Coral Reefs in Small Island States

Status, Monitoring Capacity and Management Priorities

by Rolph Antoine Payet

Introduction

The perception that islands are representations of paradise and have thus avoided the impacts of human development is fast eroding. With growing populations, increasing tourism and fisheries pressure, many island coastal and marine ecosystems are threatened. Coral reefs, in particular are affected through land-based sources of pollution, coastal reclamation, destructive and uncontrolled fishing; as well as mass coral bleaching events, the most severe on record being in 1998 (Hoegh-Guldberg 1999). On the other hand, many studies have shown that coral reefs and associated ecosystems are critical for economic and sustainable development in islands (see Cesar, 2000). Coral Reefs support an estimated 25 to 34 million islanders, and services such as tourism (see Table 1) contribute about U$ 8.9 billion in foreign exchange earnings in the Caribbean only, (Bryant et al. 1998). Following the bleaching event in 1998, one hotel in the Maldives reported over U$ 300,000 drop in revenues (MHAHE 2001). Coral reefs are clearly at the centre of economic development in island states. Furthermore, island inhabitants have traditionally depended upon coastal fisheries for food; coral and sand for construction materials, medicinal uses, and coastal protection. However, with the growth in tourism the number of conflicting activities has increased (UNESCO 2002), as indicated in Box 1 (Case Study 3). Tourism demands a more conservative approach to coral reefs and associated ecosystems, but many other coral reef users, such as fishermen think otherwise, seeing tourism as only benefiting investors with little money actually remaining in the local economy (UNESCO 2001).

The Stork patch reef in the Seychelles: before 1998 mass coral bleaching (Photo Courtesy of Riaz Aumeeruddy)

The article will focus on coral reef issues within Small Island Developing States (SIDS) rather than islands in general. Small island states have been defined as single islands or groups of islands which are independent political entities and have typically small land areas, large exclusive economic zones and a population under 1.5 million (Commonwealth Secretariat 2000). At least 34 island countries fall into that categorisation, mainly from the Caribbean, Indian Ocean and Pacific regions. Table 1 shows the characteristics of selected islands which have large areas of coral reefs.

At least 60,000 km^2, or 21% of global total of coral reefs areas lie within SIDS (See Table 1), with another 18 % found within Indonesia's islands, which implies that at least 40 % of the worlds coral reefs are found around islands (Spalding *et al*. 2001). Three types of reef systems have been described in island situations: fringing, barrier, and atoll reefs however there are variations in the use of these terms since islands have very complex geological origins and changes through time.

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Table 1 **Characteristics and coral reefs in selected island states**

	Land Area (km^2)	Population (000s)	Coastline Length (km)	EEZ (000s km^2)	Reef Area (km^2)	Tourism Receipts (% of GNP)
Caribbean						
Antigua and Barbuda	280	66	153	110	240	63.4
Bahamas	13,935	276	3,542	652	3,150	42.0
Barbados	431	262	97	186	<100	39.2
Cuba	110,861	11,041	6,073	345	3,020	8.8
Dominica	750	71	148	29	<100	15.9
Dominican Republic	48,442	7,823	940	261	610	13.6
Grenada	312	92	121	25	150	27.0
Haiti	27,750	7,180	370	127	450	3.9
Jamaica	10,991	2,447	1,022	251	1,240	31.6
St. Kitts and Nevis	269	41	135	10	180	30.6
St. Lucia	616	150	158	15	160	41.1
St. Vincent and the Grenadines	389	112	84	38	140	23.8
Trinidad and Tobago	5,128	1,306	3,760	74	<100	4.2
Indian Ocean						
Comoros	2,171	653	340	175	430	10.6
Maldives	300	254	644	996	8,920	95.0
Mauritius	1,850	1,117	177	1,291	870	15.7
Seychelles	445	81	491	1,334	1,690	34.6
Pacific Ocean						
Cook Island	236	NA	120	1,830	1,120	
Federated States of Micronesia	720	NA	6,112	2,980	5,440	
Fiji	18,272	784	1,129	1,217	10,020	19.2
Kiribati	728	79	1,143	3,600	2,940	-
Marshall Islands	181	NA	370	2,131	6,110	-
Nauru	21	11	30	436	<50	-
Palau	497	NA	NA	601	<50	-
Samoa	2,842	171	403	120	490	19.6
Solomon Islands	28,446	378	5,313	1,630	5,750	2.8
Tonga	697	98	419	700	1,500	-
Tuvalu	26	10	24	757	710	-
Vanuatu	14,763	169	2,528	680	4,110	19.3
TOTAL	**292,184**	**34,664**	**35,846**	**22,601**	**59,840**	

