (tourists etc.) to monitor and report to the Coral Reef Research Unit, the status and noticeable changes to the marine environment.

6. Train Maldivian counterparts in reef monitoring, sampling, and assessment procedures and gradually create expertise in the Maldivian team to ensure on-going continuity of the program.

The focus of the second phase of the project was mainly on the continuation of the monitoring programme to establish reliable baseline data on the status of reefs. Emphasis was laid on training staff at MRS in monitoring techniques, sampling and assessment procedures to ensure a higher level of expertise.

The essential task was to provide repeatable quantitative monitoring methodology for comparisons between representative reef habitats which have been altered by local human activities and those which have been exposed only to natural or large scale environmental variability.

3.3 Methods and sampling procedures

3.3.1 Monitoring Sites

Six permanent monitoring sites were established under the monitoring programme spread in two atolls: four in N.Male' Atoll and two in S.Male' Atoll (Fig.17a,b). The six sites were given specific names for the purposes of the monitoring programme.

1. Anchorage Reef
2. Deto Reef
3. Embudu Reef
4. Male' Reef
5. Mystery Reef
6. Villingili Reef

Figure 17. The ICOD reef monitoring sites.

The criteria behind site selection were apparently to detect and assess the anthropogenic impacts of primarily island tourism, pollution and coral mining.

Site Location and description

1. Anchorage Reef

This is a submerged reef north of Male', the capital island, in the North Male' Atoll. The reef, locally known as 'Galu Falhu' (better known as 'anchorage reef' among the research personnel), had been subjected to coral mining activities about 16 years ago. Mining was abandoned after virtual clearance of almost all massive corals on the reef flats. The reef is also a monitoring site for coral settlement and recruitment patterns.

Transects were located at the NE edge of the reef at a depth of 10 metres.

2. Deto Reef

This reef is located just inside the northern atoll rim in South Male' Atoll. The site is about one kilometre SW of Vadhu resort island. The transects were placed at the north to north east edge of the reef at a depth of 10 metres.

3. Embudu Reef

Embudu island is a tourist resort island in South Male' Atoll. The monitoring site is located on the house reef of this island. The site is also about 2 km west of the Deto Reef site. Transects were located at the NE side of the island reef at a depth of 10 metres.

4. Male' Reef

This site is located on the house reef at the southern side of Male', the capital island. The transects were placed at a depth of 9 metres. Untreated sewage is discharged over the reef in Male'. Regular dredging has been going on under harbour development projects for a long time in Male'. Sewage pollution and sedimentation are thus potentially damaging impacts on Male' reef.

5. Mystery Reef

This is a submerged reef NW of the island of Bandos Tourist Resort. The site is subjected to coral mining occasionally. The transects were located at the eastern side of the reef at a depth of 10 metres.

6. Villingili Reef

Villingili island (a former tourist resort island) is situated approximately 1 km or so west of Male' island. Tourism was abandoned on the island recently. The island is now being developed as an extension of Male' to alleviate the population pressures in Male'. The transects were placed at the northern side of the island reef at a depth of 10 meters.

No environmental data were available for the sites at this stage. Some water quality data appear to have been collected for the sites, but these were not available at the time of analysis.

3.3.2 Sampling methods

There were two methods developed for the sampling of transects: the line intercept transect method and the point intercept transect method. The principles of these methods have been described in Chapter 2. The methods were adopted from line transect methods described by Loya (1978), De Silva (1982), and Sukarno (1982).

At each site three 20 meter transects were placed along the eight to nine meter depth contour of the reef slope. The transects were marked at approximately 5m intervals with metal stakes, hammered onto the reef substrate which acted as permanent markers of the transects. At each sampling occasion, a 20 meter tape was laid along the transect taking the stakes as reference points.

The sampling frequency ranged from monthly, biannually, to annual sampling of transects (Fig. 18). A single water sample was collected for analysis at each site on the sample date on some occasions, but not regularly. Although 4 individual observers were involved in sampling at the transects, only two of them were regularly involved in the sampling process throughout the monitoring period.

At the transects data were written onto underwater slates and then transcribed to a customised FOXBASE database on a personal computer. A total of 109 sets of transect data describing benthic community structure had been entered into the database by the end of 1992.

Figure 18. The sampling frequency of the ICOD reef monitoring programme. for the period July 1990 to July 1992. (x = No of samples)

SITE AND TRANSECT NO.	1990						1991												1992							TOTAL
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	
Anchorage 1	x	x x	x									x														5
Anchorage 2	x	x	x x			x																	x	x x		8
Anchorage 3	x	x		x		x						x											x			6
Deto 1	x	x		x x			x				x												x			7
Deto 2	x	x		x			x				x												x			6
Deto 3	x	x					x				x												x	x		6
Embudu 1	x	x		x x			x				x												x x			8
Embudu 2	x	x		x			x				x												x			6
Embudu 3	x	x		x x			x				x															6
Male' 1	x x		x x													x									x	6
Male' 2		x	x													x									x	4
Male' 3	x x			x												x								x		5
Mystery 1	x	x	x x								x													x		6
Mystery 2	x	x		x							x	x														5
Mystery 3	x	x	x								x														x	5
Villingili 1	x	x	x x		x x							x											x x			9
Villingili 2	x	x	x			x					x															5
Villingili 3	x	x	x			x						x											x			6
																										109

3.3.3 Data storage and organisation

The data collected under the ICOD reef monitoring programme was stored in a customised FOXBASE database at the Marine Research Section. The following account is a brief description of the data files relating to the various aspects of the monitoring programme, held within the database. Six main database files were created:

1. Transent.dbf

2. Samples.dbf
3. Objects.dbf
4. People.dbf
5. Obj_type.dbf
6. Sites.dbf

1. "Transent.dbf" file

This was the main file into which the transect data were transcribed. Each data record in the file contained the following fields (Table 10):

START_DIST	This represents the starting distance for the organism or "object" recorded.
END_DIST	Represents the end distance for the organism recorded.
OBJECT_ID	This is a shortened identification given to each of the recorded organisms or "objects".
PCNT_COVER	This field gives the percentage cover of the organism within the distance covered
NEW_OBJECT	This is an indication of whether the "object" recorded is a new organism or not for a given transect.
SAMPLE_NR	This is sample number by which the characteristics of a given transect data set can be identified in another file (see below).

109 sets of transect data for the 3 transects at the six 6 sites were found in the file.

Table 10. The organisation of data in the main data file (Transent.dbf) in the ICOD reef monitoring database. One whole data set for a transect is shown.

START_DIST	END_DIST	OBJECT_ID	PCNT_COVER	NEW_OBJECT	SAMPLE_NR
0.00	0.20	POR	100	TRUE	1
0.20	0.30	SYN	100	TRUE	1
0.30	0.65	DC	100	TRUE	1
0.65	0.75	GALAX	100	TRUE	1
0.75	1.05	DC	100	TRUE	1
1.05	1.15	SYN	100	TRUE	1
1.15	1.20	DC	100	TRUE	1
1.20	1.30	GONIAS	100	TRUE	1
1.30	1.85	MONTI	100	TRUE	1
1.85	2.30	RL	100	TRUE	1
2.30	2.55	ACT	100	TRUE	1
2.55	2.70	DC	100	TRUE	1
2.70	2.80	GONIAS	100	TRUE	1
2.80	2.85	DC	100	TRUE	1
2.85	2.95	MONTI	100	TRUE	1
2.95	3.35	DC	100	TRUE	1
3.35	3.50	MONTI	100	TRUE	1
3.50	3.55	FUNG	100	TRUE	1
3.55	3.85	ACB	100	TRUE	1
3.85	3.90	MONTI	100	TRUE	1
3.90	4.10	PAV	100	TRUE	1
4.10	4.20	GONIAS	100	TRUE	1
4.20	4.30	PAV	100	TRUE	1
4.30	4.55	OULO	100	TRUE	1
4.55	5.50	RC	50	TRUE	1
4.55	5.50	S	50	TRUE	1
5.50	5.70	POR	100	TRUE	1
5.70	5.75	DC	100	TRUE	1
5.75	5.80	OULO	100	TRUE	1
5.80	6.00	DC	100	TRUE	1
6.00	6.05	PAV	100	TRUE	1
6.05	6.25	DC	100	TRUE	1
6.25	6.35	POR	100	TRUE	1
6.35	6.40	RC	100	TRUE	1
6.40	6.50	MONTI	100	TRUE	1
6.50	6.70	S	100	TRUE	1
6.70	7.00	TA	50	TRUE	1
6.70	7.00	S	50	TRUE	1
7.00	7.60	MONTI	100	TRUE	1
7.60	7.90	ACB	100	TRUE	1
7.90	8.40	S	100	TRUE	1
8.40	8.65	MONTI	100	TRUE	1
8.65	8.70	DC	100	TRUE	1
8.70	8.80	MONTI	100	TRUE	1
8.80	9.30	DC	100	TRUE	1
9.30	9.45	MONTI	100	TRUE	1
9.45	9.55	POR	100	TRUE	1
9.55	9.95	DC	100	TRUE	1
9.95	10.00	PAV	100	TRUE	1
10.00	10.30	DC	100	TRUE	1
10.30	10.45	LEPTAS	100	TRUE	1
10.45	12.20	RC	100	TRUE	1
12.20	12.30	MONTI	100	TRUE	1
12.30	13.60	RC	50	TRUE	1
12.30	13.60	S	50	TRUE	1
13.60	13.75	POR	100	TRUE	1
13.75	13.85	OULO	100	TRUE	1
13.85	14.00	DC	100	TRUE	1
14.00	14.10	ASTREO	100	TRUE	1
14.10	14.30	DC	100	TRUE	1
14.30	14.55	ACB	100	TRUE	1
14.55	14.75	RC	50	TRUE	1
14.55	14.75	S	50	TRUE	1
14.75	14.80	MONTI	100	TRUE	1
14.80	15.20	DC	100	TRUE	1
15.20	15.60	MONTI	100	TRUE	1

Table 10 cont.

15.60	17.65	RC	100	TRUE	1
17.65	17.70	POR	100	TRUE	1
17.70	18.70	RC	50	TRUE	1
17.70	18.70	S	50	TRUE	1
18.70	18.75	ACB	100	TRUE	1
18.75	19.30	RC	100	TRUE	1
19.30	19.40	PAV	100	TRUE	1
19.40	20.00	RC	100	TRUE	1

2. "Objects.dbf" file

This file contained all the organisms or "objects" as they were called in the database files, recorded along the transect line. The records were organised into three columns (see Appendix B) which are explained below:

OBJ_NAME	This column gives the name of the organism or object recorded at the transect.
OBJECT_ID	This column gives the shortened identification for the 'object name'. Objects are identified in the main file (Transent.dbf) by this identification.
OBJ_TYPE	This is the type of the object recorded. Object types were defined in a different file called the "Obj_type" file (see below).

All together 485 different "objects" were listed in the "Objects,dbf" file (Appendix B). Only 185 of these were actually recorded on the transects (See next chapter). It is not clear why all these objects appear in the "Objects.dbf" file. The immediate conclusion is that they are meant to be used in further transect recordings.

3. "Obj_type.dbf" file

This file contained the object types and their description (Table 11). Each object given in the "Objects.dbf" file described above, was placed in one of the six object types given in this file.

Table 11. The "Obj_type.dbf" file of the ICOD database.

OBJ_DESC	OBJ_TYPE
Hard Coral	HC
Soft Coral	SC
Sponge	SP
Algae	AL
Other Organism	OT
Substrate	SU

4. "Samples.dbf" file

This file identifies the characteristics of the sets of transect data for all transects for the six sites. A given set of transect data in the main data file (Transent.dbf) can be defined by four unique features which appear in this file:

i) the site where the transect is.
ii) the number of the transect at that site.
iii) date of data collection.
iv) the person who collected the data.

The file has 10 fields each describing the elements of an individual sample (Appendix C):

SAMPLE_NR	This is the sample number and refers to the order by which the data were entered into the database. Each dataset for a given transect therefore has a unique sample number assigned to it which appears in the order of entry in the main data file (Transent.dbf). By referring to this number all the characteristics of a dataset can be obtained from the "Samples.dbf" file.
SITE	Name of the site where the transect was sampled.
DATE	The date of sampling.
S_TIME	The start time of sampling at the transect.
SAMPLE_BY	Name of the person who sampled the transect.
TRANSCRIBE	Name of the person who transcribed the data from the underwater recording slate to the data entry sheets.
ENTRY_BY	Person who entered the data into the database.
ENTRY_CHK	Person who checked the entered data.
E_TIME	The end time of sampling at the transect.
SAMPLE_TYPE	Refers to the method of sampling. "l" stands for the line intercept method and "p" stands for the point transect method.

Although 126 sets of transect data were listed in this file, some of them were not from the six permanent monitoring sites. The data from sites other than the permanent monitoring sites were not used for the data analysis given in the next chapter.

5. "People.dbf" file

This file contained the names of the persons involved in sampling and entry of data to the database.

6. "Sitename.dbf" file

This file contained the names of the monitoring sites

A database program was written specifically for the entry and storage of the transect data within the database files described above, for the reef sites established for long term monitoring under the ICOD reef monitoring programme.

3.4 Discussion

A major expectation from the monitoring programme related to management was to be able to report to the Government on the state of the marine environment. Establishment of a monitoring programme was one of the most important components of the ICOD project. The general goal of this component of the project was to provide repeatable, quantitative basis for comparisons between representative reef habitats which have been altered by local human activities and those which have been exposed only to natural or large scale environmental variability. The essential task was to quantify variability in community structure and partition it between identifiable sources spatially and temporally. Hypothesis concerning the effects of anthropogenic versus natural environmental changes can be tested over time by comparing carefully paired sites (Birkeland, 1984; Brown, 1988).

Under the ICOD reef monitoring programme, a total of 126 sets of transect data describing benthic community structure had been entered into the computer database by the end of 1992.

While the objective was to detect anthropogenic impacts on the reefs, it is not clear how this can be achieved by sampling and monitoring the current sites alone. Baseline data need to be obtained for comparable control reef sites with no potential human impacts in order to enable comparisons to be made.

None of the six sites appear to be free of anthropogenic influence. The sites are distributed within a busy tourist zone of the country. No control site is apparent with which to compare changes in order to detect human influences.

The methods developed for sampling at the transect level in the ICOD reef monitoring programme depended heavily on a knowledge of extensive and complicated classification system. No widely agreed strategy was formulated for the classification of corals, algae and other groups of organisms recorded at the transect. Hence corals were in some instances identified to species level and sometimes to generic level on a transect by the same observer. This makes it very difficult to analyse and interpret the data. Furthermore a complicated classification system allows only a few observers to use it with confidence. Easily identifiable species of corals and coral growth forms are better classification systems for monitoring programmes. These problems will be discussed further in chapter 4 after data analysis.

Chapter 4. Analysis of data from the ICOD reef monitoring programme

4.1 Introduction

Data analysis and dissemination of information which can be interpreted by decision-makers is vital to the success of any management oriented reef monitoring scheme. The technical design and the long-term success of the monitoring scheme can only be evaluated by the strength of the information produced. Refinements to the design and methodologies can then be made accordingly. The strength and weaknesses of the sampling procedures and methodologies can be established by data analysis and appropriate measures can be then taken to correct any problems encountered.

The line transect distance data collected under the reef monitoring programme of the ICOD project described in the last chapter has not been analysed in a comprehensive manner at the time of this study. A summary of the transect data based on hard coral, soft coral, fleshy algae, coralline algae, substrate type and others were given by Allison, (1992). In this chapter attempts will made to analyse the data and interpret the results.

4.2 Data Analysis

As described in the last chapter, the transect data were stored in a file named "Transent.dbf" in the database along with other relevant files. For the purposes of data analysis in this study, a dBase programme was written to extract individual sets of transect data and their characteristics from the database (Dr. A.J. Edwards, 1993: see Appendix D).

Data were available for 6 reef sites each with 20 meter transects. The line intersect method provides data in the form of distances covered by the 'objects' (coral, algae, sand, rock, etc.) along the transect line. Percentage cover of 'objects' in selected transects were determined using the linear distance data. Comparisons were made between and within sites for coral cover. Observations were also made of changes in coral cover through out the monitoring period at various sites. Since there were more than one samplers of transects, variations between observers were determined.

4.3 Results

4.3.1 Results based on "objects" recorded at transects.

Altogether 185 different "objects" consisting of corals, algae, soft corals, sponges, other animals and substrate types were recorded along transects at the ICOD reef monitoring sites. Table 12. lists the individual "objects" categorised by their six "object types" as defined in the database.

Initial results revealed a lack of repeatability of data recording at the same transect at the same site by various observers over time (Fig. 19). Objects covering less than 0.5% of the transect were lumped as 'miscellaneous' in Fig. 19. Even without carrying out proper statistics, it was not difficult to observe the differences between samples temporally. The differences were very obvious. Different observers have recorded completely different "objects" on temporal observations.

Table 12. List of objects recorded along transects at all sites.

HARD CORALS

OBJ_NAME	OBJECT_ID	OBJ_NAME	OBJECT_ID
Acanthastrea sp.	ACANTH	Gardineroseris	GARD
Acropora Arborescent	ACARB	Goniastrea retiformis	GOR
Acropora Bottlebrush	ACBOT	Goniastrea sp.	GONIAS
Acropora Branching	ACB	Goniopora sp.	GONIOP
Acropora Corymbose	ACCOR	Halomitra sp.	HALO
Acropora Digitate	ACD	Herpolitha sp.	HERPO
Acropora Encrusting	ACE	Hydnophora sp.	HYDNO
Acropora Recruit	ACR	Leptastrea	LEPTAS
Acropora Submassive	ACSM	Leptastrea purpurea	LP
Acropora Tabulate	ACT	Leptastrea transversa	LT
Acropora austera	ACA	Leptos or Pav	LEPAV
Acropora Caespitose	ACCAES	Leptoseris explanata	LEE
Acropora digitifera	ACDI	Leptoseris sp.	LEPTOS
Acropora echinata	ACEC	Live Coral, Detatched	CD
Acropora formosa	ACFORM	Lobophyllia sp.	LOBPHYL
Acropora gemmifera	ACGE	Merulina ampliata	MEA
Acropora humilis	ACHU	Merulina sp.	MERU
Acropora humilus group	ACHUG	Millepora sp.	MILLE
Acropora hyacinthus	ACHY	Montastrea sp.	MONTAS
Acropora hyacinthus 1	ACHY1	Montipora informis	MONI
Acropora hyacinthus 1 group	ACHY1G	Montipora millepora	MONMI
Acropora hyacinthus 2 L&hairy	ACHY2	Montipora sp.	MONTI
Acropora palifera	ACPA	Montipora tuberculosa	MONT
Acropora sp.	AC	Montipora venosa	MONV
Acropora tenuis?	ACTEN	Mycedium sp.	MYCE
Acropora palifera	ACPA	Oulophyllia sp.	OULO
Acropora sp.	AC	Oxypora sp.	OXY
Acropora tenuis?	ACTEN	Pachyseris sp.	PACHY
Alveopora sp.	ALVEO	Pachyseris speciosa	PS
Astreopora sp.	ASTREO	Palauastrea sp.	PALAU
Coral Encrusting	CE	Pavona clavus	PAC
Coral Foliose	CF	Pavona explanulata	PAE
Coral Massive	CM	Pavona maldivensis	PAM
Coral Massive Cerioid	CMC	Pavona sp.	PAV
Coral Massive Plocoid	CMP	Pavona varians	PAVV
Coral Meandroid	CME	Pectinia sp.	PECT
Coral Solitary	CS	Platygyra daedalea	PLD
Cyphastrea chalcidicum	CYC	Platygyra sp.	PLATY
Cyphastrea microphthalma	CYM	Plerogyra sp.	PLERO
Cyphastrea serailia	CYSE	Pocillopora damicornis	POD
Cyphastrea sp.	CYPHA	Pocillopora meandrina	POM
Dendrophyllia	DENDRO	Pocillopora sp.	POC
Diploastrea sp.	DIPLO	Pocillopora verrucosa	POV
Echinophyllia sp.	ECHPHYL	Porites cylindrica	PORC
Echinopora gemmacea	ECG	Porites lichen	PORL
Echinopora hirsutisima	ECH	Porites lobata	PORLO
Echinopora sp.	ECHPOR	Porites lutea	PORLU
Echinopora lamellata	ECL	Porites massive	PORMAS
Favia pallida	FP	Porites sp.	POR
Favia rotumana	FR	Psammocora sp.	PSAM
Favia sp.	FAVIA	Seriatopora sp.	SERI
Favites abdita	FAA	Stylocoeniella guentheri	STG
Favites chinensis	FAC	Symphyllia sp.	SYM
Favites pentagona	FAP	Synarea sp.	SYN
Favites sp.	FAVIT	Tubastraea	TUBA
Fungia sp.	FUNG	Tubipora sp.	TUBI
Galaxea sp.	GALAX	Turbinaria sp.	TURBI

Table 12, Contd...