Data extracted from GEO Data Portal
(http://geodata.grid.unep.ch/); Spalding et al., 2001; and Wilkinson, 2002; Nurse et al., 2001)

Early research indicated that the abundance and diversity of coral reefs are much higher around islands than along continental coasts (Nunn 1994). The reason for this is related to oceanographic factors which are more dominant in island situations than along continental coastlines. Coral reef diversity is also at its greatest where the Indian and Pacific Oceans meet. However, little is known how these factors influence reef growth and development in island areas, and why in some cases upward reef growth could not keep pace with the last Pleistocene sea-level rise, for example the ancient drowned atolls in the Marshall islands (Lincoln and Schlanger 1991).

The importance of coral reefs has been recognised by many SIDS, especially through deliberations of various international meetings and processes such as the International Coral Reef Initiative (ICRI), the World Summit on Sustainable Development (WSSD), the Convention on Biological Diversity (CBD), and Ramsar Convention (UNEP 2003).

Since the launching of ICRI in 1994, SIDS have played an important role in mobilising support for global commitment on coral reefs. At least 12 paragraphs of the WSSD implementation plan refer to the need to reverse the growing decline in coral reefs through coordination, cooperation, conservation, research, and partnership among stakeholders, as well as engage in sustainable fisheries and tourism. Paragraph 52 specifies that SIDS should manage their rich and diverse coral reef inheritance and support the development of SIDS-specific programmes on marine and coastal biodiversity. The CBD recognised the need to focus on marine and coastal biodiversity since its first Conference of the Parties (COP), and by the sixth COP had adopted a work programme to address the specific issue of coral reefs, the emerging threat of mass bleaching and actions to reverse the physical degradation of coral reefs (*Decisions I/7; VI/2; and Annex 1 & 2 of COP Report*, http://www.biodiv.org/decisions/ accessed on 23/10/03).

At regional levels, the UNEP (United Nations Environment Programme) Regional Seas Conventions have provided an important mechanism to address coral reef issues in SIDS. The Regional Seas network with support of the UNEP Coral Reef Unit provides an effective network for the implementation of key global programmes such as the International Coral Reef Action network (ICRAN) and the identification of key centres of excellence in coral reef and marine park management at regional level. For example, through the Nairobi Convention (encompassing the Indian Ocean islands), a Coral Reef Task Force was set-up to implement the Protocol on the Protection and Management of coastal and marine resources (COP3 2001).

State of Coral Reefs

Comparable information on the current state of coral reefs in small island states has been sparse (Wells 1988) until 1997 with the formation of the Global Coral Reef Monitoring Network (GCRMN) through the first ICRI meeting. GCRMN is currently a growing network of regional nodes, national monitoring programmes, regional partnerships and collaborations among various intergovernmental organisations. The first global coral reef status report was published in 1998 (Wilkinson 1998), and subsequently two updates have been published (Wilkinson 2000, 2002). These two reports form the basis of this section on the status of coral reefs in selected island states. Figure 1 summarises the relevance of the key threats to coral reefs within the small island states. Table 2 summarises the impact of coral bleaching in selected SIDS.

The Caribbean

The islands states in the Caribbean consist of large islands such as Cuba, and groups of small low-lying islands such as the Bahamas. Coral reefs in the Caribbean are well developed and can be grouped into fringing reefs, as well as patch (small isolated reefs in lagoons) and bank reefs. Coral reefs

Box 1: **Cases from selected islands illustrating practical approaches and constraints to coral reef monitoring and management.**

Case Study 1: **Community Approach to Coral Reef Monitoring and Management in Samoa**

An approach to involve the community based upon the customary marine tenure is being implemented in Samoa. Initial outcomes resulted in the setup of well-defined fisheries reserves and marine protected areas falling under the direct responsibility of coastal villages. Leadership from village leaders as well as capacity building is observed as being critical to the success of the approach. In fact, compliance to local rules was found to be higher than those imposed by the national government, and now community by-laws are even being enforced by national authorities. However, consistent monitoring has been problematic since it depends upon factors of financial sustainability and training. Delineation of marine boundaries between villages is also unresolved in some areas, but overall the approach is seen as an acceptable mechanism for the management of coral reefs in Samoa.