ALGAE

OBJ_NAME	OBJECT_ID
Algal Assemblage	AA
Calcareous Algae	CA
Crustose Coralline Algae	CCA
Caulerpa - Corkscrew	CCAUL
CA exceeds TA Mosaic	CTA
Dense Alga Sand Mat	DASM
Dead Coral Algae	DCA
Algae Dictyota	DIC
Tydemania	DRED
Algae Filamentous	FA
Filamentous Red Algae "Slime"	FRA
Algae Halimeda	HA
Heavy Turf Algae	HTA
Heavy Turf Algae With Sand	HTAS
Light Algal Sand Mat	LASM
Light Turf Algae	LTA
Light Turf Algae With Sand	LTAS
Light TA in CA Mosaic	LTCA
Lyngbia	LYNG
Algae Macro	MA
Orange Macro Algae	MAO
Maiden Hair Fern Algae	MHA
Medium Turf Algae	MTA
Medium Turf Algae Holding Sand	MTAS
Medium TA in CA Mosaic	MTCA
Algae Padina	PAD
Red Algal Film	RAF
Algal Turf	TA
Turf Algae Holding Sand	TAS
TA exceeds CA Mosaic (TA usual	TCA

SUBSTRATE TYPE

OBJ_NAME	OBJECT_ID
Coral Rock	CR
Dead Coral	DC
Dead Coral in growth position	DCI
Dead Coral Recent	DCR
No Data Taken	ND
Pavement	P
Rubble	R
Rubble Cemented	RC
Rubble Loose	RL
Sand	S
Sand/Rubble Matrix	S/R
Silt	SI

SPONGES

OBJ_NAME	OBJECT_ID
SpongeLikeAdocea	ADOC
Cliona	CLIONA
Sponge Boring	SPB
Sponge Encrust	SPE
Sponge Foliose	SPF
Sponge Plate	SPP
Sponge Vase	SPV

SOFT CORALS

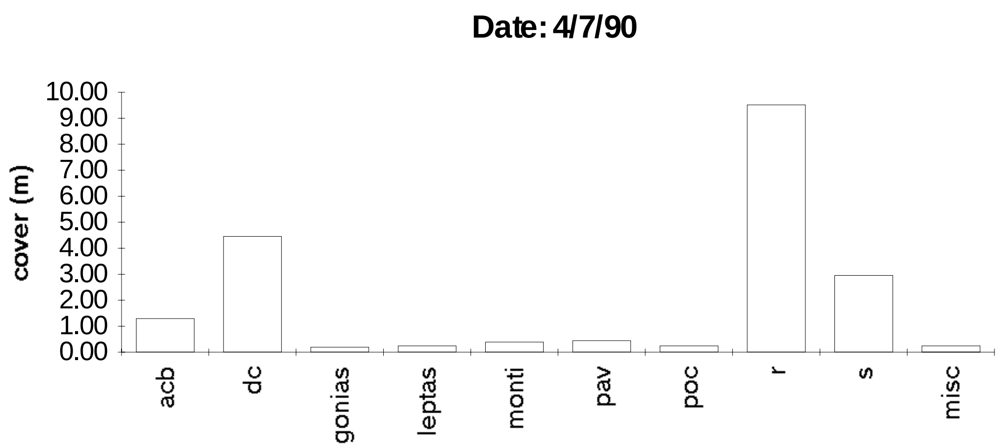
OBJ_NAME	OBJECT_ID
Dendronepthia	DENEP
Gorgonians	GO
Lobophyton sp.	LOBPHY
Nephthea	NEPH
Sarcophyton sp.	SARCO
SoftCoral	SC
Soft Coral Encrusting	SCE
Digitate Encrusting Soft Cora	SCED
Sinularia sp.	SINU

OTHER ANIMALS

OBJ_NAME	OBJECT_ID
UNCERTAIN I.D.	???
Anemone	ANEM
Ascidians	ASC
Black Band Disease	BBD
Bryozoa	BRYO
Didemnum molle	DIDI
Green Colonial Encrust Ascid	GCEA
Feather Hydroids	HYDRO
Palythoa sp. 1 (Large polyp)	PAL
Palythoa sp. 2 (Small polyp)	PAL2
Tridacna maxima	Tmax
Tridacna sp.	TRI
Vermetid Snail	VERM
Zooanthids	ZO

For example, in Fig. 19, on 4/7/90, six coral genera (*Acropora, Goniastrea Leptastrea, Montipora, Pavona, Pocillopora*) were recorded but only three genera (*Montipora, Palaustrea, Porites*) were recorded on 18/9/90. The number of categories recorded varied between samples from 8 on 15/8/90 to 22.on 12/6/92 On the same day (18/9/90), *Goniastrea* and *Montastrea* were recorded on one occasion but not on the other.

Fig. 19. Total distance in meters, covered by various "objects" (corals, algae, soft corals, sponges, other animals and substrate types) along transect 2 at Anchorage Site.



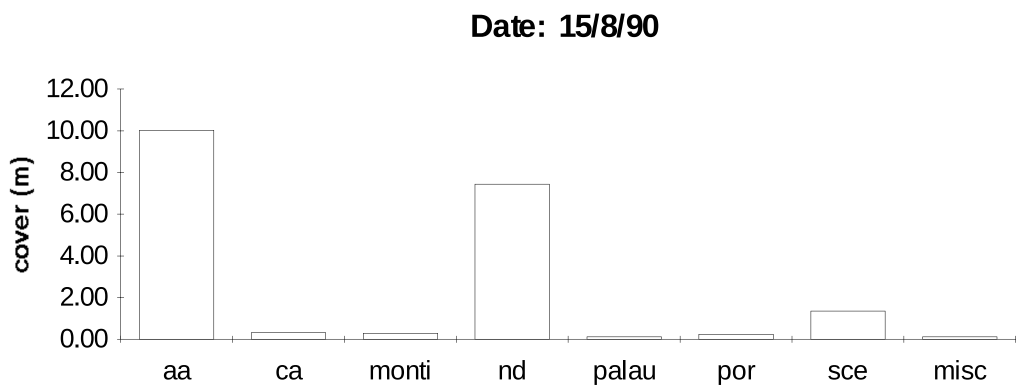
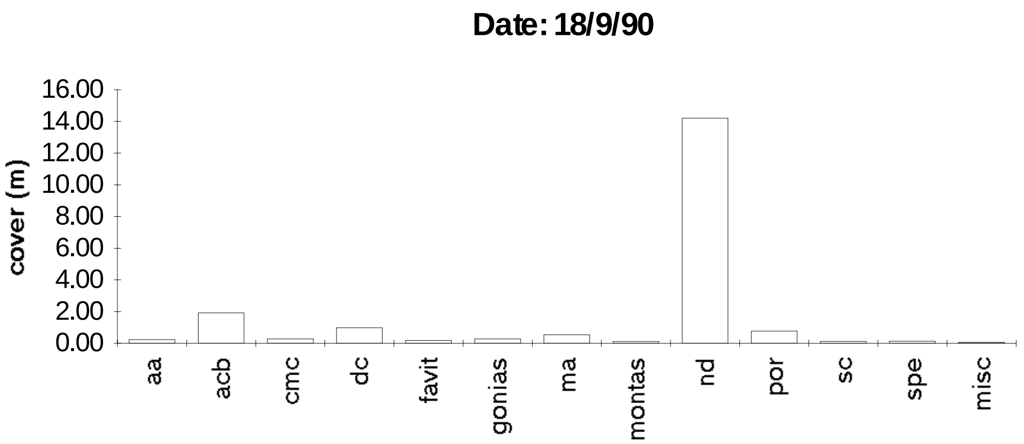
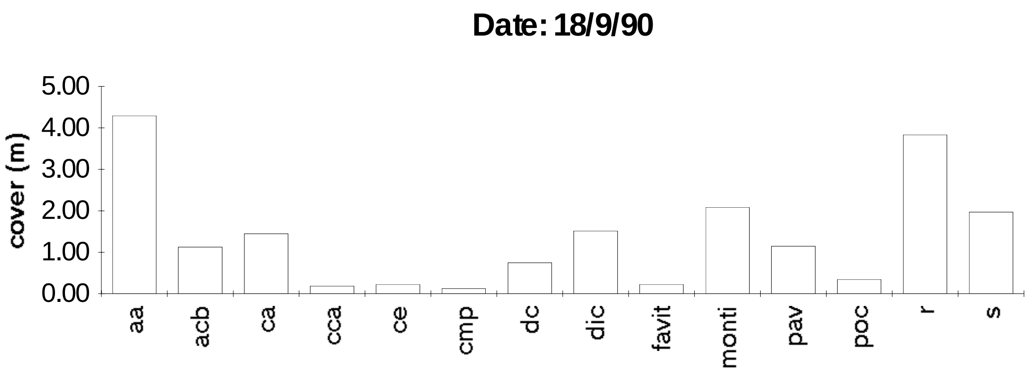


Fig. 19 contd...





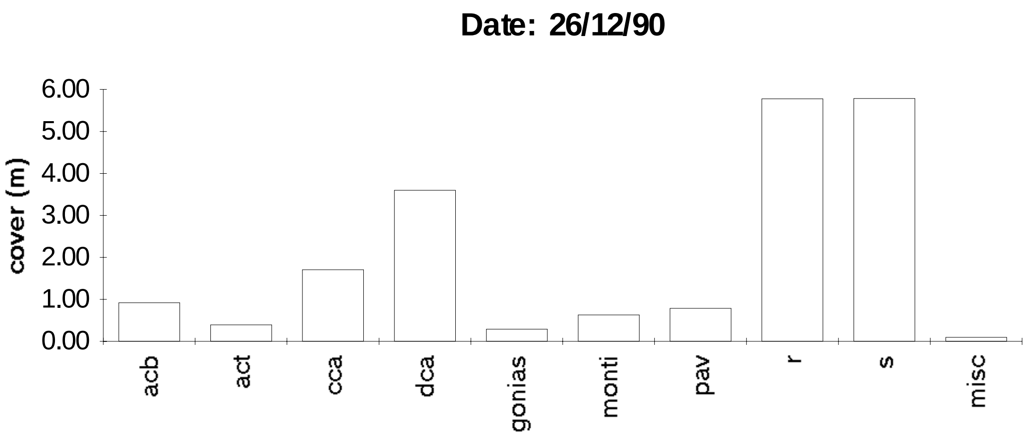
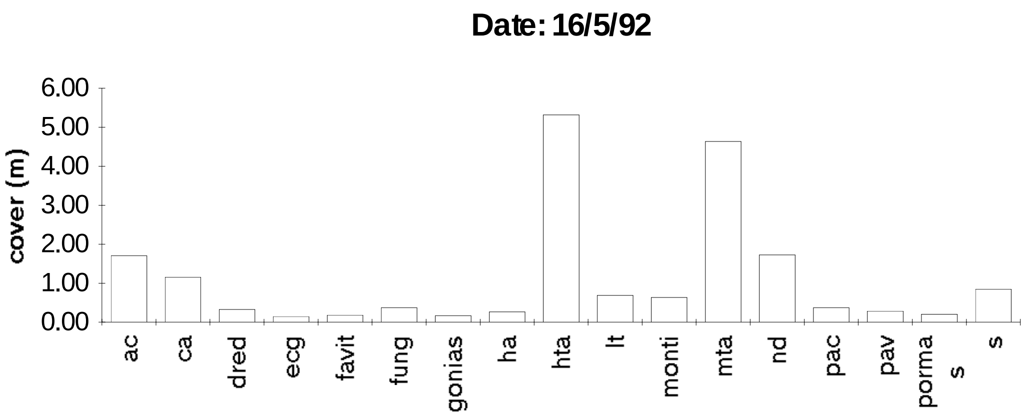
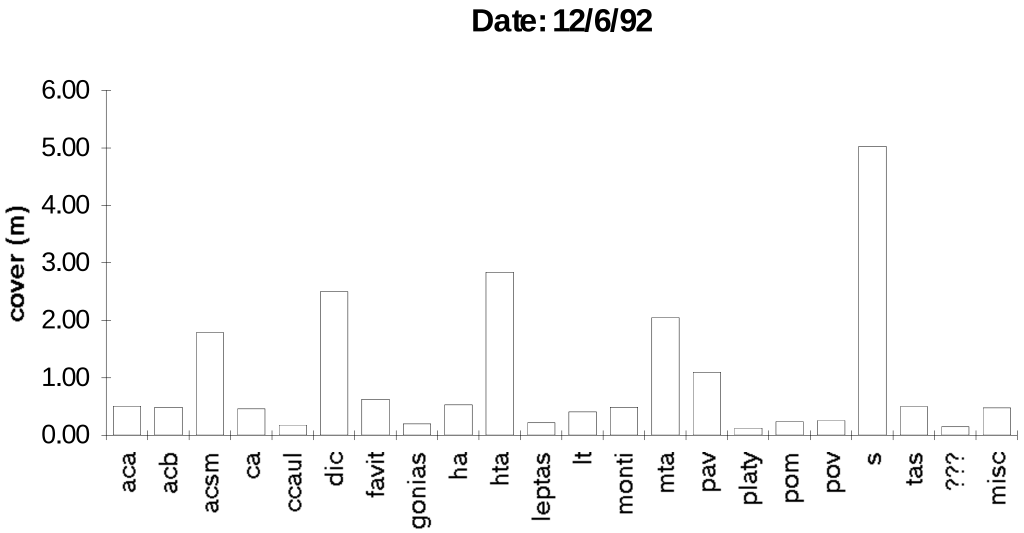
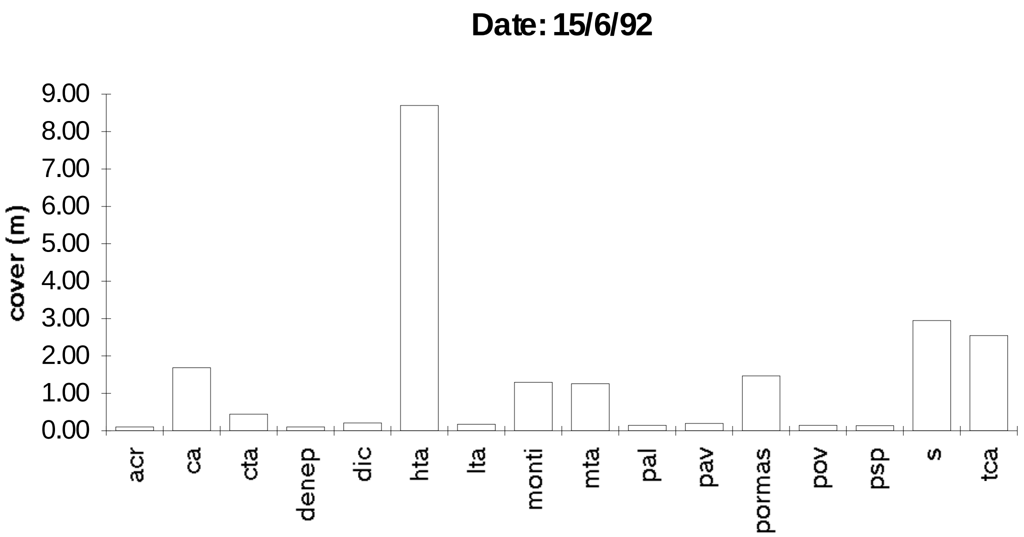


Fig. 19, contd...


Date: 16/5/92
cover (m)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
ac
ca
dred
ecg
favit
fung
gonias
ha
hta
lt
monti
mta
nd
pac
pav
pormas
s


Date: 12/6/92
cover (m)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
aca
acb
acsm
ca
ccaul
dic
favit
gonias
ha
hta
leptas
lt
monti
mta
pav
platy
pom
pov
s
tas
???
misc


Date: 15/6/92
cover (m)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
acr
ca
cta
denep
dic
hta
lta
monti
mta
pal
pav
pormas
pov
psp
s
tca

All transects at all sites showed variations similar to that of Figure 19. Considerable cover of a coral genera recorded on one sampling occasion may not be recorded again on the next occasion sometimes in less than a month, and reappears at a later sampling occasion. In Fig. 19, the growth form 'porites massive' ('pormas') appears only on 16/5/92 and 15/6/92. Corals were sometimes identified to species level and sometimes to generic levels. On occasions coral growth forms were recorded instead of generic or species names. The application of such a complex identification strategy is the main reason for the inconsistencies observed in daily to monthly transect recordings in Figure 19. Hence at this level of object identification, no pattern was observable and what is seen is basically recording noise.

Because of the use of different identification levels (e.g. coral species, genera and growth forms), some of the corals and other "objects" recorded or identified along the transects were not mutually exclusive and hence could be easily misinterpreted for one or the other by the semi-skilled observer. For example, among the 'hard coral' group in (Table 12), "Acropora Branching", "Acropora Arborescent" and the species *Acropora formosa* are all branching forms of *Acropora*.

In the group, 'algae' in Table 12 turf algae was recorded as almost nine different types. Recording to such detail is rarely a possibility in a monitoring scheme developed to involve many observers of varying levels of expertise. A similar overlap of categories was observed in the 'substrate types' group. The substrate types, "rubble", "rubble loose", "sand/rubble mix" are not clearly separable and an observer could record these as one or the other.

The taxonomic detail given is also a concern. Many coral species and even genera are extremely difficult to identify underwater (see later). It is highly unlikely that all of the corals apparently identified at the transects could be done so with confidence. The taxonomic detail sought should reflect the level of expertise available for monitoring.

The temporal variations in the recordings of objects could be attributed to the following problems:

1. The urge to identify coral and other organisms to the highest level possible.
2. The overlap of categories (e.g. heavy turf algae, medium turf algae, algal turf etc.)
3. lack of adequate definition of objects.
4. Movement of the transect.

To overcome this problem objectively it was decided to categorise the present objects into higher taxonomic levels or groupings. This would achieve a degree of lumping of the current "objects". This is an effort to understand whether the variability of recordings was a problem with identification of objects, or due to overlap of categories. It was decided to group the "objects" into 2 identification levels. Two such groupings were established: one, a finer grouping (Group1) and the other a coarser grouping (Group 2) (Table 13). As explained in Chapter 3, each object recorded at the transects was identified by an object identification ("object_id") and its object type ("obj_type"). The new groupings (Group1 and Group2) given in Table 13 are essentially new object types.

The criteria behind the formation of the new taxonomic groupings were that the objects in "group1" could be identified by the semi-skilled observer and that objects in "group2" could be identified by a less skilled group of observers. This also reflects the levels of skill available at the Marine Research Section to undertake transect monitoring. The objects should also be mutually exclusive when growth forms and other non taxonomic categories are employed. For monitoring purposes it is best to use simple growth forms (Physiognomic structural attributes of coral reef benthos, Australian Institute of Marine Science, 1985). and where possible corals were grouped into growth forms. It was possible to lump most *Acropora sp*. into a growth form group.

Table 13 "Objects" recorded at the transects, obtained from the "Objects.dbf" file in the ICOD database. Group1 and Group2 are the new object identifications drawn up for the purposes of data analysis (see text for details of groupings).

ALGAE:

OBJ_NAME	OBJECT_ID	OBJ_TYPE	GROUP1	GROUP2
Algal Assemblage	AA	AL	AL	AA
Calcareous Algae	CA	AL	CA	AA
Crustose Coralline Algae	CCA	AL	CA	AA
Caulerpa - Corkscrew	CCAUL	AL	MA	AA
CA exceeds TA Mosaic	CTA	AL	TA	TA
Dense Alga Sand Mat	DASM	AL	FA	AA
Dead Coral Algae	DCA	AL	FA	AA
Algae Dictyota	DIC	AL	MA	AA
Tydemania	DRED	AL	MA	AA
Algae Filamentous	FA	AL	FA	AA
Filamentous Red Algae "Slime"	FRA	AL	FA	AA
Algae Halimeda	HA	AL	HA	AA
Heavy Turf Algae	HTA	AL	TA	TA
Heavy Turf Algae With Sand	HTAS	AL	TA	TA
Light Algal Sand Mat	LASM	AL	FA	AA
Light Turf Algae	LTA	AL	TA	TA
Light Turf Algae With Sand	LTAS	AL	TA	TA
Light TA in CA Mosaic	LTCA	AL	TA	TA
Lyngbia	LYNG	AL	MA	AA
Algae Macro	MA	AL	MA	AA
Orange Macro Algae	MAO	AL	MA	AA
Medium Turf Algae	MTA	AL	TA	TA
Medium Turf Algae Holding Sand	MTAS	AL	TA	TA
Medium TA in CA Mosaic	MTCA	AL	TA	TA
Algae Padina	PAD	AL	PAD	PAD
Red Algal Film	RAF	AL	FA	AA
Sand Algae Combination	SA	AL	TA	AA
Algal Turf	TA	AL	TA	TA
Turf Algae Holding Sand	TAS	AL	TA	TA
TA exceeds CA Mosaic (TA usual)	TCA	AL	TA	TA

Table 13, contd...