Source: MacKay, K. 2003

Case Study 2: **Coordination of coral reef monitoring at national level in Seychelles**

The Seychelles National Coral Reef Network (SNCRN) was setup in 1998 a few months prior to the catastrophic coral bleaching event of that year with a view to coordinate coral reef monitoring in Seychelles. Whilst it groups organisations working in the marine sector ranging from the government institutions to conservation NGOs, academic institutions and the dive and fishing industry, each organisation have their own monitoring programmes. It also provided links into regional programmes and with GCRMN and ICRI. The network is currently implementing a monitoring programme as part of a regional initiative, and several training activities have been organised. The SNCRN has provided an essential platform for partnerships to be made in monitoring and also sharing of knowledge and experiences. At first many organisations were doubtful the process would work, but it has proved to be critical in encouraging wider support from NGOs and the private sector. However the network has yet to address several critical questions related to coral reefs - such as sustainable financing of monitoring, monitoring methods, centralised database management or not, and coverage of existing network.

Contributed by: Bijoux, J. 2003 Seychelles Centre for Marine Research & Technology

Case Study 3: **Policy issues in the management of reefs in Trinidad and Tobago**

The leasing of prime coastal property adjacent to reefs in Tobago for tourism development, without proper allocation of rights and consultation has lead to serious conflicts with local fishermen. The developer imposed three conditions of access on local fishermen: (i) need to pay to fish; (ii) need to define time to fish; and (iii) needs identification to fish. The resulting conflict led to government intervention and it was agreed the no entrance fees should be paid by fishermen, but they would only be required to enter at certain times and always carry identification. Due to a lack of a national framework for access rights an open access regimes dominate, causing losses to all parties when there are conflicts over use. Multiple uses of coral reef within coastal areas and marine protected areas system is critical in establishing long-term sustainable use of coral reefs in SIDS. Governments have a very important role to play in the definition of access rights and ensure coral reefs are managed for multiple uses as well and protected against degradation.

Source: Potts, A. 2003.

throughout the Caribbean have little variation in the number and types of species, although there area variances in abundances (Edmunds *et al.* 1990). Reef development within this region are affected through surface runoff, wave exposure and periodical hurricane disturbances, and sea temperatures which are influenced by cool upwelling from nearby deep trenches and the Gulf stream. Hard coral diversity is high in most areas, although coral diseases have affected much of the hard coral cover (Goreau *et al.* 1988). Associated species and ecosystems includes over 500 species of fish, large areas of mangroves (especially on the larger islands, such as Cuba), and algal beds.

Coral reefs and associated ecosystems have been seriously damaged over the last 20 years as a result of a combination of activities and natural effects. Growths in population and unplanned coastal tourism are the most likely causes of this degradation, but sedimentation arising from deforestation in the larger islands (such as in Cuba, Haiti, Jamaica and the Dominican Republic) also have an important effect at local levels. Sewage pollution from tourism, large coastal cities and runoff from agricultural land are also important stressors on the coral reef environment. Over-fishing and land-based sources of pollution is a major cause of coral reef degradation in many areas of the Caribbean (UNEP 1999).

Natural disturbances, such as mass deaths of sea urchins (*Diadema antillarum*), over-growth of macro-algae, white-band and other coral diseases, and large-scale coral bleaching associated with elevated sea surface

Table 2 **Impact of coral bleaching on reef mortality in the three SIDS regions and the proportion of reefs at risk**

Island State	Reef Mortality Pre-1998	Reef Mortality (bleaching event) Post-1998	Reefs at Risk Indicator Low	Medium	High	Regional Summary
Caribbean	21%	1%	39%	32%	29%	Highest risk due to direct impacts
Barbados	43%					
Trinidad & Tobago	-	1-2%				
		~4%				
Indian Ocean	13%	46%	46%	29%	25%	Highest risk due to elevated sea-surface temperatures (SST)
Comoros	-	40-50%				
Mauritius	-	15%				
Maldives	~4%	60-90%				
Seychelles	5%	50-90%				
Pacific	4%	5%	59%	31%	10%	Relatively unaffected but at risk form live coral trade and SST
Federal States of Micronesia	-	5%				
Palau	-	~50%				