CORALS:

Acropora sp.	AC	HC	AC	AC
Acropora austera	ACA	HC	ACB	AC
Acanthastrea sp.	ACANTH	HC	MUSSID	UID
Acropora Branching	ACB	HC	ACB	AC
Acropora Bottlebrush	ACBOT	HC	ACBOT	AC
Acropora caespitose	ACCAES	HC	ACB	AC
Acropora Corymbose	ACCOR	HC	ACD	AC
Acropora Digitate	ACD	HC	ACD	AC
Acropora digitifera	ACDI	HC	ACD	AC
Acropora Encrusting	ACE	HC	ACE	AC
Acropora echinata	ACEC	HC	ACBOT	AC
Acropora formosa	ACFORM	HC	ACB	AC
Acropora gemmifera	ACGE	HC	ACD	AC
Acropora humilis	ACHU	HC	ACD	AC
Acropora humilus group	ACHUG	HC	ACD	AC
Acropora hyacinthus	ACHY	HC	ACT	AC
Acropora hyacinthus 1	ACHY1	HC	ACT	AC
Acropora hyacinthus 1 group	ACHY1G	HC	ACT	AC
Acropora hyacinthus 2 L&hairy	ACHY2	HC	ACT	AC
Acropora palifera	ACPA	HC	ACPA	AC
Acropora Recruit	ACR	HC	AC	AC
Acropora Submassive	ACSM	HC	ACD	AC
Acropora Tabulate	ACT	HC	ACT	AC
Acropora tenuis?	ACTEN	HC	ACT	AC
Alveopora sp.	ALVEO	HC	ALVEO	POR
Astreopora sp.	ASTREO	HC	ASTREO	UID
Live Coral, Detatched	CD	HC	DC	DC
Coral Encrusting	CE	HC	CE	CE
Coral Foliose	CF	HC	CF	CF
Coral Massive	CM	HC	CM	CM
Coral Massive Cerioi	CMC	HC	CM	CM
Coral Meandroid	CME	HC	CM	CM
Coral Massive Plocoi	CMP	HC	CM	CM
Coral Solitary	CS	HC	CS	CS
Cyphastrea chalcidicum	CYC	HC	FAVID	FAVID
Cyphastrea microphthalma	CYM	HC	FAVID	FAVID
Cyphastrea sp.	CYPHA	HC	FAVID	FAVID
Cyphastrea serailia	CYSE	HC	FAVID	FAVID
Dendrophyllia	DENDRO	HC	DEND	DEND
Diploastrea sp.	DIPLO	HC	DIPLO	FAVID
Echinopora gemmacea	ECG	HC	FAVID	FAVID
Echinopora hirsutisima	ECH	HC	FAVID	FAVID
Echinophyllia sp.	ECHPHYL	HC	PECT	PECT
Echinopora sp.	ECHPOR	HC	FAVID	FAVID
Echinopora lamellata	ECL	HC	FAVID	FAVID
Favites abdita	FAA	HC	FAVID	FAVID
Favites chinensis	FAC	HC	FAVID	FAVID
Favites pentagona	FAP	HC	FAVID	FAVID
Favia sp.	FAVIA	HC	FAVID	FAVID
Favites sp.	FAVIT	HC	FAVID	FAVID
Favia pallida	FP	HC	FAVID	FAVID
Favia rotumana	FR	HC	FAVID	FAVID
Fungia sp.	FUNG	HC	CS	CS
Galaxea sp.	GALAX	HC	GALAX	GALAX

Table 13, contd...

Gardineroseris	GARD	HC	GARD	AGAR
Goniastrea sp.	GONIAS	HC	GONIAS	FAVID
Goniopora sp.	GONIOP	HC	GONIOP	GONIOP
Goniastrea retiformis	GOR	HC	GONIAS	FAVID
Halomitra sp.	HALO	HC	CS	CS
Herpolitha sp.	HERPO	HC	CS	CS
Hydnophora sp.	HYDNO	HC	MERU	MERU
Leptoseris explanata	LEE	HC	LEPAV	AGAR
Leptos or Pav	LEPAV	HC	LEPAV	AGAR
Leptastrea	LEPTAS	HC	LEPTAS	FAVID
Leptoseris sp.	LEPTOS	HC	LEPAV	AGAR
Lobophyllia sp.	LOBPHYL	HC	MUSSID	MUSSID
Leptastrea purpurea	LP	HC	LEPTAS	FAVID
Leptastrea transversa	LT	HC	LEPTAS	FAVID
Merulina ampliata	MEA	HC	MERU	MERU
Merulina sp.	MERU	HC	MERU	MERU
Millepora sp.	MILLE	HC	MILLE	MILLE
Montipora informis	MONI	HC	MONTI	MONTI
Montipora millepora	MONMI	HC	MONTI	MONTI
Montipora tuberculosa	MONT	HC	MONTI	MONTI
Montastrea sp.	MONTAS	HC	MONTAS	FAVID
Montipora sp.	MONTI	HC	MONTI	MONTI
Montipora venosa	MONV	HC	MONTI	MONTI
Mycedium sp.	MYCE	HC	PECT	PECT
Oulophyllia sp.	OULO	HC	FAVID	FAVID
Oxypora sp.	OXY	HC	PECT	PECT
Pavona clavus	PAC	HC	PAV	AGAR
Pachyseris sp.	PACHY	HC	PACHY	AGAR
Pavona explanulata	PAE	HC	PAV	AGAR
Palauastrea sp.	PALAU	HC	PALAU	POC
Pavona maldivensis	PAM	HC	PAV	AGAR
Pavona sp.	PAV	HC	PAV	AGAR
Pavona varians	PAVV	HC	PAV	AGAR
Pectinia sp.	PECT	HC	PECT	PECT
Platygyra sp.	PLATY	HC	PLATY	FAVID
Platygyra daedalea	PLD	HC	PLATY	FAVID
Plerogyra sp.	PLERO	HC	PLERO	PLERO
Pocillopora sp.	POC	HC	POC	POC
Pocillopora damicornis	POD	HC	POD	POC
Pocillopora meandrina	POM	HC	POC	POC
Porites sp.	POR	HC	POR	POR
Porites cylindrica	PORC	HC	POR	POR
Porites lichen	PORL	HC	POR	POR
Porites lobata	PORLO	HC	POR	POR
Porites lutea	PORLU	HC	POR	POR
Porites massive	PORMAS	HC	POR	POR
Pocillopora verrucosa	POV	HC	POV	POC
Pachyseris speciosa	PS	HC	PACHY	AGAR
Psammocora sp.	PSAM	HC	PSAM	PSAM
Psammacora profundacella?	PSP	HC	PSAM	PSAM
Sandolitha dentata	SD	HC	CS	CS
Seriatopora sp.	SERI	HC	SERI	POC
Stylocoeniella guentheri	STG	HC	STYLOC	UID
Symphyllia sp.	SYM	HC	MUSSID	MUSSID
Synarea sp.	SYN	HC	SYN	POR

Table 13, contd...

Tubastraea	TUBA	HC	DEND	DEND
Tubipora sp.	TUBI	HC	TUBI	TUBI
Turbinaria sp.	TURBI	HC	DEND	DEND
Caulastrea tumida	CAT	HC	UID	UID
OTHER ANIMALS				
UNCERTAIN I.D.	???	OT	UID	UID
Anemone	ANEM	OT	OTH	OTH
Ascidians	ASC	OT	OTH	OTH
Black Band Disease	BBD	OT	OTH	OTH
Bryozoa	BRYO	OT	OTH	OTH
Didemnum molle	DIDI	OT	OTH	OTH
Green Colonial Encrust Ascid	GCEA	OT	OTH	OTH
Feather Hydroids	HYDRO	OT	OTH	OTH
Palythoa sp. 1 (Large polyp)	PAL	OT	OTH	OTH
Palythoa sp. 2 (Small polyp)	PAL2	OT	OTH	OTH
Tridacna maxima	Tmax	OT	OTH	OTH
Tridacna sp.	TRI	OT	OTH	OTH
Vermetid Snail	VERM	OT	OTH	OTH
Zooanthids	ZO	OT	OTH	OTH
SOFT CORALS				
Dendronepthia	DENEP	SC	SC	SC
Gorgonians	GO	SC	OTH	OTH
Lobophyton sp.	LOBPHY	SC	SC	SC
Nephthea	NEPH	SC	SC	SC
Sarcophyton sp.	SARCO	SC	SC	SC
SoftCoral	SC	SC	SC	SC
Soft Coral Encrusting	SCE	SC	SC	SC
Digitate Encrusting Soft Cora	SCED	SC	SC	SC
Sinularia sp.	SINU	SC	SC	SC
SPONGES				
SpongeLikeAdocea	ADOC	SP	SP	SP
Cliona	CLIONA	SP	SP	SP
Sponge Boring	SPB	SP	SP	SP
Sponge Encrust	SPE	SP	SP	SP
Sponge Foliose	SPF	SP	SP	SP
Sponge Plate	SPP	SP	SP	SP
Sponge Vase	SPV	SP	SP	SP
SUBSTRATE TYPES				
Coral Rock	CR	SU	SUB	SUB
Dead Coral	DC	SU	DC	SUB
Dead Coral in growth position	DCI	SU	DC	SUB
Dead Coral Recent	DCR	SU	DC	SUB
No Data Taken	ND	SU	SUB	SUB
Pavement	P	SU	SUB	SUB
Rubble	R	SU	S/R	S/R
Rubble Cemented	RC	SU	S/R	S/R
Rubble Loose	RL	SU	S/R	S/R
Sand	S	SU	S/R	S/R
Sand/Rubble Matrix	S/R	SU	S/R	S/R
Silt	SI	SU	SUB	SUB

NEW IDENTIFICATION LEVELS - 'GROUP1' AND 'GROUP2'.(See Table 13)

CORALS:

114 different types of corals consisting of individual species, genera, and growth forms were recorded along the transects (see Table 12). New taxonomic levels and categorisation of growth forms were achieved as below, taking each object into perspective, and judging the degree to which they can be identified by the semi-skilled observer.

GROWTH FORMS OF ACROPORIDS

Nine different growth forms of acroporids were identified by the ICOD reef monitoring programme:

- Acropora Arborescent
- Acropora Bottlebrush
- Acropora Branching
- Acropora Caespitose
- Acropora Corymbose
- Acropora Digitate
- Acropora Encrusting
- Acropora Submassive
- Acropora Tabulate

These growth forms were described by Veron, (1986) and some of them are shown in Fig. 20.

Figure 20 Growth forms used to describe corals.

Many of these growth forms are not entirely separable and depends to a large extent on the observer's perception. Only expert observation can identify some of these growth forms confidently. For example, the growth forms 'Acropora Branching', 'Arborescent' and 'Caespitose' are all essentially branching forms (see Fig. 20). Therefore these three forms were lumped into one group as 'Acropora Branching' under the new 'Group1' identification level.

The growth forms 'Acropora Corymbose', 'Digitate' and 'Submassive' also have one fundamental similarity. They are all finger like in their appearance. These three forms were thus lumped into one group as 'Acropora digitate'. In most instances the 'digitate' growth forms can be distinguished from 'branching' forms (Fig. 20).

The growth forms 'Acropora Bottlebrush', 'Encrusting' and 'Tabulate' are all distinct and can be generally recognised (Figure 20).

For the coarse level of grouping (Group2), acroporids were lumped into one group: 'Acropora' (AC).

OTHER CORAL GROWTH FORMS

Seven other growth forms of corals were recorded along transects in the ICOD reef monitoring programme (Table 13) They are:

- Coral Encrusting
- Coral Foliose
- Coral Massive
- Coral Massive Cerioid
- Coral Massive Plociod
- Coral Meandroid
- Coral Solitary

The growth forms 'coral massive cerioid', 'coral massive plocoid' and 'coral meandroid', all refer to a distinctive morphology of the corallum (Wood, 1983). While recognising that these corallum morphologies can be interpreted in coral skeletons for identification purposes, it is not a useful strategy to employ such features in describing just what type of a massive coral a particular species is. It is confusing to have such closely resembling groupings. The growth form is the important term. The 4 massive growth forms recorded in at the transects were lumped into one group as 'coral massive' for the two new groupings.

The growth form, 'Coral encrusting' and 'Coral solitary' can be generally recognised. These were left as they were in the two new groupings.

ACROPORIDAE:

Acropora sp.

The genus *Acropora* can be identified by most observers underwater although it is difficult identify species (Veron, 1986; Wood, 1983). This level of identification was judged to be possible for both groups of observers.

Acropora austrea

A. austrea colonies are arborescent to caespitose (Veron, 1986). It does not resemble any other species closely, but its wide range of growth forms makes it difficult to identify (Veron, 1986). It can however be identified as a branching form of *Acropora*. This species was thus placed in the 'Acropora Branching' group.

Acropora digitifera, Acropora humilis, A. gemmifera

Colonies of these three species are corymbose to digitate (Veron, 1986). Their similarities in growth form can lead to misidentification in the field by the semi-skilled observer and thus they are placed in one group, the 'Acropora humilis' group, as suggested by Veron (1986). This group was placed in the 'Acropora Digitate' group for the new groupings.

Acropora echinata

A. echinata is an uncommon but a very conspicuous coral (Veron, 1986). It is fairly easy to identify underwater by its distinctive growth form (bottlebrush) and blue to purple colour. For the purposes of grouping, this species was placed under the growth form 'Acropora Bottlebrush'.

Acropora formosa

A. formosa colonies are arborescent, usually forming thickets in lagoons (Veron, 1986). It is a common and dominant coral on most reefs and can be readily identified. However, in order to have all growth form groupings for *Acropora*, this species was place under the 'Acropora Branching' group.

Acropora hyacinthus group

This grouping was discussed by Veron, (1986). The group comprises of flat table or plate-like colonies. *A. hyacinthus* is one of the most abundant corals of the upper reef slopes and outer reef flats. The 4 types of *A. hyacinthus* recorded at the transects (see Table 13) were placed under the 'Acropora Tabulate' group for the new level of categorisation.

Acropora palifera

A. palifera are encrusting plates, ridges, or columns without axial corallites (Veron, 1986). It is an abundant coral but due to its wide ranging growth forms, It can be difficult to identify to the species level. For the semi-skilled observer, *A. palifera* is most likely to be identified as an encrusting growth form. Therefore this species was placed under 'Acropora Encrusting' group.

Acropora tenuis

Colonies are corymbose plates (Veron, 1986). It is most likely to be identified as 'Acropora Tabulate'.

Montipora

Montipora colonies display many different growth forms. Most commonly *Montipora* are confused with *Porites*. The foliacous types are usually unmistakable (Wood, 1983). The genus is possible to be identified to generic level by semi skilled observers. Four species of Montipora were identified at the transects. These were grouped into generic levels in the new 'group1' category as well as 'group2' category.

Astreopora

This genus resembles *Turbinaria* (Dendrophyllidae) and can only be confused with this genus (Veron, 1986).

PORITIDAE

Three genera (*Alveopora, Goniopora, Porites*) and one sub-genus (*Synaraea*) of this family were recorded at the transects.

Alveopora

Alveopora forms massive, plate-like or branching colonies (Wood,1983). The skeleton of this genus is unmistakable but the living coral can occasionally be mistaken for *Goniopora* or *Porites*. It was decided that the genus can be identified under water by the semi skilled group of observers.

Goniopora

Goniopora can be readily distinguished underwater by its long polyps and prominent tentacles. (Wood, 1983; Veron, 1986). It is unusual to see other corals grouping up close to a *Goniopora* species in a natural situation due to its aggressiveness (Veron, 1986). The genus can be identified by most observers.

Porites

This genus demonstrates many growth forms ranging from branching to massive types (Wood, 1983). In most cases it can be readily distinguished underwater. only skeletal examination can however lead to positive identification of species. The semi-skilled group of observers could identify the poritiids to genus levels. The 5 species of *Porites* (Table 13) recorded at the transects were grouped in to the genus level. The growth form 'Porites massive' was also combined into this generic grouping.

Synaraea

This sub-genus can sometimes be confused with *Montipora* underwater (Veron, 1986). It was left at the generic level for the 'group1' grouping.

For the second level of grouping the genera of poritiids were lumped in to one group at the family level.

FAVIIDAE

Most faviid corals are difficult to identify to species or even to generic levels underwater (Veron, 1986; Wood, 1983). Positive identification can only be achieved by skeletal examination. Eleven genera of this family were recorded at transects in the ICOD reef monitoring programme. All the faviid corals were lumped into one group as 'Faviid' in the 'Group2' level of identification.

Favites

Three species of *Favites* were recorded at the transects. The few recording of these species (five) in the whole of the data demonstrates the difficulty in identification of species of this genus.

Favites can be mistaken for other faviid genera sometimes (Wood, 1983). Only skeletal examination can lead to positive identification. For the 'Group1' grouping the 3 species in the genus were lumped into the family level 'Faviid' grouping.

Favia

The colonies of *Favia* are mostly massive but there are also encrusting forms (Wood, 1983). The genus can be confused with many other genera of the same family and are difficult to identify underwater (Wood, 1983; Veron, 1986). Two species of *Favia* were recorded at transects occasionally. The two species in the genus were lumped at family level in the 'group1' category.

Goniastrea

Goniastrea colonies are mostly massive and can sometimes be confused with other faviids. It was however considered to be identifiable to generic level underwater. Only once was a species was recorded on the transects.

Platygyra

Colonies of *Platygyra* display many growth forms (Wood, 1983). It also shows similarities to other faviid corals. Only one species was recorded at the transects. The genus was considered to be identifiable by the semi-skilled group of observers at genus level.

Oulophyllia

The genus *Oulophyllia* can be mistaken for *Platygyra* and *Favites* (Veron, 1986) due to the similarities in corallum arrangement. It is unlikely to be positively identified underwater by the semi-skilled observers. The genus was grouped into family level.

Montastrea

Colonies can be sometimes confused underwater with *Favia* (Wood, 1983). It can be however recognised from other faviid genera by its extratentacular budding of polyps. The genus was considered to be identifiable by the semi skilled group at the genus level.

Diploastrea

Diploastrea colonies reach very large sizes (Veron, 1986) and is an easily recognised coral genus. The genus can be identified underwater.

Leptastrea

Two species of *Leptastrea* were recorded at the transects. The genus is similar to *Favites* and *Goniastrea* (Wood, 1983). The genus was considered to be identifiable to generic level.

Cyphastrea

Cyphastrea colonies are have many growth forms and can resemble other faviids (Veron, 1986). The genera can also be confused with genera of other families such as *Astreopora* (Wood ,1983). Three species of *Cyphastrea* were recorded at the transects. It does not seem an easy genus to be identified underwater with confidence and was thus grouped at family level as 'faviid' for 'group1' observers.

Echinopora

This genus has a wide ranging growth form, more than any other genus of corals (Veron, 1986). This should make it very difficult to be identified underwater confidently. Four species of the genus were recorded. All four species in the genus were lumped at family level in the 'group 1' grouping.

CARYOPHYLLIIDAE

Only one genus (*Plerogyra*) of this family was recorded just once at a transect. *Plerogyra* is a very conspicuous genus and can be readily identified underwater (Veron, 1986). Living corals have vesicles during the day which are very distinct.

DENDROPHYLLIIDAE

Three genera of this family were recorded at transects: *Turbinaria*, *Dendrophyllia*, and *Tubastrea*. *Turbinaria* is a difficult genus to identify and resembles the genera of other families as well (Wood, 1983). *Dendrophyllia* and *Tubastrea* are similar and closely resemble each other (Veron, 1986). These three genera were lumped at family level in both of the new groupings.

ASTROCOENIIDAE

One species of the genus *Stylocoeniella* was recorded. The genus *Stylocoeniella* resembles *Porites* and *Palaustrea* underwater (Veron, 1986). Only skeletal examination could reveal the differences. The species was replaced at the genus level for the 'group1' grouping and as an uncertain identification (UID) in the 'group2' grouping.

POCILLOPORIDAE

All pocilloporids were lumped into family level in the second level of grouping (group 2).

Pocillopora

Pocilloporids are easily identified by the presence of verrucae which cover the colonies (Veron, 1986). Three species of *Pocillopora* were recorded. The species *P.verrucosa* and *P.damicornis* can be identified by most observers. *P.meandrina* can be confused with *P. verrucosa* (Veron, 1986) and hence was replaced at the generic level for the 'group1' grouping.

Seriatophora

This genus can be identified by its characteristic growth form and arrangement of corallites (Veron, 1986; Wood, 1983).

Palaustrea

Palaustrea resembles closely to *Porites* and only close inspection of corallites can reveal the differences (Veron, 1986).

SIDERASTREIDAE

Psammocora

The distinct appearance of septal arrangement giving the corallum a petalloid appearance makes this genus possible to be recognised at the generic level.

AGARICIDAE

All agariciids were placed in one group at family level for the 'group2' groupings. Four genera of this family were recorded.

Pavona

Four species of this genus were recorded. The calix arrangement of this genus can in most instances lead to identification of the genera. Identification of this genus was considered to be possible by the semi-skilled group of observers ('group1').

Leptoseris

Only one species was recorded. In most cases this genus can be identified by the leafy corallum (Wood, 1983). It can however be sometimes mistaken for *Pavona*. Hence this genus was grouped at family level.

Gardineroseris

This genus can also be mistaken for *Pavona* (Veron, 1986). For 'group1' this genus was grouped at family level.

Pachyseris

This is a well defined genus that is not easily confused with other coral genera (Wood, 1983). The parallel arrangement of septa and the leafy appearance makes the genus distinct. *Pachyseris* was considered to be identifiable to the genus level in the fine level of grouping ('Group1').