Source: Wilkinson 200,2002; Bryant et al. 1998; Linden et al. (CORDIO) 2002); Goreau et al., 2000.Lore consequismodipit exero eugait ate dunt lan hent praese tatis nullan henit landit autpat dolore dolore magna commolor si ese commy nulla commoloreet alit alis dolut euis alit la consequisim dio odolobore consequisit landrem vullamcon utet wisi estrud

Table 2: **Selected Regional Monitoring programs supporting coral reef monitoring in small island states.**

Regional Program	Focus	Coordination, Information management and Support
Caribbean		
Caribbean Coastal Marine Productivity Program (CARICOMP)	Scientific program since 1992, to study land-interaction process in the Caribbean. Recent focus shifted to coral reefs and other marine habitats. Regional network of 25 marine laboratories.	Operates through a network of observers which collect data on 1 or 2 monitoring sites per country. Data analysed at University of West Indies in a central database (the Caribbean Coastal Data Centre)www.uwimona.edu.jm/centres/caricomp/
Atlantic and Gulf Rapid Reef Assessment (AGGRA)	An international collaboration of researchers to evaluate coral reef condition in the Caribbean using a specific rapid assessment protocol. Assessments have already been undertaken on 500 reefs.	AGGRA is coordinated through the University of Miami and data is managed utilizing a purpose-built MS Access database. www.coral.noaa.gov/agra/
Indian Ocean		
Coral Reef Degradation in the Indian Ocean (CORDIO)	Currently in its third phase since 1998, it main aim is to undertake multidisciplinary scientific assessments by local scientists. Focus extended to socioeconomic aspects and impacts of coral reef degradation.	Major funding is from the Swedish Development Agency. The Indian Ocean islands network is currently coordinated through the Seychelles Centre for Marine Research and Technology. A database and GIS-based system will be developed www.cordio.org
Coral Reef Monitoring in the Indian Ocean Islands	Initiated in 2000 through the Indian Ocean Commission to strengthen coral reef monitoring capacity in all islands of the Indian Ocean	Full size project funded through the GEF. The project is coordinated from Mauritius. A coral reef data management software is in final beta-testing phase.http://coi.intnet.mu/
Nairobi Convention Regional Seas Action Plan (ICRAN)	Initiated in 2000 to strengthen marine protected area management in the island states	Through the ICRAN project and with support from IUCN and WWF. The project is coordinated through Seychelles. The database is linked through the UNEP Map Server Project.www.icran.org
Pacific		
The Polynesia Mana monitoring Network	Adoption of a common approach for the assessment of coral reefs, with focus on reef health, exploited resources, customary practices and management effectiveness.	Coordinated through the Moorea Research Centre (in French Polynesia) with support through the French Government www.environment-gouv.fr/ifrecor/
South Pacific Regional Environment Programme (SPREP)	A program initiated in 1982 aimed at improving the management and sustainable conservation of coral reefs, in terms of capacity building and assessments. In-country studies to implement ICRI Resolutions	Specific work program on coral reefs; supported by member contributions, various donors, including the GEF. Activities implement through secretariat in Samoa. http://www.sprep.org.ws/

Source: Reefbase, Accessed 23/10/2003; Wilkinson, 2002

temperatures also threaten the reefs in this region (Goreau *et al.* 1993). For example in the 1980s, the white-band disease caused a near elimination of Staghorn coral (*Acropora cervicornis)* from the reefs throughout the region, causing major changes in the composition and structure of those reefs (Peters *et al.* 1983). Other diseases such as Black-band, white-pox and white-plague diseases are now common and still causes wide spread mortality in the Caribbean (Antonius and Ballesteros 1997). Hayes and Goreau (1998) argue that the emergence of coral diseases may have been caused by pollution of coastal waters and reduction in coral's normal defences, but indicate that further research is required to determine these linkages.

The Western Indian Ocean

The Western Indian Ocean (WIO) region is different from the other two ocean regions as is flanked by two large continental masses (Africa and Arabia), and has a distinctive through flow exchange with the Pacific Ocean (Tomczak and Godfrey 2001). The reefs in the Indian Ocean share strong biogeographical origins with the Indo-Pacific region, and coral species diversity does not decline along the equatorial belt from Indonesia to the WIO region in contrast to the eastern part of the Indonesia (Sheppard 2000). Consequently, coral reef diversity is high and many endemic species have been documented (Ahamada *et al.* 2002). The islands in the WIO are of volcanic (Comoros & Mauritius), continental granitic (Seychelles) and coralline (Maldives and some parts of the Seychelles). Dominant reef types include fringing reefs, barrier reefs and atolls (especially in Seychelles and the Maldives) (McClanahan, Sheppard and Obura 2000).