FUNGIIDAE

Three genera of this family were recorded: *Fungia*, *Herpolitha*, and *Halomitra*. These solitary corals are easily recognised as 'solitary corals'. They were grouped as 'Coral Solitary' for both groupings.

OCULINIDAE

Galaxea

Galaxea is a distinctive genera with groups of long branching corallites (Veron, 1986). The genus can be identified at the generic level by most observers.

PECTINIDAE

The growth form of this family is distinct. Colonies are basically laminar or foliaceous. The four genera recorded at the transects can be confused with one another. For both groupings the genera were lumped at the family level.

MUSSIDAE

Three genera were recorded: *Acanthastrea*, *Lobophyllia* and *Symphyllia*. *Acanthastrea* may present identification problems due to its resemblance to faviids (Veron, 1986). *Lobophyllia* and *Symphyllia* are similar to each other. They can however be recognised as mussids by the semiskilled group of observers. All three genera were grouped as 'mussids' for both groupings

MERULINIDAE

The two genera (*Hydnophora* and *Merulina*), can be confused with faviids (Veron, 1986). Two species of *Merulina* were recorded. For the 2 new groupings, *Merulina* and *Hydnophora* were lumped into their family level.

MILLEPORIDAE

The genus *Millepora* is easily recognised underwater. It was recorded as *Millepora* for both grouping levels.

A summary of the degree of lumping achieved by the groupings (group1 and group2) is given in Table 14. The 114 types of coral recorded at the transects were reduced to 44 types in 'group1' and to 22 types in 'group2' groupings.

Table 14. Comparisons of the levels of lumping achieved for the 'ICOD objects', with group1 and group2 groupings.

CORALS:

OBJECT NAME	OBJECTS_ID	GROUP1	GROUP2
Acropora sp.	AC	AC	AC
Acropora Recruit	ACR		
Acropora austera	ACA	ACB	
Acropora Branching	ACB		
Acropora caespitose	ACCAES		
Acropora formosa	ACFORM		
Acropora Bottlebrush	ACBOT	ACBOT	
Acropora echinata	ACEC		
Acropora Corymbose	ACCOR	ACD	
Acropora Digitate	ACD		
Acropora digitifera	ACDI		
Acropora gemmifera	ACGE		
Acropora humilis	ACHU		
Acropora humilus group	ACHUG		
Acropora Submassive	ACSM		
Acropora Encrusting	ACE	ACE	
Acropora palifera	ACPA		
Acropora hyacinthus	ACHY	ACT	
Acropora hyacinthus 1	ACHY1		
Acropora hyacinthus 1 group	ACHY1G		
Acropora hyacinthus 2 L&hairy	ACHY2		
Acropora Tabulate	ACT		
Acropora tenuis?	ACTEN		
Gardineroseris	GARD	GARD	AGAR
Leptoseris explanata	LEE	LEPAV	
Leptos or Pav	LEPAV		
Leptoseris sp.	LEPTOS		
Pachyseris sp.	PACHY	PACHY	
Pachyseris speciosa	PS		
Pavona clavus	PAC	PAV	
Pavona explanulata	PAE		
Pavona maldivensis	PAM		
Pavona sp.	PAV		
Pavona varians	PAVV		
Coral Encrusting	CE	CE	CE
Coral Foliose	CF	CF	CF
Coral Massive	CM	CM	CM
Coral Massive Cerioi	CMC		
Coral Meandroid	CME		
Coral Massive Plocoi	CMP		
Coral Solitary	CS	CS	CS
Fungia sp.	FUNG		
Halomitra sp.	HALO		
Herpolitha sp.	HERPO		
Sandolitha dentata	SD		
Live Coral, Detatched	CD	DC	DC
Dendrophyllia	DENDRO	DEND	DEND
Tubastraea	TUBA		
Turbinaria sp.	TURBI		
Diploastrea sp.	DIPLO	DIPLO	FAVID
Cyphastrea chalcidicum	CYC	FAVID	
Cyphastrea microphthalma	CYM		
Cyphastrea sp.	CYPHA		
Cyphastrea serailia	CYSE		
Echinopora gemmacea	ECG		
Echinopora hirsutisima	ECH		
Echinopora sp.	ECHPOR		
Echinopora lamellata	ECL		
Favites abdita	FAA		
Favites chinensis	FAC		
Favites pentagona	FAP		
Favia sp.	FAVIA		
Favites sp.	FAVIT		
Favia pallida	FP		

Table 14, contd

Favia rotumana	FR		
Oulophyllia sp.	OULO		
Goniastrea sp.	GONIAS	GONIAS	
Goniastrea retiformis	GOR		
Leptastrea	LEPTAS	LEPTAS	

Leptastrea purpurea	LP		
Leptastrea transversa	LT		
Montastrea sp.	MONTAS	MONTAS	
Platygyra sp.	PLATY	PLATY	
Platygyra daedalea	PLD		
Galaxea sp.	GALAX	GALAX	GALAX
Goniopora sp.	GONIOP	GONIOP	GONIOP
Hydnophora sp.	HYDNO	MERU	MERU
Merulina ampliata	MEA		
Merulina sp.	MERU		
Millepora sp.	MILLE	MILLE	MILLE
Montipora informis	MONI	MONTI	MONTI
Montipora millepora	MONMI		
Montipora tuberculosa	MONT		
Montipora sp.	MONTI		
Montipora venosa	MONV		
Lobophyllia sp.	LOBPHYL	MUSSID	MUSSID
Symphyllia sp.	SYM		
Echinophyllia sp.	ECHPHYL	PECT	PECT
Mycedium sp.	MYCE		
Oxypora sp.	OXY		
Pectinia sp.	PECT		
Plerogyra sp.	PLERO	PLERO	PLERO
Palauastrea sp.	PALAU	PALAU	POC
Pocillopora sp.	POC	POC	
Pocillopora meandrina	POM		
Pocillopora damicornis	POD	POD	
Pocillopora verrucosa	POV	POV	
Seriatopora sp.	SERI	SERI	
Alveopora sp.	ALVEO	ALVEO	POR
Porites sp.	POR	POR	
Porites cylindrica	PORC		
Porites lichen	PORL		
Porites lobata	PORLO		
Porites lutea	PORLU		
Porites massive	PORMAS		
Synarea sp.	SYN	SYN	
Psammocora sp.	PSAM	PSAM	PSAM
Psammacora profundacella?	PSP		
Tubipora sp.	TUBI	TUBI	TUBI
Astreopora sp.	ASTREO	ASTREO	UID
Acanthastrea sp.	ACANTH	MUSSID	
Stylocoeniella guentheri	STG	STYLOC	
Caulastrea tumida	CAT	UID	
TOTAL	**114**	**44**	**22**

<u>ALGAE:</u>

The algal groups employed for the monitoring programme were grouped into seven categories for the first level grouping and are given below: (Table 13)

- Algal assemblages (AL)
- Calcareous algae (CA)
- Macro algae (MA)
- Turf algae (TA)
- Filamentous algae (FA)
- Halimeda (HA)
- Padina (PAD)

For the second level of grouping the algae were grouped into three categories: Algal assemblages (AA), Turf algae (TA) and Padina (PAD) (See Table 13).

The groupings were based on the intention of lumping vague and unclear categories such as various types of turf algae. Table 15 shows the levels of lumping achieved for the algal types with the fine and coarse groupings.

Table 15. Comparisons of the levels of lumping of algal types recorded at transects.

ALGAE:

OBJ_NAME	OBJECT_ID	GROUP1	GROUP2
Algal Assemblage	AA	AL	AA
Calcareous Algae	CA	CA	
Crustose Coralline Algae	CCA		
Dense Alga Sand Mat	DASM	FA	
Dead Coral Algae	DCA		
Algae Filamentous	FA		
Filamentous Red Algae "Slime"	FRA		
Light Algal Sand Mat	LASM		
Red Algal Film	RAF		
Algae Halimeda	HA	HA	
Caulerpa - Corkscrew	CCAUL	MA	
Algae Dictyota	DIC		
Tydemania	DRED		
Lyngbia	LYNG		
Algae Macro	MA		
Orange Macro Algae	MAO		
Sand Algae Combination	SA	TA	
Algae Padina	PAD	PAD	PAD
CA exceeds TA Mosaic	CTA	TA	TA
Heavy Turf Algae	HTA		
Heavy Turf Algae With Sand	HTAS		
Light Turf Algae	LTA		
Light Turf Algae With Sand	LTAS		
Light TA in CA Mosaic	LTCA		
Medium Turf Algae	MTA		
Medium Turf Algae Holding Sand	MTAS		
Medium TA in CA Mosaic	MTCA		
Algal Turf	TA		
Turf Algae Holding Sand	TAS		
TA exceeds CA Mosaic (TA usual)	TCA		
TOTAL	**30**	**7**	**3**

SUBSTRATE TYPES

The substrate types recorded at the transects consisted of many overlapping categories such as 'sand' 'sand rubble matrix' 'rubble' 'rubble loose' and 'rubble cemented'. This has led to confusion when recordings were made. Sometimes sand and rubble were recorded separately and at another occasion sand and rubble were mixed as one group.

For the first level of grouping, substrate types were lumped into 3 groups: 'Substrate' (SUB), 'Dead coral' (DC), and 'Sand or rubble' (S/R). For the second level of grouping substrate types were lumped into 2 categories: 'Substrate' and 'sand/rubble'.

The sponges, soft corals and other animals were all grouped as their 'object types' for both levels of groupings (Table 13).

Figure 21 shows the percentage cover of objects along transect 1, at Embudu Reef Site, using the new object identifications. Objects covering less than 0.5% of the transect have been lumped as 'miscellaneous' (misc).

Figure 21. Percent cover of 'objects' based on the new groupings ('group 1' and 'group 2') at Embudu Reef, Transect 1.

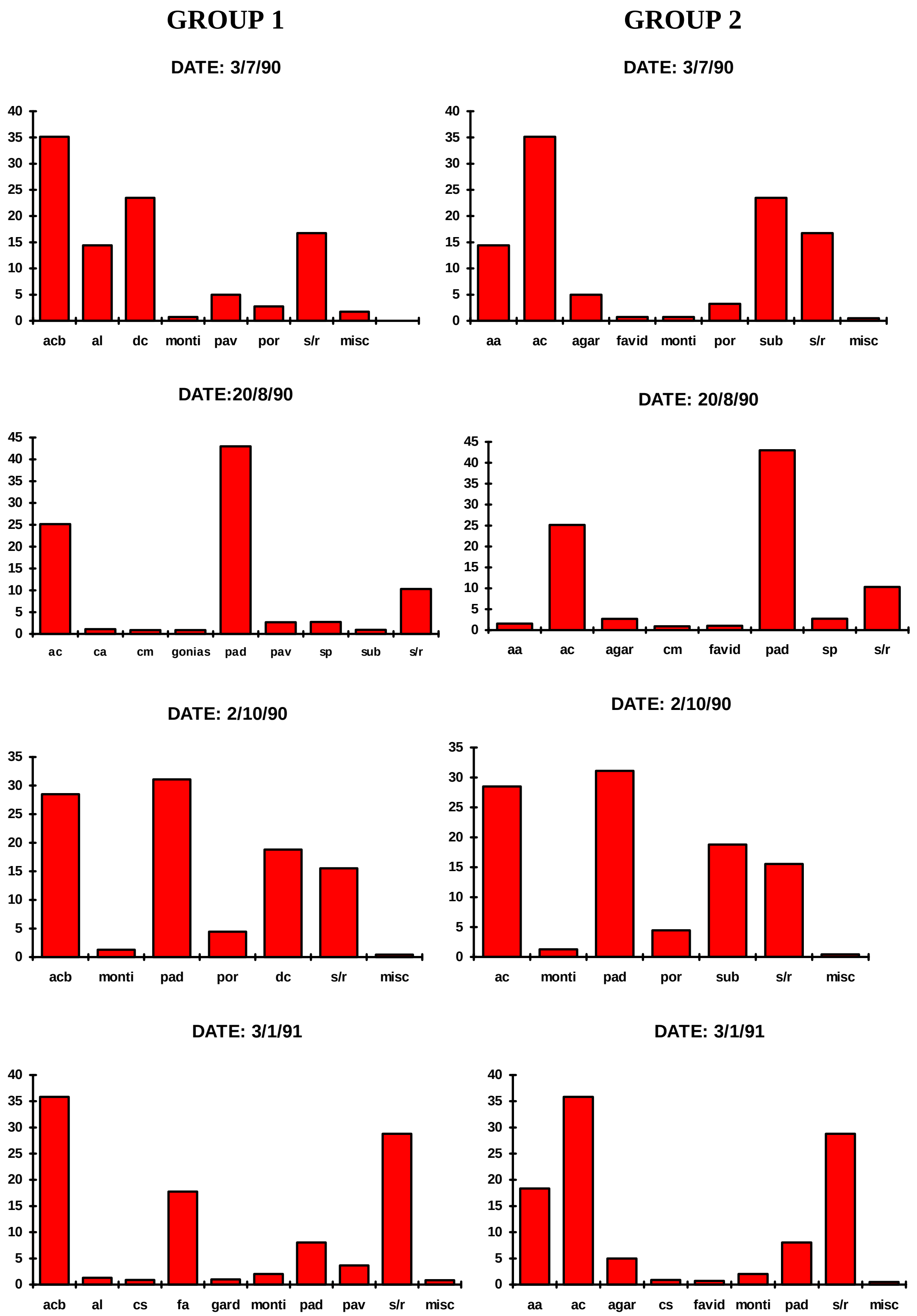
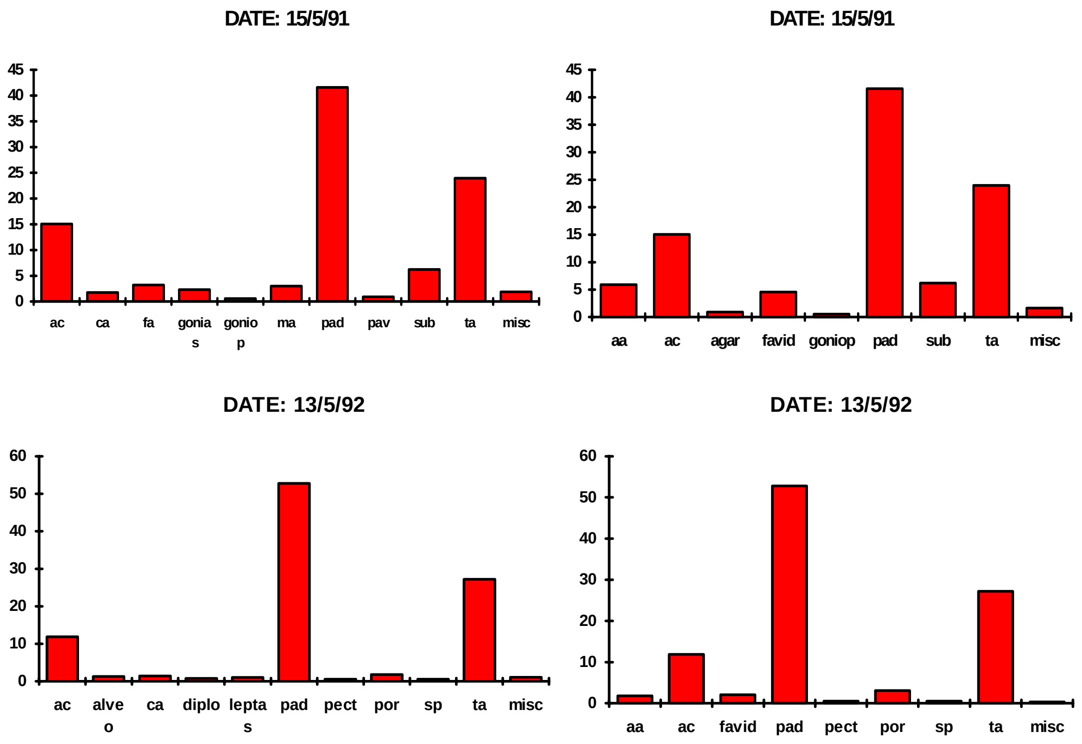


Fig. 21, contd...



With 'group2' level of lumping, pattern of changes and consistencies were seen in the recording of data temporally. The indication is that with a better strategy for recording objects, usable information can be obtained from the transect data. The main problem with the recording of data seems to be the use of mixed levels of identification with overlapping categories. Corals were identified to three levels: growth form, species and generic levels.

4.3.2 Results based on "object types"

For this part of the analysis, the organisms were lumped into 6 broad categories established by the ICOD project, based on the type of object recorded (see Table 13). Comparisons of results for percentage cover of different object types for all transects at all sites are shown in Table 16. It is hard to come to firm conclusions about the variability observed between temporal samples. Enormous differences between the cover of object types were observed between different samples of the same transect taken on the same day by different observers (Fig. 22) and even by the same observer (Fig.23,24). This cannot certainly be attributed to natural variability. It shows the amount of sampling error resulting from inadequate design of sampling procedures.

Figure 22 Percent cover of object types recorded by two observers (HZ and WA) on 15/08/90 at Anchorage Reef site, Transect 1. (HC=Hard Coral; AL=algae; SC=Soft Coral; SP=Sponge; SU=Substrate; OT=Others)

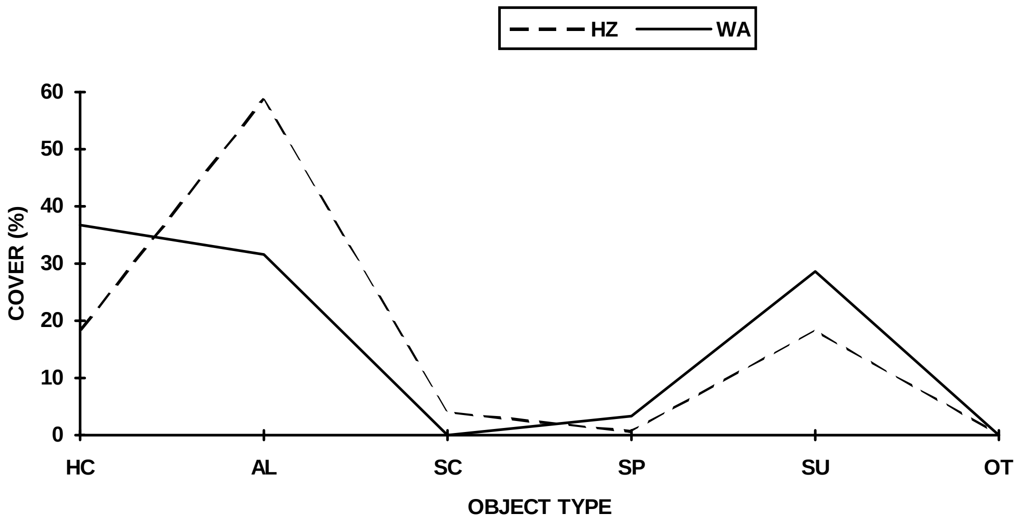


Figure 23 Percent cover of object types recorded by observer HZ for 2 samples on 18/09/90 at Anchorage Reef site, Transect 2. (HC=Hard Coral; AL=algae; SC=Soft Coral; SP=Sponge; SU=Substrate; OT=Others)

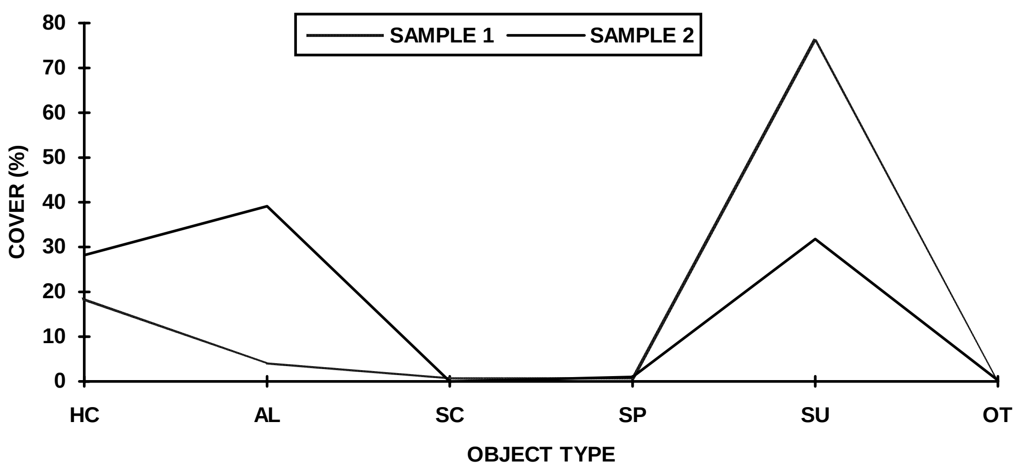


Figure 24. Percent cover of object types recorded by observer WA, for 2 samples on 2/10/90 at Embudu Reef site, Transect 3. (HC=Hard Coral; AL=algae; SC=Soft Coral; SP=Sponge; SU=Substrate; OT=Others)

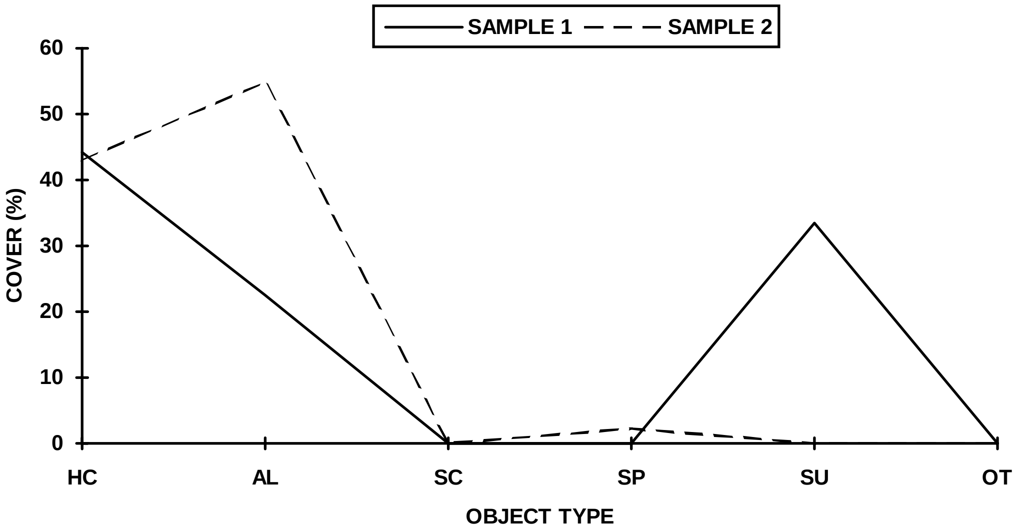


Table 16 Summary results for percent cover of object types (Hard corals, algae, soft corals, sponges, substrate types and other animals) for all transects at all sites. (HC=Hard Coral; AL=Algae; SC=Soft Coral; SP=Sponge; SU=Substrate; OT=Others

SAMPLE NO	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
25	ANCH	1	GF	L	04/07/90	32.00	22.25	0.00	0.00	45.75	0.00
63	ANCH	1	HZ	L	15/08/90	18.50	58.45	4.05	0.65	18.40	0.10
84	ANCH	1	WA	L	15/08/90	36.75	31.60	0.00	3.35	28.65	0.00
13	ANCH	1	WA	L	18/09/90	29.70	66.20	0.00	0.50	3.75	0.00
103	ANCH	1	HZ	L	17/06/91	19.05	50.25	1.00	4.45	25.55	0.00

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
34	ANCH	2	GF	L	04/07/90	15.50	0.00	0.50	0.00	84.20	0.00
64	ANCH	2	HZ	L	15/08/90	4.05	51.85	6.85	0.00	37.25	0.00
67	ANCH	2	HZ	L	18/09/90	18.45	4.00	0.70	0.75	76.10	0.00
86	ANCH	2	HZ	L	18/09/90	28.20	39.15	0.00	1.00	31.80	0.25
39	ANCH	2	HZ	L	26/12/90	15.55	26.65	0.00	0.00	57.85	0.00
113	ANCH	2	WA	L	16/05/92	22.45	61.95	1.10	2.95	8.80	0.00
120	ANCH	2	WA	L	12/06/92	32.50	46.50	2.15	4.20	19.25	1.35
119	ANCH	2	WA	L	15/06/92	18.30	76.15	12.15	0.00	3.15	0.00

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
33	ANCH	3	GF	L	04/07/90	31.00	0.00	0.00	1.00	67.35	0.75
71	ANCH	3	HZ	L	15/08/90	22.10	44.20	0.55	0.75	32.40	0.00
21	ANCH	3	WA	L	13/10/90	10.75	0.00	15.00	0.50	73.40	0.00
38	ANCH	3	HZ	L	26/12/90	22.55	51.70	0.35	0.00	25.60	0.00
102	ANCH	3	HZ	L	12/06/91	17.75	38.85	0.00	0.50	41.40	1.60
114	ANCH	3	WA	L	17/05/92	24.00	61.40	0.00	2.05	7.20	5.65

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
28	DETO	1	GF	L	03/07/90	30.25	2.90	0.50	1.75	64.65	0.00
81	DETO	1	WA	L	26/08/90	41.45	40.65	0.00	0.00	17.95	0.00
14	DETO	1	WA	L	04/10/90	24.20	57.50	0.00	0.00	18.35	0.00
15	DETO	1	WA	L	04/10/90	31.95	68.05	0.00	0.10	0.00	0.00
57	DETO	1	HZ	L	16/01/91	29.45	53.15	0.00	0.55	16.85	0.05
93	DETO	1	WA	L	12/05/91	48.85	29.95	0.00	1.75	19.65	0.00
107	DETO	1	WA	P	10/05/92	40.00	67.50	0.00	1.25	11.25	1.25

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
27	DETO	2	GF	L	03/07/90	47.00	25.30	0.00	0.00	27.80	0.00
80	DETO	2	WA	L	26/08/90	46.25	39.45	0.00	0.25	14.45	0.00
16	DETO	2	HZ	L	04/10/90	28.45	44.35	0.20	3.35	22.20	1.45
61	DETO	2	WA	L	16/01/91	31.75	67.35	0.00	0.95	0.00	0.00
92	DETO	2	WA	L	12/05/91	25.45	51.00	0.00	0.00	23.85	0.00
108	DETO	2	WA	P	10/05/92	36.25	50.00	0.00	0.00	17.50	0.00

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
26	DETO	3	GF	L	03/07/90	28.75	21.85	0.00	0.25	49.20	0.00
79	DETO	3	WA	L	26/08/90	28.80	50.00	0.00	0.00	21.25	0.00
58	DETO	3	HZ	L	16/01/91	13.55	69.45	1.95	0.30	14.45	0.45
91	DETO	3	WA	L	12/05/91	22.65	61.30	0.00	1.65	14.60	0.00
109	DETO	3	WA	P??	10/05/92	30.00	48.75				
118	DETO	3	WA	L???	10/06/92	?	?		0.55	11.05	0.10

Table 16, contd...

SAMPLE NO	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
35	EMBU	1	GF	L	03/07/90	45.40	14.40	0.00	0.00	40.25	0.00
74	EMBU	1	HZ	L	20/08/90	45.50	44.55	0.00	2.75	0.00	0.00
7	EMBU	1	HZ	L	02/10/90	34.65	31.15	0.00	0.00	34.35	0.00
8	EMBU	1	HZ	L	02/10/90	34.85	26.80	0.00	0.00	38.40	0.00
43	EMBU	1	WA	L	03/01/91	44.50	26.40	0.00	0.50	28.80	0.00
90	EMBU	1	WA	L	15/05/91	22.25	71.45	0.00	0.00	6.65	0.00
110	EMBU	1	WA	P	13/05/92	18.75	80.00	0.00	1.25	0.00	0.00
111	EMBU	1	WA	L	13/05/92	17.65	81.75	0.00	0.55	0.35	0.00

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
36	EMBU	2	GF	L	03/07/90	43.75	19.60	0.00	0.50	36.35	0.00
73	EMBU	2	HZ	L	20/08/90	37.90	45.20	0.00	0.00	17.00	0.00
6	EMBU	2	HZ	L	02/10/90	37.40	61.50	0.00	0.85	0.35	0.00
44	EMBU	2	HZ	L	03/01/91	36.70	20.40	0.00	0.00	43.20	0.35
89	EMBU	2	WA	L	15/05/91	31.90	67.95	0.00	0.45	0.00	0.00
112	EMBU	2	WA	L	13/05/92	11.75	80.55	0.00	0.15	7.65	0.05

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
37	EMBU	3	GF	L	03/07/90	38.75	22.05	0.00	2.00	37.30	0.00
72	EMBU	3	HZ	L	20/08/90	41.50	34.40	0.00	0.00	24.20	0.00
9	EMBU	3	WA	L	02/10/90	44.20	22.50	0.00	0.00	33.45	0.00
99	EMBU	3	WA	L	02/10/90	42.95	54.90	0.00	2.25	0.00	0.00
50	EMBU	3	WA	L	03/01/91	37.30	34.65	0.00	1.10	26.90	0.45
94	EMBU	3	WA	L	15/05/91	36.65	60.90	0.00	1.30	1.10	0.25

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
68	MALE	1	HZ	L	18/07/90	11.65	42.65	0.00	0.00	45.70	0.00
82	MALE	1	SC	L	30/07/90	24.25	35.90	1.25	0.00	39.05	0.00
11	MALE	1	WA	L	24/09/90	17.85	30.15	0.60	1.00	50.50	0.00
12	MALE	1	HZ	L	24/09/90	8.20	12.40	21.70	0.30	57.45	0.00
17	MALE	1	HZ	L	30/10/90	27.10	55.50	0.20	0.40	16.80	0.10
70	MALE	1	HZ	L	26/10/91	15.00	44.60	0.00	2.40	38.00	0.00
124	MALE	1	WA	L	17/07/92	12.25	59.15	0.35	0.05	28.40	0.35

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
83	MALE	2	HZ	L	30/08/90	18.05	51.00	0.35	0.95	29.65	0.30
24	MALE	2	WA	L	30/10/90	7.75	86.80	3.70	0.00	0.75	1.00
105	MALE	2	WA	L	07/10/91	13.90	59.80	15.50	0.00	9.25	1.85
125	MALE	2	WA	L	17/07/92	31.60	37.70	0.00	0.70	30.35	0.00

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
69	MALE	3	WA	L	18/07/90	17.85	25.10	1.85	0.75	54.55	0.00
75	MALE	3	SC	L	30/07/90	13.45	40.05	0.50	0.00	46.10	0.00
23	MALE	3	WA	L	30/10/90	15.15	64.55	13.55	0.25	3.25	3.40
106	MALE	3	WA	L	08/10/91	7.05	85.45	2.90	0.55	2.00	2.20
121	MALE	3	WA	L	14/06/92	12.45	82.75	0.65	0.65	3.10	0.65

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
20	MYST	1	GF	L	04/07/90	18.25	0.00	0.25	1.25	80.55	0.00
78	MYST	1	WA	L	23/08/90	22.50	4.30	21.65	2.15	49.50	0.00
1	MYST	1	HZ	L	24/09/90	31.75	0.75	0.00	0.00	67.55	0.00
95	MYST	1	WA	L	24/09/90	26.00	50.40	0.70	0.80	21.55	1.00
85	MYST	1	WA	L	04/05/91	11.50	46.60	12.10	0.25	29.85	0.00
122	MYST	1	WA	L	20/06/92	22.05	71.40	2.25	0.20	0.85	0.00

Table 16, contd...

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
19	MYST	2	GF	L	04/07/90	14.50	0.75	0.00	0.25	84.70	0.00
77	MYST	2	WA	L	23/08/90	21.90	0.70	1.00	0.00	76.15	0.60
22	MYST	2	WA	L	16/10/90	14.30	80.25	0.95	0.45	4.25	0.00
97	MYST	2	WA	L	19/05/91	21.45	30.15	0.60	1.00	46.90	0.00
123	MYST	2	HZ	L	17/06/91	21.20	44.55	2.20	1.00	27.75	3.50

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
18	MYST	3	GF	L	04/07/90	20.35	46.50	0.75	5.35	27.10	0.00
76	MYST	3	WA	L	23/08/90	22.40	0.75	1.05	0.50	75.40	0.00
10	MYST	3	WA	L	24/09/90	10.85	39.85	0.25	0.75	48.70	0.00
96	MYST	3	WA	L	19/05/91	15.05	35.55	23.40	2.70	23.30	0.05
126	MYST	3	WA	L	24/07/92	21.30	34.60	19.15	0.95	25.90	0.05

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
5	VILL	1	GF	L	05/07/90	11.80	43.20	0.00	0.75	44.60	0.00
4	VILL	1	HZ	L	12/08/90	30.00	31.05	0.00	1.25	37.55	0.20
2	VILL	1	WA	L	11/09/90	18.05	37.60	0.00	0.00	44.45	0.00
3	VILL	1	HZ	L	11/09/90	21.90	44.30	0.25	0.30	33.45	0.00
62	VILL	1	HZ	P	13/11/90	30.00	62.50	0.00	0.00	7.50	0.00
42	VILL	1	HZ	P	14/11/90	20.00	40.00	2.50	2.50	35.00	0.00
104	VILL	1	HZ	L	16/06/91	23.45	53.20	0.00	0.90	22.85	0.75
115	VILL	1	WA	L	02/05/92	16.25	69.95	0.20	0.35	9.45	6.40
116	VILL	1	WA	L	11/05/92	26.60	43.90	0.00	1.65	26.70	1.40

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
30	VILL	2	GF	L	05/07/90	24.75	0.00	0.75	1.75	72.80	0.00
66	VILL	2	HZ	L	12/08/90	10.40	6.80	18.55	0.00	64.25	0.00
88	VILL	2	HZ	L	11/09/90	28.45	20.25	1.00	0.35	50.20	0.00
40	VILL	2	WA	L	12/12/90	33.35	48.95	0.35	2.10	10.95	4.65
101	VILL	2	HZ	L	29/05/91	22.00	68.85	0.60	0.00	4.40	4.30

SAMPLE NO.	SITE	TRANSECT	OBSERVER	METHOD	DATE	HC	AL	SC	SP	SU	OT
29	VILL	3	GF	L	05/07/90	28.75	0.65	2.50	0.25	67.95	0.00
65	VILL	3	HZ	L	12/08/90	14.85	5.15	5.15	0.00	75.05	0.00
87	VILL	3	WA	L	11/09/90	18.40	9.70	0.75	0.00	71.30	0.00
41	VILL	3	HZ	P	13/12/90	35.00	22.55	5.00	0.00	37.50	0.00
100	VILL	3	HZ	L	10/06/91	26.95	69.10	0.00	0.15	3.85	0.00
117	VILL	3	WA	L	12/05/92	21.65	59.80	2.15	4.05	12.35	0.05

The levels of sampling error shown in Fig.22 and 23 are unacceptable for a monitoring scheme developed to detect anthropogenic disturbances on the reefs.

There are many possible reasons for the sampling error observed in Fig. 22,23 and 24:.

- The observer ignored or missed or misidentified an object.

- The use of overlapping catagories of objects.

- The tape was not laid exactly on the permanent transect.

- The movement of tape side ways on the transect during sampling.

- The tightness and the slack of the tape may also affect the recordings.

An examination of the transect data confirmed that a combination of the above reasons may be the cause of sampling error. Table 17 shows parts of the raw transect data corrosponding to the samples analysed in Figures 22,23 and 24. It is evident that the tape was not laid exactly on the permanent transect at successive recordings. The detail recorded also varied between the samples (Table 17).

Table 17. Segments of actual transect recordings corrosponding to the pairs of samples in Fig. 22,23 and 24.

(Anchorage Reef, Transect:1)

Obsever: HZ
Date: 15/8/90

START DIST	END DISTANCE	OBJECT ID
0.00	0.35	DCA
0.35	0.49	S/R
0.49	0.55	MA
0.62	0.63	S
0.63	0.79	DCA
0.79	0.81	POR
0.81	0.90	MONTI
0.90	0.92	S
0.92	0.93	PSAM
0.93	0.98	CA
0.98	1.06	DCA
1.06	1.21	S
1.21	1.26	AA
1.26	1.35	CA
1.35	1.47	PSAM
1.47	1.64	DCA
1.64	1.70	R
1.70	1.83	SPE
1.83	1.85	DCA
1.85	1.93	FAVIA
1.93	2.00	CCA
2.00	2.06	AA
2.06	2.15	LEPTAS
2.15	2.41	CCA
2.41	2.48	MONTI
2.48	2.60	R
2.60	2.70	CCA
2.70	3.01	R
2.70	3.01	AA
3.01	3.04	PLATY
3.04	3.24	S
3.24	3.45	SC
3.45	3.55	DCA
3.55	3.70	POR
3.70	3.73	MA
3.70	3.73	DCA
3.73	4.01	AA
4.01	4.03	LEPTAS
4.03	4.50	MA
4.03	4.50	DCA
4.50	4.63	GONIAS
4.63	5.06	DCA
4.63	5.06	R
5.06	5.08	PSAM
5.08	5.29	R
5.08	5.29	S
5.29	5.32	POR
5.32	5.78	MA
5.32	5.78	DCA
5.78	5.88	SC
5.88	6.60	DCA
5.88	6.60	R
6.60	6.61	POR
6.61	6.69	SARCO
6.69	7.05	DCA
6.69	7.05	R
6.69	7.05	MA
7.05	7.07	CA
7.07	7.85	R
7.07	7.85	DCA
7.85	7.92	CA
7.92	8.30	DCA
8.30	8.31	SC
8.31	8.60	R
8.31	8.60	AA
8.60	8.85	DCA
0.55	0.62	DCA
8.85	9.62	DCA
8.85	9.62	CCA
9.62	10.02	POR
10.02	10.26	DCA
10.02	10.26	AA
10.26	10.30	ACR
10.30	10.54	DCA
10.54	10.58	POR
10.58	10.70	DCA
10.70	10.81	SC
10.81	10.85	MONTI
10.85	10.98	DCA
10.85	10.98	ASC
10.98	11.07	MONTI
11.07	11.37	DCA
11.37	11.42	POR
11.42	11.60	CCA
11.60	11.63	MONTI
11.63	11.84	DCA
11.63	11.84	AA
11.84	12.12	MONTI

Observer: WA
Date: 15/8/90

START DIST	END DISTANCE	OBJECT ID
0.00	0.28	S
0.00	0.28	FA
0.28	0.35	CM
0.35	1.10	S
0.35	1.10	FA
1.10	1.22	ECHPOR
1.22	1.25	SPE
1.25	1.33	PAV
1.33	1.70	S
1.33	1.70	FA
1.70	1.80	GONIAS
1.80	1.95	GONIAS
1.95	2.00	SPE
2.00	2.05	CM
2.05	2.10	SPE
2.10	2.30	LEPTAS
2.30	2.75	DIC
2.75	2.80	PACHY
2.80	2.90	DIC
2.90	3.02	PACHY
3.02	3.10	DC
3.02	3.10	S
3.10	3.12	CM
3.12	3.25	CYPHA
3.25	3.32	CM
3.32	4.03	DC
3.32	4.03	DIC
4.03	4.11	CF
4.11	4.17	CM
4.17	4.30	FA
4.17	4.30	SPE
4.30	4.40	CM
4.40	4.48	FA
4.48	4.60	POR
4.60	4.70	ACB
4.70	4.92	FA
4.92	5.08	SPE
5.08	5.17	ACB
5.17	5.42	FA
5.17	5.42	DIC
5.42	5.56	ACB
5.56	5.60	FA
5.60	5.65	PAV
5.65	5.67	POR
5.67	5.72	POC
5.72	5.94	FA
5.72	5.94	SPE
5.94	5.98	ACB
5.98	6.05	CME
6.05	6.10	ACB
6.10	6.20	DIC
6.20	6.25	SPE
6.25	6.32	PAV
6.32	6.42	DIC
6.42	6.65	S
6.65	6.80	DIC
6.80	7.30	S
6.80	7.30	FA
7.30	7.37	CD
7.37	7.55	ACB
7.55	7.77	MONTI
7.77	8.30	ACB
8.30	8.40	ECHPOR
8.40	8.90	CE
8.90	9.05	TA
9.05	9.09	PAV
9.09	9.27	FA
9.09	9.27	DIC
9.27	9.52	MONTI
9.52	9.70	HALO
9.70	10.02	R
9.70	10.02	CA
10.02	10.05	ACB
10.05	10.19	PAV
10.05	10.19	FA
10.19	10.55	FA
10.55	10.62	PSAM
10.62	10.77	DIC
10.77	11.04	CA
11.04	11.60	R
11.04	11.60	TA
11.60	11.63	CA
11.63	11.74	MONTI
11.74	11.79	PAV
11.79	12.10	FA
12.10	12.35	DC
12.35	12.50	ACB
12.50	12.55	SPE

12.12	12.16	CA	12.55	12.60	GALAX
12.16	12.20	DCA	12.60	13.00	DC

Table 17, contd...