Population growth and tourism development on the coastal plateau in the Seychelles and on the small coral atolls of the Maldives is on the increase, and in some areas, such as on the east coast of Mahe (Seychelles) and Male (Maldives) major reclamation projects have severely affected coral reefs in the immediate area (Payet 1999). Coral reefs on the outer islands of the Seychelles are however devoid of such pressures. There have been reports of coral reef extraction for construction in Comoros (Ahmed 1988) but this is still ongoing, despite evidence of accelerated beach erosion in the Comoros (Payet *et al.* 2003). Over-fishing is also a threat to coral reefs in all of the islands in the region, and evidence of blast fishing have been recorded some parts of the WIO (Salm, Muthiga and Muhando 1998). In Mauritius, the reefs are already affected through over-fishing and pollution discharges from agriculture and industry (Turner 1999).

By far the largest impact on reefs in the Indian Ocean has been the severe mass coral bleaching linked to elevated seas-surface temperatures (SST) in 1997/1998 where in Seychelles, for example 90% coral reef cover mortality was observed (Linden & Sporong, 1999). In Comoros and Mauritius, coral cover loss as a result of the mass coral bleaching was 50% and 15%, respectively. The most affected species were the *Acropora* spp. Thereafter several bleaching events linked to elevated SST have been recorded in Seychelles since 1998 (Wendling *et al.*

2003).Recovery of the reefs has not been uniform across the region, and the recovery rate has generally been very low (Linden *et al.* 2002). Evidence of recruitment in the inner granitic Seychelles is also slow and recovery would be affected in the long-term if there are recurrent bleaching events and direct pressures are not reduced (Engelhardt *et al.* 2002). Coral recovery in uninhabited and remote areas such as the Aldabra Atoll (Seychelles) likewise is also slow but surveys undertaken from 1999 to 2001 indicates that the diversity of coral families being recruited is high (Stobart *et al.* 2002).

Pacific Ocean

The Pacific region is a vast region with almost 40% of the world's coral reef areas. Pacific island states can be grouped into (i) Melanesia (south-western Pacific Ocean, e.g. Fiji, the Solomon islands and Vanuatu); (ii) Micronesia (central and western Pacific, e.g. Palau, Marshall Islands, Nauru and Kiribati), and (iii) Polynesia (eastern Pacific, e.g. Tuvalu, Samoa, Tonga and the Cook islands).

Melanesia is dominated by high volcanic islands where fringing and barrier reefs are well developed and extensive. The Great Sea Reef in Fiji extends over 370 km and is one of the largest in the region (Wilkinson 2002). Patch reefs also occur. Micronesia, on the other hand consists of groups of scattered archipelagos (Spalding *et al.* 2001). Palau, which is of mixed geological origins (volcanic and carbonate limestone), exhibits very high levels of coral reef diversity, with an estimated 425 species of corals, 300 species of sponges and 1 278 reef fish species. Other associated ecosystems include patches of seagrass beds and some mangrove areas. Atolls and several island archipelagos litter the large area of the Polynesian sub-region. However, species diversity is quite low, owing to its distance from the Indo-Pacific region.

Overall, the condition of the reefs in the Pacific island states region are the healthiest on the planet (Bryant *et al.* 1998), but increasing human pressure as well as mass coral bleaching episodes are also threatening reefs in these isolated areas (Salvat 2001).