(Anchorage Reef, Transect 2)

Observer: HZ

Date:18/9/90

Sample 1

START DIST	END DISTANCE	OBJECT ID
0.00	0.17	POR
0.37	0.45	POR
1.09	1.23	ACB
1.23	2.20	DC
2.20	2.40	ACB
2.90	3.15	ACB
3.35	3.45	ACB
3.95	4.20	ACB
5.43	5.57	POR
5.57	5.64	PAV
5.76	5.90	AA
5.90	5.94	GONIAS
6.55	6.75	FAVIT
6.99	7.20	ACB
8.57	8.72	SPE
8.85	9.14	CMC
10.40	10.65	GONIAS
10.66	10.89	ACB
12.05	12.12	ACB
12.40	12.67	POR
14.69	14.83	ACB
14.94	15.06	POR
15.90	16.15	ACB
16.83	16.92	ACB
16.96	17.07	AA
17.08	17.11	DC
17.26	17.40	SC
18.83	18.96	MONTAS
19.45	20.00	MA
0.17	0.37	ND
0.45	1.09	ND
2.40	2.90	ND
3.15	3.35	ND
3.45	3.95	ND
4.20	5.43	ND
5.64	5.76	ND
5.94	6.55	ND
6.75	6.99	ND
7.20	8.57	ND
8.72	8.85	ND
9.14	10.40	ND
10.65	10.66	ND
10.89	12.05	ND
12.12	12.40	ND
12.67	14.69	ND
14.83	14.94	ND
15.06	15.90	ND
16.15	16.83	ND
16.92	16.96	ND
17.07	17.08	ND
17.11	17.26	ND
17.40	18.83	ND
18.96	19.45	ND

Sample 2

START DIST	END DISTANCE	OBJECT ID
0.00	0.09	MONTI
0.09	0.10	CA
0.10	0.15	MONTI
0.15	1.08	DC
0.15	1.08	TA
0.15	1.08	CCA
0.15	1.08	DIC
1.08	1.16	PAV
1.16	2.20	R
1.16	2.20	AA
1.16	2.20	S
1.16	2.20	DIC
2.20	2.40	ACB
2.40	3.90	S
2.40	3.90	R
3.90	4.20	ACB
4.20	4.30	AA
4.20	4.30	CA
4.30	4.40	POR
4.40	5.40	AA
4.40	5.40	R
5.40	5.55	MONTI
5.55	5.75	PAV
5.75	5.78	CA
5.78	6.10	DIC
6.10	6.18	CA
6.18	6.21	SPE
6.21	6.35	DC
6.21	6.35	AA
6.35	6.39	SPE
6.39	6.52	S
6.39	6.52	R
6.52	6.75	FAVIT
6.75	6.95	MONTI
6.95	8.10	AA
6.95	8.10	R
8.10	8.17	GALAX
8.17	8.20	AA
8.20	8.25	MONTI
8.25	8.60	CA
8.25	8.60	AA
8.25	8.60	R
8.60	8.63	SPE
8.63	8.98	AA
8.63	8.98	DC
8.98	9.16	CE
9.16	9.20	SPE
9.20	9.25	CE
9.25	9.30	ASC
9.30	9.43	MONTI
9.43	9.56	CA
9.56	9.73	MONTI
9.73	11.95	R
9.73	11.95	DIC
9.73	11.95	CA
9.73	11.95	AA
11.95	12.03	PAV
12.03	12.05	DIC
12.05	12.10	GONIAS
12.10	12.27	POC
12.27	12.35	AA
12.35	12.37	GARD
12.37	12.75	MONTI
12.75	13.20	DC
12.75	13.20	R
12.75	13.20	CA
13.20	13.40	ACB
13.40	14.10	DIC
13.40	14.10	AA
13.40	14.10	R
14.10	14.15	ACB
14.15	14.60	R
14.15	14.60	S
14.60	14.80	MONTI
14.80	15.37	PAV
15.37	15.53	ACB
15.53	15.75	PAV
15.75	16.45	DC
15.75	16.45	R
15.75	16.45	AA
16.45	16.67	ACB
16.67	17.22	MONTI
17.22	17.40	POC
17.40	17.55	AA
17.40	17.55	CA
17.55	17.61	SPE

17.61	17.70	HALO
17.70	17.90	CA
17.70	17.90	AA
17.90	18.02	MONTI
18.02	18.92	S
18.02	18.92	AA
18.02	18.92	CA
18.02	18.92	R
18.92	19.05	CMP
19.05	19.50	R

Table 17, contd...

(Embudu Reef, Transect: 3)

Observer: WA

Date: 2/10/90

Sample 1

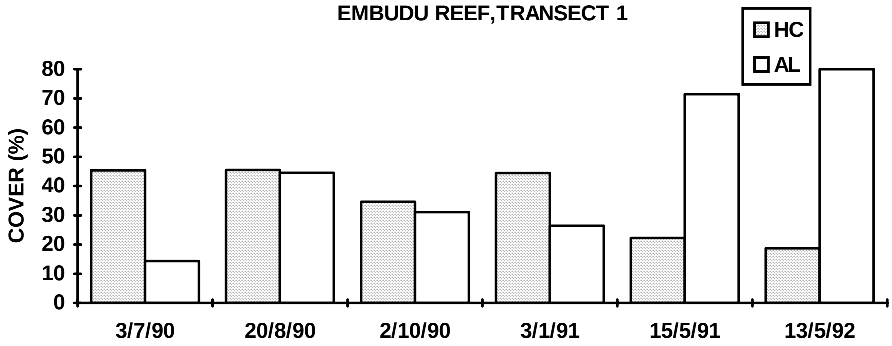
START DIST	END DISTANCE	OBJECT ID
0.00	0.06	DC
0.06	0.27	ACB
0.27	0.37	DC
0.37	0.55	ACB
0.55	0.65	MONTI
0.65	0.80	DC
0.80	0.82	PAV
0.82	0.95	DC
0.95	1.01	ACB
1.01	1.07	AA
1.07	1.45	ACB
1.45	1.60	DC
1.60	1.67	MONTI
1.67	1.96	ACB
1.96	2.25	DC
2.25	2.30	PAV
2.30	2.65	DC
2.30	2.65	PAD
2.65	2.80	ACB
2.80	3.30	DC
2.80	3.30	AA
3.30	3.41	FUNG
3.41	3.71	DC
3.41	3.71	AA
3.71	3.72	ACB
3.72	3.91	DC
3.72	3.91	AA
3.91	3.92	ACB
3.92	4.03	DC
4.03	4.10	ACB
4.10	4.20	DC
4.10	4.20	AA
4.20	4.22	PAV
4.22	5.25	DC
4.22	5.25	AA
5.25	5.50	PAD
5.25	5.50	DC
5.50	5.53	PAV
5.53	5.59	AA
5.59	5.79	PAV
5.79	6.08	DC
5.79	6.08	PAD
6.08	6.32	ACB
6.32	6.50	PAD
6.50	6.69	ACB
6.69	7.30	PAD
7.30	7.34	SYM
7.34	7.48	DC
7.80	7.83	PAV
7.48	7.57	FAVIT
7.57	7.58	DC
7.58	7.66	S
7.66	7.78	PAV
7.78	7.80	GARD
7.83	7.92	DC
7.92	8.35	PAD
8.35	8.50	MONTI
8.50	8.65	S
8.65	8.69	POR
8.69	8.80	DC
8.80	8.90	LEPTOS
8.90	8.95	DC
8.95	10.80	PAD
8.95	10.80	S
10.80	11.40	ACB
11.40	11.92	DC
11.92	13.20	ACB
13.20	13.40	DC
13.20	13.40	PAD
13.40	15.65	ACB
13.40	15.65	PAD
15.65	15.90	PAD
15.90	16.18	ACB
16.18	16.65	R
16.18	16.65	PAD
16.18	16.65	S
16.65	18.55	ACB

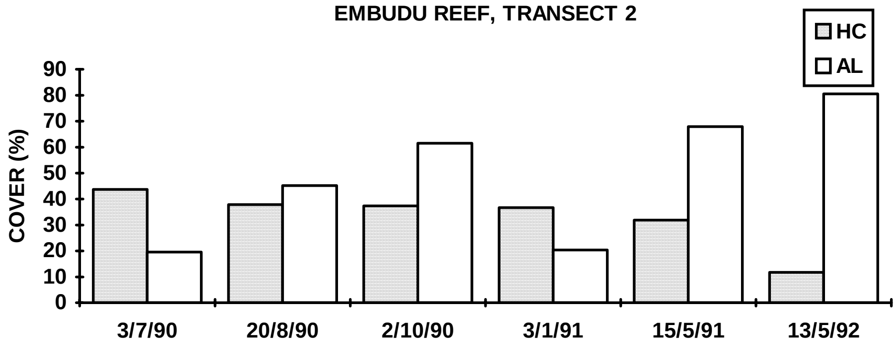
Sample 2

START DIST	END DISTANCE	OBJECT ID
0.00	0.18	CCA
0.18	0.25	GARD
0.25	0.95	CCA
0.25	0.95	PAD
0.95	1.10	LEPAV
1.10	1.55	PAD
1.10	1.55	CCA
1.55	1.65	FUNG
1.65	3.55	PAD
1.65	3.55	CCA
1.65	3.55	ACB
3.55	3.80	CCA
3.80	3.85	SPE
3.85	4.00	CCA
4.00	4.25	PAD
4.00	4.25	ACB
4.00	4.25	CCA
4.25	4.60	ACB
4.60	4.72	AA
4.72	4.75	PAV
4.75	4.85	CCA
4.85	5.10	MONTI
5.10	5.15	ACB
5.15	5.45	MONTI
5.45	5.75	CCA
5.75	5.80	PAV
5.80	5.90	CCA
5.90	6.30	ACB
6.30	8.65	ASTREO
6.30	8.65	CCA
8.65	8.75	MONTI
8.75	8.90	CCA
8.75	8.90	PAD
8.90	9.15	ACB
9.15	9.55	AA
9.55	10.35	ACB
10.35	10.75	CCA
10.75	10.80	PAV
10.80	10.90	TUBI
10.90	10.95	GALAX
10.95	11.65	CCA
10.95	11.65	PAD
11.65	11.80	SPE
11.80	12.15	ACB
12.15	12.42	CCA
12.42	12.80	FAVIT
12.80	12.90	AA
12.90	13.15	SPE
13.15	13.25	MONTI
13.25	13.50	ACB
13.50	13.60	TUBI
13.60	13.65	AA
13.65	14.30	ACB
14.30	14.90	CCA
14.30	14.90	PAD
14.90	15.30	ACB
15.30	15.50	TUBI
15.50	15.70	CCA
15.70	16.90	ACB
16.90	17.95	CCA
16.90	17.95	PAD
17.95	18.05	SYN
18.05	20.00	PAD
18.05	20.00	CCA

18.55	19.60	PAD
18.55	19.60	S
18.55	19.60	R
19.60	20.00	R

Figure 25 Percent live coral and algal cover at Embudu Reef site for all transects.





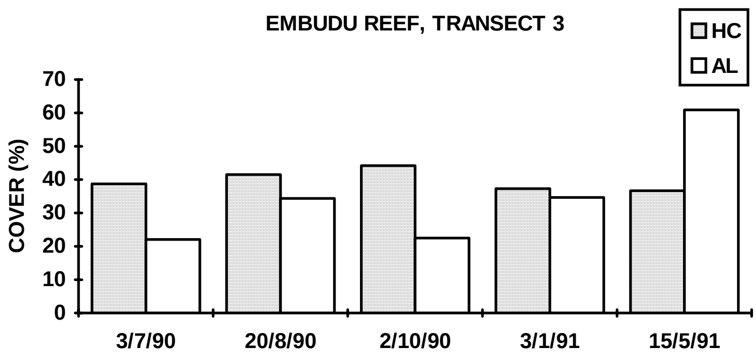
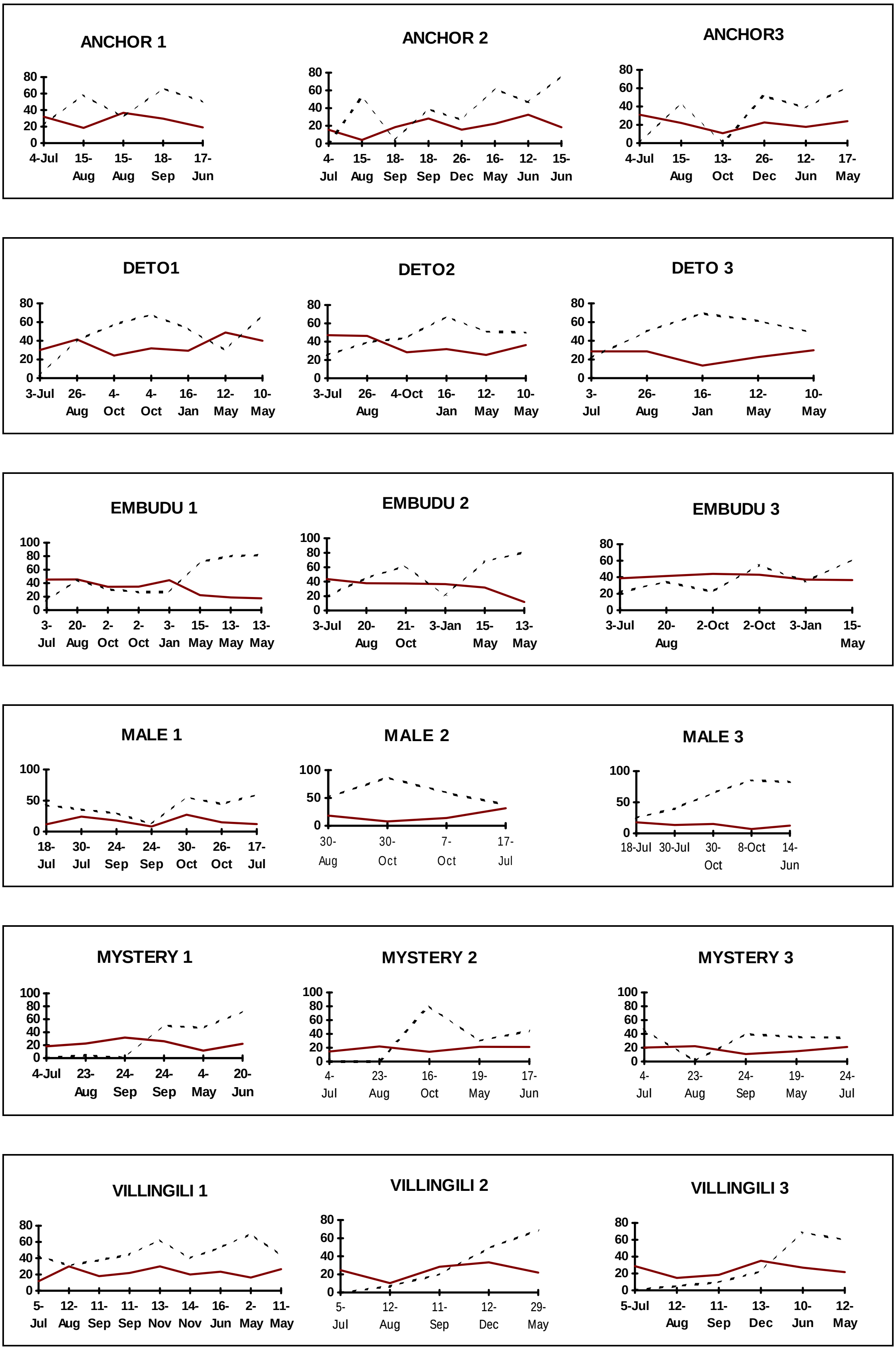


Figure 25 shows the percentage live coral and algal cover at Embudu Reef Site for Transects 1, 2 and 3. Algal cover appears to have increased by almost 60% and live coral cover decreased by 30% for transects 1 and 2, during the 2 years of monitoring. These changes could be just natural variability or signs of human disturbances. This cannot be verified without more information on environmental parameters and further studies.

Figure 26 shows the percentage cover of live coral and algal cover for all transects at the six sites, for the duration of the study. It was interesting to find that algal cover remained fairly high at Male' site throughout the monitoring period. Coral cover was also lower at the Male' site compared to other sites. The temporal variations observed cannot be attributed to any human or natural influence at this stage. Sampling error appears to be great in all samples and can be a significant factor in the observed variations. Further studies and refinements to the sampling design are necessary to make firm conclusions from the data in the future.

Figure 26 Comparisons of percentage live coral and algal cover between sites and within sites temporally during the sampling period. [------ ALGAE —— CORAL]



4.4 Discussion

It is difficult to draw valid conclusions from the results at this stage. The variations in algal cover and coral cover observed at the sites during the monitoring period cannot be attributed to any human influences simply because anthropogenic impacts have not been quantified throughout the study. Considerable spatial and temporal variability exists in natural reef systems (Birkeland, 1984). Water quality and other essential environmental parameters were not measured and were not available for the study sites. Because of sampling error in the methodologies these were abandoned quite early on in the monitoring programme (Allison, 1992).

The sites have not been selected with the primary objective in mind i.e. to detect anthropogenic impacts on the reefs. While it is clear that there may be many human influences on the reefs on Male', there is no control site for Male'. This makes it impossible to make any valid comparisons.

It appears that there are considerable problems with the sampling design and operation of the monitoring programme. The design aspects of monitoring programmes have been described elsewhere in this study. There is no single correct approach to designing a monitoring programme. There are however basic rules and procedures to ensure that it serves the intended purpose (Dahl, 1977,1981,1982; Birkeland, 1984; Kenchington, 1984). It must be designed with a view to eventually testing a clearly stated set of hypotheses. It must use proven sampling methodologies which are appropriate to the questions asked and which are truly repeatable in the long term.

Sampling transects does not appear to have been carried out in a standardised manner. The order seems to be recording whatever objects observed under the transect line by the observer. In some instances recordings were made of objects as small as 1-2 cm. The intention was certainly to produce as much detail as possible of the transect. Recording such detail requires extensive understanding of the taxonomy of species being recorded. In line intercept studies, sampling individual organisms per centimetre may be less useful than measuring whole communities at larger scales (Dahl, 1977). The results of the data analysis indicated that comparable information can be obtained with coarser levels of recordings.

The data must be obtained and stored in a fashion which is interpretable by any one. The data must also be amenable to statistical analysis and should represent a true permanent record of community structure suitable for future comparisons and interpretations. The data collected under the ICOD reef monitoring programme appear to be quite good in this respect.

The monitoring programme, however, does not meet some of the design criteria of monitoring programmes. The are no firm hypothesis or questions developed for the programme. While the objective was to detect anthropogenic impacts on reefs, the design does not reflect this objective. As a result the sampling strategy was not clearly defined. In order to detect and quantify anthropogenic impacts on reefs it is necessary to develop repeatable methods to measure environmental parameters. The methods for recording transects need to be standardised. A simpler classification system need to be formulated in order to enable lesser skilled staff to carry out monitoring work.

Sites should be selected with the aim of testing a given hypothesis or question. Carefully paired and selected reef sites would enable comparisons to be made between impacted sites and sites free from human influence. (Brown and Dunne, 1988). The permanent sites selected for the ICOD reef monitoring programme does not appear to have any control sites which are completely free of anthropogenic impacts. Without adequate controls, the changes in the treatment site cannot be interpreted as unequivocally being the result of human activity. Permanent control sites need to be established for the reef monitoring programme at MRS. There are many pristine reef areas in Maldives. Carefully planned surveys could identify adequate control sites for the purposes of the monitoring programme.

The effort to record intricate detail of the transects appears to be a serious drawback in the design of the sampling programme. A basic principle in designing simple monitoring surveys is to collect only that information that can be usefully interpreted (Dahl, 1977). Application of techniques which strive for great detail and accuracy becomes meaningless because of inadequate sampling of the natural variability, poor taxonomic knowledge of the organisms involved, or incomplete understanding of the ecological principles or processes at work. Tecniques should be developed with the aim to reduce recording noise as much as possible, which was probably the main reason for the variability observed on transects by the same observer on the same day. Recording noise can be reduced to a large extent by simplifying the classifications of organisms as shown in the groupings drawn up to analyse the data.

The recording inconsistencies in the transect data sets could have been avoided to a large extent by the formulation of standardised data recording sheets similar to that described by De Silva (1982) and Dahl (1980). When data are recorded on underwater slates with no specified format, the tendency is great to record more information than necessary. A well formatted and standardised data sheet would enable observers to refer to previous record sheets and discuss the problems encountered at an early stage without having to wait for later data analysis or the need to look at the database or other paper work.

With the current design of the ICOD permanent transects there is apparently little chance that the tape can be laid confidently at the same position in consecutive recordings. Even if the tape can be laid on the site at each sampling occasion, the tape movement sideways can easily miss small objects or even larger objects. The transects if they are to be permanent need to be marked clearly with permanent structures and efforts should be made to enable the transects to be located with ease (Rogers, 1988). Stakes which marked the transects were lost on many occasions. It is necessary to seek a more permanent and long-lasting structure to mark the transects.

The lack of widely agreed "objects" to be recorded on transects is a serious flaw in the monitoring programme to be continued with different people sampling. While one observer recorded the "object" - sand (S) and rubble (R) as two different entities, another observer recorded them as one entity (S/R). Such overlapping catagories need to be combined to give well defined and clearly separable larger categories.

This study has pointed out the main constraints and short comings of the ICOD reef monitoring programme at MRS in Maldives by analysing the data collected under the programme. Without further refinements to the sampling design, there is little chance that the data from the ICOD monitoring programme can be utilised for management purposes. The methods need to be reviewed totally and recordings need to be simplified and standardised.

Efforts are required to reduce the sampling error as much as possible. Control sites for the study sites need to defined and data collection extended to those reefs. The monitoring programme, if redesigned on a sound sampling design and methodology, represents an important component in the management requirements of coral reefs in Maldives in the future.

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APPENDIX B. "Objects.dbf" file of the ICOD database.