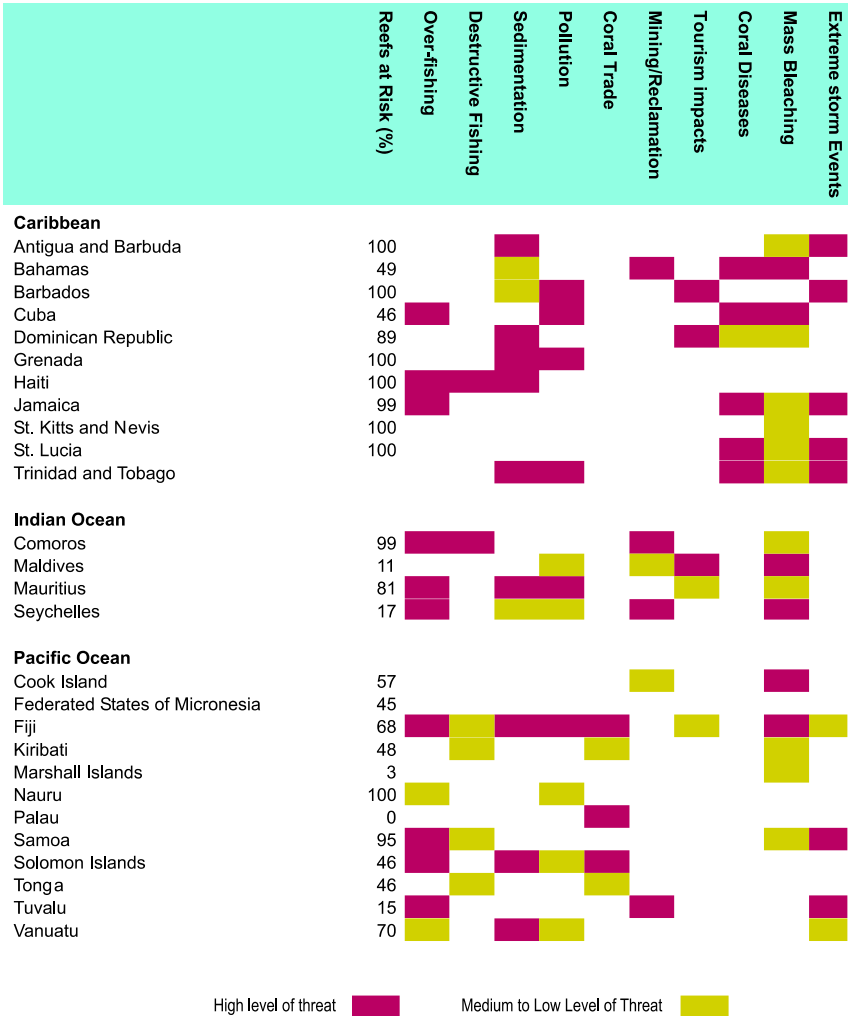
Over-exploitation of reef species, especially for the live trade, is considered to be the largest direct threat. Whilst Pacific island fisheries is largely subsistence, commercial and exports of invertebrate catches such as mollusks, shrimps, clams, sea cucumbers, and the pearl shell is increasing. Furthermore, Fiji, the Solomon Islands, and Tonga account for almost 25% of global live coral exports (Wabnitz *et al.*, 2003). Destructive fishing methods such as dynamite and poisoning (the *Derris* root), chronic in South East Asia, is also on the rise (Adams and Dalzell, 1996). Strong traditional and customary practices that prevail in many Pacific island states may play a role in reversing present trend; see Box 1 (Case Study 1).

The threat from mass coral bleaching is also a major issue for the future status of coral reefs in the Pacific region (Wilkinson 2002). The extent of the bleaching in 1998 and consequent reef mortality has been the most severe in Fiji and extending to the Cook Islands. In contrast to other SIDS region, the effects of bleaching have less disastrous, but there are signs of increasing bleaching incidences with *Acropora* spp. also being the most common species affected.

Monitoring

A number of international organisations have implemented coral reef and associated monitoring programmes in small island states, such as the Australian Institute of Marine Science (AIMS), the Coral Reef Alliance, Conservation International, the World Fish Centre, the Intergovernmental Oceanographic Commission (IOC), International Union for Conservation of Nature (IUCN), the Nature Conservancy, UNEP, UNEP-World Conservation Monitoring Centre, the World Bank, World Resource Institute, and World Wildlife Fund (WWF) among others. Several Governments, through their bilateral overseas development pro-

Figure 1: **Matrix showing the major threats to coral reefs in selected small island states**



Data Extracted from: Wilkinson 1998, 2000, 2002; Bryant, et al., 1998; UNESCO, 1994; Linden et al., 2002

grammes have also contributed, for example Australia, Canada, Finland, France, Sweden, United Kingdom, the United States., among others. Collaborations with universities and research centres in some SIDS, for example the Univeristy of West Indies (Caribbean), the University of South Pacific and South Pacific Regional Environment Programme (SPREP), have also contributed significantly to the wealth of information on coral reefs in islands states. The International Society for Reef Studies, which publishes a specialised journal dedicated to coral reef research, offers important networking among coral reef scientists. Global coral reef datasets maintained by *Reefbase*, a user friendly web accessible database with information on the status of coral reefs, have supported various SIDS with data management capacity. However, many areas remain to be tackled to address the global decline in coral reefs.