OBJ_NAME	OBJECT_ID	OBJ_TYPE
UNCERTAIN I.D.	???	OT
Algal Assemblage	AA	AL
AABOR 50 at .40	AABOR	HC
Acropora sp.	AC	HC
Acropora austera	ACA	HC
Acanthurus leucosternon Lawn	ACANLEU	OT
Acanthurus lineatus Lawn	ACANLIN	OT
Acanthastrea sp.	ACANTH	HC
Acropora Arborescent	ACARB	HC
Acropora Branching	ACB	HC
Acropora Bottlebrush	ACBOT	HC
Acropora caespitose	ACCAES	HC
Acropora cerealis	ACCE	HC
Acropora clathrata	ACCL	HC
Acropora corymbosa	ACCO	HC
Acropora Corymbose	ACCOR	HC
Acropora cytherea	ACCY	HC
Acropora Digitate	ACD	HC
Acropora danai	ACDA	HC
Acropora digitifera	ACDI	HC
Acropora Encrusting	ACE	HC
Acropora Encrusting, tan, 1st	ACE2	HC
Acropora Encrusting, chocolate	ACE3	HC
Acropora echinata	ACEC	HC
Acropora effluens	ACEF	HC
Acropora elseyi	ACEL	HC
ACES 80 & 81	ACES	HC
Acropora eurystoma	ACEU	HC
Acropora formosa	ACFORM	HC
Acropora forskalii	ACFORS	HC
Acropora granulosa	ACG	HC
Acropora gemmifera	ACGE	HC
Acropora hemprichi	ACH	HC
Acropora horrida	ACHO	HC
Acropora humilis	ACHU	HC
Acropora humilus group	ACHUG	HC
Acropora hyacinthus	ACHY	HC
Acropora hyacinthus 1	ACHY1	HC
Acropora hyacinthus 1 group	ACHY1G	HC
Acropora hyacinthus 2 L&hairy	ACHY2	HC
Acropora irregularis	ACIR	OT
Acropora loripes	ACL	HC
Acropora microclados	ACMICRO	HC
Acropora monticulosa	ACMON	HC
Acropora nasuta	ACNA	HC
Acropora nobilis	ACNO	HC
Acropora, Palmate Type	ACP	HC
Acropora palifera	ACPA	HC
Acropora pharaonis	ACPH	HC
Acropora pulchra	ACPU	HC
Acropora Recruit	ACR	HC

Acropora robusta	ACROB	HC
Acropora Submassive	ACSM	HC
Acropora stoddarti	ACST	HC
Acropora syringoides	ACSY	HC
Acropora Tabulate	ACT	HC
Acropora teres	ACTE	HC
Acropora tenuis?	ACTEN	HC
Acropora valenciennesi	ACVAL	HC
Acropora valida	ACVALI	HC
Acropora vaughani	ACVAU	HC
Acropora yongei	ACY	HC
SpongeLikeAdocea	ADOC	SP
Acanthastrea echinata	AE	HC
Acropora gemmifera	AGEM	HC
Aglaophenia (large feather)	AGLAOPH	OT
Alveopora allingi	ALA	HC
Alveopora daedalea	ALD	HC
Alveopora superficialis	ALS	HC
Alveopora viridis	ALV	HC
Alveopora sp.	ALVEO	HC
Anacropora sp.	ANACRO	HC
Anemone	ANEM	OT
Anomastrea sp.	ANOM	HC
Antipatharian	ANTI	SC
Acropora palifera	APAL	HC
Ascidians	ASC	OT
Ascidian-sm,individual, orange	ASCSIO	OT
Astreopora gracilis	ASG	HC
Astreopora listeri	ASL	HC
Astreopora myriophthalma	ASM	HC
Astreopora ocellata	ASO	HC
Astreopora sp.	ASTREO	HC
Avrainvillea sp	AVRAIN	AL
Axinella carteri	AXINCAR	SP
Barabattoia	BARABA	HC
Black Band Disease	BBD	OT
Black Coral Boring Sponge	BCBS	SP
Blue Colonial Encrust Ascid	BCEA	OT
Blue Eyes ACB	BEACB	HC
Black Hardground Boring Sponge	BHBS	SP
Blastomussa	BLASTO	HC
Bryozoa	BRYO	OT
Bryopsis	BRYOP	AL
Calcareous Algae	CA	AL
Caulastrea furcata	CAF	HC
Colonial Sea Anemone	CANEM	OT
Caulastrea tumida	CAT	HC
Catalaphyllia sp.	CATALA	HC
Caulastrea sp.	CAUL	HC
Caulerpa sp.	CAULER	AL
Cauliflower Soft Coral	CAULFLO	SC
Coral Branching	CB	HC
Bleached HC, Cul-size	CBC	SU
Bleached HC, Cul-size, HTA	CBCHA	SU
Bleached HC, Cul-size, LTA	CBCLA	SU
Bleached HC, Cul-size, MTA	CBCMA	SU

Bleached HC, Cul-size, Tissue	CBCT	SU
Bleached HC, Cul-size, White	CBCW	SU
Bleached HC, Larger	CBL	SU
Coral Columnar	CC	HC
Crustose Coralline Algae	CCA	AL
Caulerpa - Corkscrew	CCAUL	AL
Live Coral, Detatched	CD	HC
Coral Encrusting	CE	HC
Coral Foliose	CF	HC
Chlorodesmis	CHLOR	AL
Catalaphyllia jardinei	CJ	HC
Coral Long Corallite	CLC	HC
Cliona	CLIONA	SP
Cliona Viridis	CLIOVIR	SP
Coral Massive	CM	HC
Coral Massive Cerioi	CMC	HC
Coral Meandroid	CME	HC
Coral Massive Plocoi	CMP	HC
Cauliflower Nepthea	CNEP	SC
Coscinaraea monile	COM	HC
Coscinaraea	COSCI	HC
Acanthaster plancii	COT	OT
Coral Plate	CP	HC
Coral Rock	CR	SU
Crak Cnidarian	CRAK	OT
Loose Coral Rock	CRL	SU
Coral Solitary	CS	HC
Coral SubMassive	CSM	HC
Coral Tabulate	CT	HC
CA exceeds TA Mosaic	CTA	AL
Ctenella	CTEN	HC
Culcita	CUL	OT
Cyphastrea chalcidicum	CYC	HC
Cycloseris cooperi	CYCOO	HC
Cycloseris costulata	CYCOS	HC
Cynarina lachrymalis	CYL	HC
Cyphastrea microphthalma	CYM	HC
Cynarina sp.	CYN	HC
Cyphastrea sp.	CYPHA	HC
Cycloseris somervillei	CYS	HC
Cyphastrea serailia	CYSE	HC
Dead ACB/Growth Position	DACBI	SU
Dead ACB Loose	DACBL	SU
Dead A.palifera/GrowthPosition	DACPALI	SU
Dead A.palifera Loose	DACPALL	SU
Dead Acropora Cemented	DACROC	SU
Dead A.Submas/GrowthPosition	DACSMI	SU
Dense Alga Sand Mat	DASM	AL
Dead Coral	DC	SU
Dead Coral Algae	DCA	AL
Dead coral bleached	DCB	SU
Dead Coral Cemented	DCC	SU
Dead coral, heavy algae	DCHA	SU
Dead Coral in growth position	DCI	SU
Dead Coral Loose	DCL	SU
Dead coral, light algae	DCLA	SU

Dead coral, medium algae	DCMA	SU
Dead Coral Recent	DCR	SU
Dense, Cropped Turf Algae	DCTA	AL
Dead, worn coral with TA & CA	DCTCA	SU
Diaseris distorta	DD	HC
Dendrophyllia	DENDRO	HC
Dendronepthia	DENEP	SC
Diploastrea heliopora	DH	HC
Diaseris	DIAS	HC
Algae Dictyota	DIC	AL
Didemnum molle	DIDI	OT
Diploastrea sp.	DIPLO	HC
Distichopora	DISTICH	HC
Damselfish Lawn	DL	AL
Tydemania	DRED	AL
Echinophyllia aspera	EA	HC
Echinopora gemmacea	ECG	HC
Echinopora hirsutisima	ECH	HC
Echinophyllia sp.	ECHPHYL	HC
Echinopora sp.	ECHPOR	HC
Echinopora lamellata	ECL	HC
Algae Enteromorpha	ENTER	AL
Epibiont Assemblage	EPIBASS	OT
Euphyllia fimbriata	EUF	HC
Euphyllia glabrescens	EUG	HC
Euphyllia sp.	EUPHYL	HC
Algae Filamentous	FA	AL
Favites abdita	FAA	HC
Favites chinensis	FAC	HC
Favites complanata	FACO	HC
Favites flexuosa	FAF	HC
Favites halicora	FAH	HC
Favites pentagona	FAP	HC
Favia sp.	FAVIA	HC
Favites sp.	FAVIT	HC
Filamentous Blue Green Alga	FBGA	AL
Favia favus	FF	HC
Favia matthai	FM	HC
Feather Macro Algae	FMA	AL
Favia pallida	FP	HC
Favia rotumana	FR	HC
Filamentous Red Algae "Slime"	FRA	AL
Favia speciosa	FS	HC
Favia stelligera	FST	HC
Fungia danai	FUD	HC
Fungia echinata	FUE	HC
Fungia fungites	FUF	HC
Fungia sp.	FUNG	HC
Fungia paumotensis	FUP	HC
Fungia repanda	FUR	HC
Fungia scutaria	FUS	HC
Favia valenciennesi	FV	HC
Galaxea astreata (green)	GA	HC
Galaxea fascicularis (brown)	GAFA	HC
Galaxea sp.	GALAX	HC
Gardineroseris planulata	GAP	HC

Gardineroseris	GARD	HC
Grazed Algal Turf	GAT	AL
Green Colonial Encrust Ascid	GCEA	OT
Gorgonians	GO	SC
Goniopora djiboutiensis	GOND	HC
Goniopora granulosa	GONG	HC
Goniastrea sp.	GONIAS	HC
Goniopora sp.	GONIOP	HC
Goniopora minor	GONM	HC
Goniopora planulata	GONP	HC
Goniopora stokesi	GONS	HC
Goniastrea pectinata	GOP	HC
Goniastrea retiformis	GOR	HC
Goniastrea (dk tan) edwardsi?	GOR2	HC
Goniastrea Micro-atoll	GORMIC	HC
Green Wire Coral	GWC	OT
Algae Halimeda	HA	AL
Halomitra sp.	HALO	HC
Heteropsammia cochlea	HEC	HC
Herpolitha limax	HEL	HC
Heliopora sp.	HELIO	HC
Herpolitha sp.	HERPO	HC
Herpetoglossa simplex	HES	HC
Heterocyanthus	HETERO	HC
Heteropsammia	HETEROP	HC
Herpolitha weberi	HEW	HC
Halomitra pileus	HP	HC
Heavy Turf Algae	HTA	AL
Heavy Turf Algae With Sand	HTAS	AL
Heavy TA in CA Mosaic	HTCA	AL
Hydnophora sp.	HYDNO	HC
Feather Hydroids	HYDRO	OT
Hydnophora exesa	HYE	HC
Hydnophora microconos	HYM	HC
Jewel Damsel Lawn	JEWLAWN	OT
Kashiveli	KASHI	SU
Light Algal Sand Mat	LASM	AL
Leptastrea bottae	LB	HC
Live Coral on Loose Substrate	LCLS	HC
Leptoseris explanata	LEE	HC
Leptoseris fragilis	LEF	HC
Leptoseris gardineri	LEG	HC
Leptoseris incrustans	LEI	HC
Leptoseris mycetoseroides	LEM	HC
Leptoria phrygia	LEP	HC
Leptos or Pav	LEPAV	HC
Leptastrea	LEPTAS	HC
Leptoria sp.	LEPTOR	HC
Leptoseris sp.	LEPTOS	HC
Leptoseris scabra	LES	HC
Leptoseris yabei	LEY	HC
Lithophyllon sp.	LITHO	HC
Lithophag	LITHOP	OT
Loose Live Coral Colony	LLCC	HC
Loose Live Coral Fragment	LLCF	HC
Large nestling bivalve	LNB	OT

Lobophyton sp.	LOBPHY	SC
Lobophyllia sp.	LOBPHYL	HC
Lobophyllia corymbosa	LOC	HC
Lobophyllia hemprichii	LOH	HC
Leptastrea purpurea	LP	HC
Leptastria prunosa	LPR	HC
Leptastrea transversa	LT	HC
Light Turf Algae	LTA	AL
Light Turf Algae With Sand	LTAS	AL
Light TA in CA Mosaic	LTCA	AL
Lyngbia	LYNG	AL
Lytocarpus (small feather)	LYTOCAR	OT
Algae Macro	MA	AL
Madracis sp.	MAD	HC
Encrusting Macro Algae	MAE	AL
Orange Macro Algae	MAO	AL
Merulina ampliata	MEA	HC
Merulina sp.	MERU	HC
Maiden Hair Fern Algae	MHA	AL
Millepora sp.	MILLE	HC
Montastrea valenciennesi	MO	HC
Montastrea annuligera	MOA	HC
Montastrea curta	MOC	HC
Montipora danae	MOND	HC
Montipora foliosa	MONF	HC
Montipora informis	MONI	HC
Montipora maldivensis	MONM	HC
Montipora monasteriata	MONMA	HC
Montipora millepora	MONMI	HC
Montipora sinuosa	MONS	HC
Montipora suvadivae	MONSI	HC
Montipora tuberculosa	MONT	HC
MONTA 70 at 8.55	MONTA	HC
Montastrea sp.	MONTAS	HC
Montipora sp.	MONTI	HC
Montastrea Micro-atoll	MONTMIC	HT
Montipora venosa	MONV	HC
Medium Turf Algae	MTA	AL
Medium Turf Algae Holding Sand	MTAS	AL
Medium TA in CA Mosaic	MTCA	AL
Mycedium sp.	MYCE	HC
Mycedium elephantotus	MYE	HC
No Data Taken	ND	SU
Nodal Dichotomous Thing	NDT	SC
Nephthea	NEPH	SC
Not Identified	NI	OT
Oulophyllia crispa	OC	HC
Oulophyllia sp.	OULO	HC
Oxypora lacera	OXL	HC
Oxypora sp.	OXY	HC
Pavement	P	SU
Pavona acuticarinata	PAA	HC
Pavona clavus	PAC	HC
Pachyseris sp.	PACHY	HC
Algae Padina	PAD	AL
Pavona duerdeni	PADU	HC

Pavona explanulata	PAE	HC
Palythoa sp. 1 (Large polyp)	PAL	OT
Palythoa sp. 2 (Small polyp)	PAL2	OT
Palauastrea sp.	PALAU	HC
Pavona maldivensis	PAM	HC
Pavona minuta? tan	PAMI	HC
Pavona sp.	PAV	HC
Pavona varians	PAVV	HC
Pocillopora damicornis	PD	HC
Pectinia alcicornis	PEA	HC
Pectinia sp.	PECT	HC
Pectinia lactuca	PEL	HC
Physogyra lichtensteini	PHL	HC
Phyllospongia foliascens	PHYLFOL	SP
Physogyra sp.	PHYSOG	HC
Physophyllia	PHYSOP	HC
Platygyra sp.	PLATY	HC
Platygyra daedalea	PLD	HC
Plerogyra sp.	PLERO	HC
Plerogyra sinuosa	PLES	HC
Plesiastrea sp.	PLESIA	HC
Plesiastrea versipora	PLESV	HC
Platygyra lamellina	PLL	HC
Platygyra sinensis	PLS	HC
Pocillopora sp.	POC	HC
Pocillopora damicornis	POD	HC
Podabacia sp.	PODA	HC
Podobacia crustacea	PODC	HC
Pocillopora eydouxi	POE	HC
Pocillopora ligulata	POL	HC
Polyphyllia talpina	POLT	HC
Polyphyllia sp.	POLY	HC
Pocillopora meandrina	POM	HC
Pocillopora molokensis	POMO	HC
Porites sp.	POR	HC
Porites cylindrica	PORC	HC
Porites (N) horizontalata	PORH	HC
Porites lichen	PORL	HC
Porites lobata	PORLO	HC
Porites lutea	PORLU	HC
Porites lutea or lobata	PORLULO	HC
Porites mauritiensis	PORM	HC
Porites massive	PORMAS	HC
Porites Micro-atoll	PORMIC	HC
Porites murrayensis	PORMU	HC
Porites nigrescens	PORN	HC
Porites palmata	PORP	HC
Porites profundus	PORPR	HC
Porites (S) rus	PORR	HC
Porites solida	PORS	HC
Pocillopora verrucosa	POV	HC
Pachyseris rugosa	PR	HC
Pachyseris speciosa	PS	HC
Psammocora sp.	PSAM	HC
Psammocora contigua	PSC	HC
Psammocora digitata	PSD	HC

Psammocora explanulata	PSE	HC
Psammocora folium	PSF	HC
Psammocora haimeana	PSH	HC
Psammocora nierstrazi	PSN	HC
Psammacora profundacella?	PSP	HC
Pocillopora verrucosa	PV	HC
Rubble	R	SU
Red Algal Film	RAF	AL
Rubble Cemented	RC	SU
Branching Red Coralline Alga	RCAB	AL
Rhodactis on Loose Substrate	RHLS	OT
Rhodactis sp	RHOD	OT
Rubble Loose	RL	SU
Sand	S	SU
Sand/Rubble Matrix	S/R	SU
Sand Algae Combination	SA	AL
Sandalolitha sp.	SANDAL	HC
Sarcophyton sp.	SARCO	SC
SoftCoral	SC	SC
Soft Coral Encrusting	SCE	SC
Digitate Encrusting Soft Cora	SCED	SC
Soft Coral on Loose Substrate	SCLS	OT
Scolymia sp.	SCOL	HC
Soft Coral Tree	SCT	SC
Scolymia vitiensis	SCV	HC
Sandolitha dentata	SD	HC
Seriatopora caliendrum	SEC	HC
Seriatopora hystrix	SEH	HC
Seriatopora sp.	SERI	HC
Silt	SI	SU
Siderastrea sp.	SID	HC
Sinularia sp.	SINU	SC
Siphonodictyon	SIPHON	SP
Stegastes nigricans Lawn	SNLAWN	OT
Sponge Boring	SPB	SP
Sponge Cup	SPC	SP
Sponge Encrust	SPE	SP
Sponge, Encrusting charcoal pa	SPECP	SP
Sponge Foliose	SPF	SP
Sponge Globular	SPG	SP
Sponge on Loose Substrate	SPLS	OT
Sponge Massive	SPM	SP
Sponge Plate	SPP	SP
Sponge Tube	SPT	SP
Sponge Vase	SPV	SP
Sandolitha robusta	SR	HC
Stylocoeniella guentheri	STG	HC
Stylophora pistillata	STP	HC
Stylaraea	STYLAR	HC
Stylaster sp.	STYLAS	HC
Stylocoeniella guentheri	STYLOC	HC
Stylophora sp.	STYLOP	HC
Symphyllia sp.	SYM	HC
Synarea sp.	SYN	HC
Synarea, brown	SYNBR	HC
Synarea, green	SYNGR	HC

Symphyllia radians	SYR	HC
Symphyllia recta	SYRE	HC
Symphyllia valenciennesii	SYV	HC
Turbinaria sp2	T2	AL
Algal Turf	TA	AL
Turf Algae Holding Sand	TAS	AL
TA exceeds CA Mosaic (TA usual	TCA	AL
Trachyphyllia geoffroyi	TG	HC
Thalassia sp.	THAL	OT
Tridacna maxima	Tmax	OT
Turbinaria ornata	TOR	AL
Trachyphyllia sp.	TRACHY	HC
Tridacna sp.	TRI	OT
Tridacna Shell	TSHELL	SU
Tridacna squamosa	Tsqua	OT
Tubastraea	TUBA	HC
Tube Sponge	TUBESPO	SP
Tubipora sp.	TUBI	HC
Turbinaria marmorea	TUM	HC
Turbinaria mesenterina	TUME	HC
Turbinaria peltata	TUP	HC
Turbinaria sp.	TURBI	HC
Vermetid Snail	VERM	OT
White Hardground Boring Sponge	WBS	SP
Zooanthids	ZO	OT
Coral Rock Loose	CRL	SU
Dead A. Corymbose Loose	DACCORL	SU
Dead ACT in Growth Position	DACTI	SU
Dead ACT Loose	DACTL	SU
Dead ACT Fragment(s)	DACTF	SU
Dead ACCOR Fragment(s)	DACCORF	SU
Fixed Substrate	FSU	SU
Dead ACCOR in Growth Position	DACCORI	SU
Dead ACB Fragment(s)	DACBF	SU
Dead Acropora Palmate in Place	DACPI	SU
Dead Acropora Palmate Loose	DACPL	SU
Live Coral in Place	LCI	HC
Acropora hyacinthus Group	ACHYG	HC
Platygyra/Goniastrea	PLATGON	HC
Goniastrea or Favites	GONFAV	HC
Porites, Finger Form	PORFING	HC
Beach Rock	BR	SU
HeavyTurf Algae Grazed	HTAG	AL

APPENDIX C. "Samples.dbf" file of ICOD database

SAMPLE_NR	SITE	TRANS_NR	DATE	S_TIME	SAMPLE_BY	TRANSCRIBE	ENTRY_BY	ENTRY_CHK	E_TIME	SAMPLE_TYPE
1	Mystery	1	24/09/90	12.30	Hussain Zahir	Hussain Zahir	Xaha Waheed	Bill Allison	13.30	I
2	Villingili	1	11/09/90	10.06	Bill Allison	Bill Allison	Xaha Waheed	Bill Allison	11.30	
3	Villingili	1	11/09/90	10.06	Hussain Zahir	Hussain Zahir	Xaha Waheed	Bill Allison	10.50	
4	Villingili	1	12/08/90	0.00	Hussain Zahir	Hussain Zahir	Xaha Waheed	Bill Allison	0.00	
5	Villingili	1	05/07/90	0.00	Gerard Faure		Xaha Waheed	Bill Allison	0.00	
6	Embudu Village	2	02/10/90	0.00	Hussain Zahir	Hussain Zahir	Xaha Waheed		0.00	I
7	Embudu Village	1	02/10/90	0.00	Hussain Zahir Plumb	Hussain Zahir	Xaha Waheed		0.00	I
8	Embudu Village	1	02/10/90	11.10	Hussain Zahir					
9	Embudu Village	3	02/10/90	13.49	Bill Allison Plumb	Bill Allison	Bill Allison	Bill Allison	14.34	I
10	Mystery	3	24/09/90	0.00	Bill Allison	Christine	Xaha Waheed		0.00	I
11	Malé	1	24/09/90	0.00	Bill Allison	Christine	Xaha Waheed		0.00	
12	Malé	1	24/09/90	0.00	Hussain Zahir	Hussain Zahir	Xaha Waheed		0.00	
13	Anchorage	1	18/09/90	0.00	Bill Allison	Bill Allison	Bill Allison	Bill Allison	0.00	I
14	Deto	1	04/10/90	11.45	Bill Allison Plumb	Bill Allison	Xaha Waheed	Bill Allison	11.40	I
15	Deto	1	04/10/90	12.45	Bill Allison	Bill Allison	Xaha Waheed	Bill Allison	13.08	I
16	Deto	2	04/10/90	11.05	Hussain Zahir	Hussain Zahir	Xaha Waheed	Bill Allison	11.58	
17	Malé	1	30/10/90	10.00	Hussain Zahir	Hussain Zahir	Bill Allison	Bill Allison	10.50	I
18	Mystery	3	04/07/90	0.00	Gerard Faure	Bill Allison	Bill Allison	Bill Allison	0.00	
19	Mystery	2	04/07/90	0.00	Gerard Faure	Bill Allison	Bill Allison	Bill Allison	0.00	
20	Mystery	1	04/07/90	0.00	Gerard Faure	Bill Allison	Bill Allison	Bill Allison	0.00	
21	Anchorage	3	13/10/90	16.52	Bill Allison	Bill Allison	Bill Allison	Bill Allison	17.34	I
22	Mystery	2	16/10/90	14.07	Bill Allison	Bill Allison	Hassan Shakeel	Bill Allison	14.47	I
23	Malé	3	30/10/90	12.02	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.25	I
24	Malé	2	30/10/90	10.02	Bill Allison	Bill Allison	Bill Allison	Bill Allison	10.42	I
25	Anchorage	1	04/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Bill Allison	0.00	I
26	Deto	3	03/07/90	0.00	Gerard Faure	Gerard Faure	Bill Allison	Bill Allison	0.00	I
27	Deto	2	03/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Bill Allison	0.00	I
28	Deto	1	03/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Bill Allison	0.00	I
29	Villingili	3	05/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
30	Villingili	2	05/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
31	Villingili	20	28/06/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
32	Villingili	19	28/06/90	0.00	Gerard Faure	Gerard Faure	Bill Allison	Hassan Shakeel	0.00	I
33	Anchorage	3	04/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Bill Allison	0.00	I
34	Anchorage	2	04/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Bill Allison	0.00	I
35	Embudu Village	1	03/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
36	Embudu Village	2	03/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
37	Embudu Village	3	03/07/90	0.00	Gerard Faure	Gerard Faure	Hassan Shakeel	Hassan Shakeel	0.00	I
38	Anchorage	3	26/12/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
39	Anchorage	2	26/12/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
40	Villingili	2	12/12/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel		0.00	I
41	Villingili	3	13/12/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
42	Villingili	1	14/11/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I

43	Embudu Village	1	03/01/91	12.27	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	12.54	I
44	Embudu Village	2	03/01/91	12.25	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	12.50	I
45	Addu Bushy	1	24/02/91	10.31	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.29	P
46	Addu Gans	3	23/02/91	14.13	Bill Allison	Bill Allison	Bill Allison	Bill Allison	14.49	P
47	Addu Gans	2	23/02/91	11.14	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.33	P
48	Addu Patch	1	22/02/91	15.16	Bill Allison	Bill Allison	Bill Allison	Bill Allison	15.47	P
49	Addu Gans	1	22/02/91	10.22	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.08	P
50	Embudu Village	3	03/01/91	13.14	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	13.41	I
51	Anchorage	7	06/01/91	15.39	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	16.09	I
52	Anchorage	8	12/01/91	15.40	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	15.59	I
53	Anchorage	9	20/02/91	14.54	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	15.30	I
54	Villingili	17	24/06/90	0.00	Gerard Faure	Gerard Faure	Xaha Waheed		0.00	I
55	Villingili	18	28/06/90	0.00	Gerard Faure	Gerard Faure	Bill Allison	Bill Allison	0.00	I
56	Villingili	16	24/06/90	0.00	—— unknown person ——		Xaha Waheed		0.00	I
57	Deto	1	16/01/91	10.45	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	11.05	I
58	Deto	3	16/01/91	12.45	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	13.05	I
59	Villingili	13	13/01/91	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
60	Deto	21	13/01/91	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
61	Deto	2	16/01/91	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
62	Villingili	1	13/11/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	P
63	Anchorage	1	15/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
64	Anchorage	2	15/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
65	Villingili	3	12/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
66	Villingili	2	12/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
67	Anchorage	2	18/09/90	0.00	Hussain Zahir	Xaha Waheed	Hassan Shakeel	Hassan Shakeel	0.00	I
68	Malé	1	18/07/90	0.00	Hussain Zahir	Xaha Waheed	Hassan Shakeel	Hassan Shakeel	0.00	I
69	Malé	3	18/07/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
70	Malé	1	26/10/91	11.50	Hussain Zahir	Hussain Zahir	Hussain Zahir		12.26	I
71	Anchorage	3	15/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
72	Embudu Village	3	20/08/90	0.00	Hussain Zahir	Xaha Waheed	Hassan Shakeel	Hassan Shakeel	0.00	I
73	Embudu Village	2	20/08/90	0.00	Hussain Zahir	Xaha Waheed	Hassan Shakeel	Hassan Shakeel	0.00	I
74	Embudu Village	1	20/08/90	0.00	Hussain Zahir	Xaha Waheed	Hassan Shakeel	Hassan Shakeel	0.00	I
75	Malé	3	30/07/90	0.00	Susan Clark	Susan Clark	Hassan Shakeel	Hassan Shakeel	0.00	I
76	Mystery	3	23/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
77	Mystery	2	23/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
78	Mystery	1	23/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
79	Deto	3	26/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
80	Deto	2	26/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
81	Deto	1	26/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
82	Malé	1	30/07/90	0.00	Susan Clark	Susan Clark	Hassan Shakeel	Hassan Shakeel	0.00	I
83	Malé	2	30/08/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
84	Anchorage	1	15/08/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
85	Mystery	1	04/05/91	11.49	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	12.42	I
86	Anchorage	2	18/09/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
87	Villingili	3	11/09/90	0.00	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	0.00	I
88	Villingili	2	11/09/90	0.00	Hussain Zahir	Hussain Zahir	Hassan Shakeel	Hassan Shakeel	0.00	I
89	Embudu Village	2	15/05/91	12.05	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	12.40	I

90	Embudu Village	1	15/05/91	11.05	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.41	I
91	Deto	3	12/05/91	10.38	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.13	I
92	Deto	2	12/05/91	11.39	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.12	I
93	Deto	1	12/05/91	12.57	Bill Allison	Bill Allison	Hassan Shakeel	Hassan Shakeel	13.15	I
94	Embudu Village	3	15/05/91	14.28	Bill Allison	Bill Allison	Bill Allison	Bill Allison	15.05	I
95	Mystery	1	24/09/90	0.00	Bill Allison	Bill Allison	Xaha Waheed		0.00	I
96	Mystery	3	19/05/91	13.17	Bill Allison	Bill Allison	Xaha Waheed	Bill Allison	14.36	I
97	Mystery	2	19/05/91	10.47	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.47	I
98	Deto	2	04/10/90	13.48	Bill Allison	Bill Allison	Xaha Waheed		14.14	I
99	Embudu Village	3	02/10/90	11.51	Bill Allison	Bill Allison	Xaha Waheed		12.40	I
100	Villingili	3	10/06/91	0.00	Hussain Zahir	Hussain Zahir	Xaha Waheed	Xaha Waheed	0.00	I
101	Villingili	2	29/05/91	11.45	Hussain Zahir	Hussain Zahir	Xaha Waheed	Xaha Waheed	0.00	I
102	Anchorage	3	12/06/91	10.45	Hussain Zahir	Hussain Zahir	Xaha Waheed	Xaha Waheed	11.16	I
103	Anchorage	1	17/06/91	13.13	Hussain Zahir	Hussain Zahir	Xaha Waheed	Xaha Waheed	13.48	I
104	Villingili	1	16/06/91	14.00	Hussain Zahir	Hussain Zahir	Xaha Waheed	Xaha Waheed	14.25	I
105	Malé	2	07/10/91	12.12	Bill Allison	Bill Allison	Bill Allison	Bill Allison	13.00	I
106	Malé	3	08/10/91	11.57	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.45	I
107	Deto	1	10/05/92	13.47	Bill Allison	Bill Allison	Bill Allison	Bill Allison	16.08	P
108	Deto	2	10/05/92	0.00	Bill Allison	Bill Allison	Bill Allison	Bill Allison	0.00	P
109	Deto	3	10/05/92	13.29	Bill Allison	Bill Allison	Bill Allison	Bill Allison	13.48	P
110	Embudu Village	1	13/05/92	10.33	Bill Allison	Bill Allison	Hudha Ahmed		10.59	I
111	Embudu Village	1	13/05/92	11.01	Bill Allison	Bill Allison	Hudha Ahmed	Bill Allison	11.23	P
112	Embudu Village	2	13/05/92	12.31	Bill Allison	Bill Allison	Hudha Ahmed		12.57	I
113	Anchorage	2	16/05/92	16.16	Bill Allison	Bill Allison	Hudha Ahmed		17.16	I
114	Anchorage	3	17/05/92	16.03	Bill Allison	Bill Allison	Hudha Ahmed		16.48	I
115	Villingili	1	02/05/92	16.25	Bill Allison	Bill Allison	Hudha Ahmed		17.11	I
116	Villingili	1	11/05/92	15.12	Bill Allison	Bill Allison			16.12	I
117	Villingili	3	12/05/92	15.50	Bill Allison	Bill Allison	Hudha Ahmed		16.45	I
118	Deto	3	10/06/92	11.19	Bill Allison	Bill Allison	Bill Allison	Bill Allison	11.30	I
119	Anchorage	2	15/06/92	11.17	Bill Allison	Bill Allison	Hudha Ahmed		12.33	I
120	Anchorage	2	12/06/92	11.35	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.20	I
121	Malé	3	14/06/92	11.50	Bill Allison	Bill Allison	Bill Allison	Bill Allison	12.58	I
122	Mystery	1	20/06/92	0.00	Bill Allison	Bill Allison	Bill Allison	Bill Allison	0.00	I
123	Mystery	2	17/06/91	13.50	Hussain Zahir		Hudha Ahmed		14.15	I
124	Malé	1	17/07/92	14.00	Bill Allison	Bill Allison	Bill Allison	Bill Allison	14.50	I
125	Malé	2	17/07/92	15.22	Bill Allison	Bill Allison	Bill Allison	Bill Allison	16.20	I
126	Mystery	3	24/07/92	15.23	Bill Allison	Bill Allison	Bill Allison	Bill Allison	16.07	I

APPENDIX C. "Samples.dbf" file of ICOD database 173

Appendix D

The dBase IV program written to extract data from the ICOD reef monitoring database.

```
*************************************************************************
*                                                                       *
*  PROGRAM NAME:        ICODPLOT.PRG                                    *
*                                                                       *
*  This program allows data from transects surveyed during the ICOD     *
*  coral monitoring programme and entered into the database file        *
*  TRANSENT.DBF to be extracted and dumped into a smaller database      *
*  named EXTRACT.DBF. Data for a single site among those surveyed (see  *
*  database file SAMPLES.DBF for details), or for a specified transect  *
*  at a single site can be extracted from the large database to allow
        *
*  easier analysis.                                                     *
*  As well as extracting a specific transect at a single site, or
        *
*  all transects at a single specified site, the program also creates   *
*  another database file ICODPLOT.DBF with the data organized for easy  *
*  plotting in Microsoft EXCEL so that changes over time at transects   *
*  can be readily visualised.                                           *
*  The numerous Object_Id's can also be grouped into groupings          *
*  specified in OBJECTS.DBF in fields Group1, Group2 and Obj_Type       *
*  before being preprocessed for easy plotting.                         *
*                                                                       *
*  WRITTEN BY:     Alasdair Edwards     LAST CHANGED: 27 July 1993      *
*                                                                       *
*************************************************************************

SET STATUS ON
SET SAFETY OFF
SET TALK OFF

* Allow user to specify which site (msite) and, if required, which
* transect (mtrans) is to be extracted. If mtrans is zero, then all
* transects at a given site are extracted.
msite = "          "
mtrans = 0
@ 5,10 SAY "Which site is to be extracted? " GET msite
  READ
msite = UPPER(TRIM(msite))
@ 6,10 SAY "Which transect at "+msite+" is to be extracted? "
@ 7,10 SAY "Enter number of transect or 0 (zero) for all transects: ";
  GET mtrans
  READ

* Allow user to group Object-Id's with varying degrees of coarseness
* as defined by fields Group1, Group2 and Obj_Type in database file
* Objects.dbf.
```

```
mgroup = 0
@ 9,18  SAY "*** GROUPING OF Object_Id's ***"
@ 11,10 SAY "Enter 0 (zero) if no grouping required [default]."
@ 12,10 SAY "Enter 1 for Group1 grouping (fine)."
@ 13,10 SAY "Enter 2 for Group2 grouping (coarse)."
@ 14,10 SAY "Enter 3 for grouping into ICOD Obj_Type's."
@ 15,10 SAY "Which grouping required? " GET mgroup
READ

* Set up 3 column array to store Sample_Nr, Date, and Trans_Nr for
* all transects at the specified site.
DECLARE msamples [50,3]
mcount = 1
DO WHILE mcount <= 50
  msamples [mcount,1] = 0
  mcount = mcount + 1
ENDDO

SELE 1
  * Use main ICOD database with all transect survey data
  USE Transent

SELE 2
  * Use ICOD database which lists all samples taken at each transect
  * at each site to prepare list of all Sample_Nr's (with Date and
  * Trans_Nr) for specified transect(s) at specified site.
  USE Samples
  mcount = 1
  IF mtrans = 0
    LOCATE FOR TRIM(UPPER(Site)) = msite
    IF FOUND() .AND. msamples [mcount, 1] <> Sample_Nr
      msamples [mcount, 1] = Sample_Nr
      msamples [mcount, 2] = Date
      msamples [mcount, 3] = Trans_Nr
      mcount = mcount+1
    ENDIF
    DO WHILE .NOT. EOF()
      CONTINUE
      IF FOUND() .AND. msamples [mcount-1, 1] <> Sample_Nr
            msamples [mcount, 1] = Sample_Nr
            msamples [mcount, 2] = Date
            msamples [mcount, 3] = Trans_Nr
            mcount = mcount+1
      ENDIF
    ENDDO
  ELSE
    LOCATE FOR TRIM(UPPER(Site)) = msite .AND. Trans_Nr = mtrans
    IF FOUND() .AND. msamples [mcount, 1] <> Sample_Nr
```

```
    msamples [mcount, 1] = Sample_Nr
    msamples [mcount, 2] = Date
    msamples [mcount, 3] = Trans_Nr
    mcount = mcount+1
   ENDIF
   DO WHILE .NOT. EOF()
    CONTINUE
    IF FOUND() .AND. msamples [mcount-1, 1] <> Sample_Nr
       msamples [mcount, 1] = Sample_Nr
       msamples [mcount, 2] = Date
       msamples [mcount, 3] = Trans_Nr
       mcount = mcount+1
    ENDIF
   ENDDO
  ENDIF

SELE 3
  USE Extract
  ZAP

SELE 1
  * For each Sample_Nr on list copy across records from Transent.dbf to
  * new file Extract.dbf.
  mcount = 1
  DO WHILE msamples [mcount, 1] <> 0
   LOCATE FOR Sample_Nr = msamples [mcount, 1]
   IF FOUND()
    mstart = Start_Dist
    mend = End_Dist
    mobj = Object_Id
    mpcnt = Pcnt_Cover
    mnew = New_Object
    msamp = Sample_Nr
    SELE 3
       APPEND BLANK
       REPLACE Start_Dist WITH mstart, End_Dist WITH mend, ;
        Object_Id WITH mobj, Pcnt_Cover WITH mpcnt, New_Object WITH
mnew, ;
        Sample_Nr WITH msamp, Date WITH msamples[mcount,2], ;
        Site WITH LEFT(msite,4), Trans_Nr WITH msamples[mcount,3]
    SELE 1
    DO WHILE .NOT. EOF()
       CONTINUE
       IF FOUND()
        mstart = Start_Dist
        mend = End_Dist
        mobj = Object_Id
        mpcnt = Pcnt_Cover
        mnew = New_Object
```

```
          msamp = Sample_Nr
          SELE 3
            APPEND BLANK
            REPLACE Start_Dist WITH mstart, End_Dist WITH mend, Object_Id
WITH ;
              mobj, Pcnt_Cover WITH mpcnt, New_Object WITH mnew, ;
              Sample_Nr WITH msamp, Date WITH msamples[mcount,2], ;
              Site WITH LEFT(msite,4), Trans_Nr WITH msamples[mcount,3]
          SELE 1
        ENDIF
    ENDDO
  ENDIF
  mcount = mcount + 1
ENDDO

SELE 3
SORT TO Temp ON Trans_Nr, Date, Sample_Nr, Start_Dist
ZAP
APPEND FROM Temp
GO TOP
DO WHILE .NOT. EOF()
  REPLACE Dist WITH ((End_Dist - Start_Dist)*Pcnt_cover/100)
  SKIP
ENDDO
COPY TO Icodplot FIELDS Trans_Nr, Date, Object_Id, Dist, Sample_Nr

SELE 5
  USE Objects
  mrows = RECCOUNT()
  DECLARE mobjects [mrows, 2]
  DO CASE
    CASE mgroup = 1
      COPY TO ARRAY mobjects FIELDS Object_Id, Group1
    CASE mgroup = 2
      COPY TO ARRAY mobjects FIELDS Object_Id, Group2
    CASE mgroup = 3
      COPY TO ARRAY mobjects FIELDS Object_Id, Obj_Type
  ENDCASE

SELE 4
  USE Icodplot
  DO WHILE .NOT. EOF()
    mcount = 1
    DO WHILE LOWER(TRIM(mobjects [mcount, 1])) <>
LOWER(TRIM(Object_Id))
      mcount = mcount + 1
    ENDDO
    REPLACE Object_Id WITH LOWER(TRIM(mobjects [mcount, 2]))
    SKIP
```

```
  ENDDO

  GO TOP
  SORT TO Temp ON Trans_Nr, Date, Sample_Nr, Object_Id
  ZAP
  APPEND FROM Temp

SELE 6
  USE Temp
  ZAP

SELE 4
  GO TOP
  DO WHILE .NOT. EOF()
    mtrans = Trans_Nr
    mmisc = 0
    mdate = Date
    msamp = Sample_Nr
    DO WHILE Date = mdate .AND. Sample_Nr = msamp
      mobj = LOWER(TRIM(Object_Id))
      mdist = 0
      DO WHILE LOWER(TRIM(Object_Id)) = mobj
        mdist = mdist + Dist
        SKIP
      ENDDO
      IF mdist > 0
        SELE 6
          APPEND BLANK
          REPLACE Trans_Nr WITH mtrans, Date WITH mdate, ;
            Object_Id WITH mobj, Dist WITH mdist, Sample_Nr WITH msamp
        SELE 4
      ELSE
        mmisc = mmisc + mdist
      ENDIF
    ENDDO
    IF mmisc > 0
      SELE 6
        APPEND BLANK
        REPLACE Trans_Nr WITH mtrans, Date WITH mdate, ;
          Object_Id WITH "misc", Dist WITH mmisc, Sample_Nr WITH msamp
      SELE 4
    ENDIF
  ENDDO

SELE 6
  USE
SELE 4
  ZAP
  APPEND FROM Temp
```

```
SET SAFETY ON
SET TALK ON
CLOSE DATABASES
RETURN
```