There are at least two major global coral reef monitoring programmes and networks which all include SIDS: the Global Coral Reef Monitoring Network (GCRMN) and ReefCheck, which have recently become operational. GCRMN operates through a series of regional nodes, e.g. the Indian Ocean Commission and the Polynesian 'Mana' nodes, whilst ReefCheck, works through national coordinators (See Box 1, Case Study 2 for example of linkages with national programmes). In the Caribbean, the Reef Check program has proved to be very effective in extending the coverage of existing monitoring programmes (Garzon-Ferreira *et al.* 2000). Although ReefCheck uses very simple reef monitoring protocols primarily aimed at volunteer recreational divers and community-based groups, the quick results generated could be useful in providing global coral reef status cost-effectively.

There is no network joining coral reef scientists and institutions across the three main SIDS regions. As summarised in Figure 2, these regions share similar problems and a network for interaction and exchange can provide a much better perspective for managers involved in the research and management of coral reefs in SIDS. However, at regional levels a number of monitoring programmes are in place in the SIDS regions as summarised in Table 3, but coordination among these various programmes has not been entirely successful. One reason is that sites are monitored differently and at various scales (Wilkinson 1998). The Indian Ocean Commission decide in 1998 to publish acceptable protocols for use at regional levels (Conand *et al.* 1999), but there is still disagreement as to which methods are most effective in monitoring changes and status of coral reefs.

Some monitoring programmes are only short-term and hence long-term datasets are unavailable for most regions of the world. For example, in Fiji long term data sets are only available for the Suva Reef which is located in proximity to the University of the South Pacific (Richmond *et al.* 2002). Consequently access to datasets in a comparable format which can then be easily used for management presents an emerging challenge. In the Federal State of Micronesia (Pacific), a database has been established; however the data is submitted to the World Fish Centre (previously ICLARM) for analysis. In the Indian Ocean islands software based database, COREMO, is being developed and tested to facilitate analysis of coral reef monitoring data for specific management purposes (Bigot *et al.* 2003). In many SIDS, the private sector has also funded and been involved in numerous long-term monitoring programs and have generated important datasets especially for remote areas. For example, surveys of pearl oyster populations in the Pacific by the private sector have often included reef and benthic surveys. The involvement of local communities in coral reef monitoring is also increasing. One example, in Samoa, a pilot village coral reef monitoring project was initiated in 1998. Villagers were trained, equipped and encouraged to monitor the status and health of their own coral reef resources with minimal government intervention (MacKay 2003).

Coral Reef Management Priorities

Coral reef management priorities is small island states is not uniform across the three regions as indicated by Table 4, but a number of priority issues are common, and can be addressed inter-regionally. There are many

Table 3 **Major Coral Reef Regional Monitoring Programmes in the SIDS Regions**

Management Priorities	Caribbean	Indian Ocean	Pacific Ocean
1. Policy and Institutions			
Stronger political will for conservation of coral reefs and associated resources.			●
Improvements in existing police, legislation and effectiveness in enforcement.	●	●	●
Framework for regional cooperation and coordination of activities.	●		●
2. Monitoring, Management and Research			
Development of sustainable resources for long-term representative coral reef monitoring.	●	●	●
Implementation of coral reef resource management.	●	●	●
Strengthening of coastal zone management frameworks.	●	●	●
Establishment of representative marine protected areas through community involvement.	●	●	●
Participatory approaches in monitoring, management and research.	●	●	●
Determine carrying capacities of coral reefs for sustainable tourism and fisheries.	●	●	
Research to focus on stressed areas to reduce direct human impacts.			●
Adaptive or coping mechanisms for mass coral bleaching events and related impacts.	●	●	●
3. Information & Capacity Building			
Further capacity building for monitoring and resource management.	●	●	●
Provide reliable access to information and database.	●	●	●
Further inventory and mapping of coral reef resources.	●	●	●
Consistent education and awareness programs at all levels of the society.	●	●	●
Establish meaningful linkages between public sector, NGO and private sector agencies	●	●	●

Source: Wilkinson, 2000 & 2002; Reefbase (accessed 23/10/03);

Table 4: **Coral Reef Management Priorities in SIDS**

Management Priorities	Caribbean	Indian Ocean	Pacific Ocean
1. Monitoring, Management and Research			
Development of sustainable resources for long-term representative coral reef monitoring.	●	●	●
Implementation of coral reef resource management.	●	●	●
Strengthening of coastal zone management frameworks.	●	●	●
Establishment of representative marine protected areas through community involvement.	●	●	●
Participatory approaches in monitoring, management and research.	●	●	●
Determine carrying capacities of coral reefs for sustainable tourism and fisheries.	●	●	
Research to focus on stressed areas to reduce direct human impacts.			●
Adaptive or coping mechanisms for mass coral bleaching events and related impacts.	●	●	●
2. Information & Capacity Building			
Further capacity building for monitoring and resource management.	●	●	●
Provide reliable access to information and database.	●	●	●
Further inventory and mapping of coral reef resources.	●	●	●
Consistent education and awareness programs at all levels of the society.	●	●	●
Establish meaningful linkages between public sector, NGO and private sector agencies	●	●	●
3. Policy and Institutions			
Stronger political will for conservation of coral reefs and associated resources.			●
Improvements in existing police, legislation and effectiveness in enforcement.	●	●	●
Framework for regional cooperation and coordination of activities.	●		●

Source: Wilkinson, 2000 & 2002; Reefbase (accessed 23/10/03);

lessons to be learned in-between regions, especially since there are several on-going initiatives as shown in Box 1. However, many gaps exist which are further elaborated below. It is to be emphasized that monitoring is one of the most important tools for reef managers and policy-makers alike to enable tracking of changes in the reef ecosystem, and attention on sustainability of monitoring programmes is a key to maintaining long-term data sets (Westmacott *et al*. 2000).

Monitoring, Management and Research

Monitoring before the 1997/1998 mass coral bleaching was limited to a few stations in selected SIDS. The need to understand the extent and impacts of the mass coral mortality turned into monitoring for recovery, and restoration (Westmacott *et al.* 2000). Monitoring not only provides coral reef status but also supports the management and restoration of degraded ecosystems. Since monitoring is expensive and human resource demanding any long-term monitoring programme for recovery and restoration requires firm financial commitment. Many sustainable financing strategies have been developed and implemented successfully in many areas of the world (Hatziolos *et al*. 1998). Examples include utilising revenues from marine protected areas, community involvement, university-based programmes and increasingly difficult - dedicated national budget.

Various management approaches, such as coastal management and resource management have not yet been implemented in SIDS. These management approaches provides integrated frameworks for implementing sustainability in the use of coral reefs (Haq *et al.* 1997). One such example discussed earlier is the reef fishery community program setup in Samoa. The determination of carrying capacities of marine ecosystems is still an emerging approach which depends upon a range of data sets such as coral reef health, visitor impacts, fishery yield estimates and socio-economic data. However, the tool is seen as a very essential policy tools to guide governments in the development of coastal areas with minimum impact on coral reefs.

A strong need for participatory management of marine protected areas (MPAs), especially through the involvement of local communities has been expressed in all three regions (Wilkinson 2002). Rightly, many case studies have shown that local ownership and equitable rights allocation of coastal marine resources will improve marine protected area management, enable recovery of coral reefs, reduces incidences of poaching and increased the tourism value of such sites. MPA play a key role in reef recovery and an exercise to identify reef areas which are least damaged and representative of the marine ecosystem in tat areas and in the regional biogeographical context is also an important consideration (Roberts 1998).

The continued mass coral bleaching is of considerable concern to SIDS, even at political level. For example, the Seychelles Parliament requested a special report on coral bleaching and its effects on the economy. Linkages to climate change research are important but capacity is required. Only a small number of coping and adaptive measures have been proposed but are yet to be implemented in SIDS.

Information & Capacity Building

Information management forms the core of any coral reef monitoring and management programme. There is, indeed, a number of coral reef monitoring protocols and database systems, but it is highly unlikely one system will be utilised although Reefbase has successfully put together a system in which long-term data sets and comparative analyses can be made. Capacity is critical to the management of data on coral reefs and access to coral reef data should not be limited to scientists but to local communities and other stakeholders.

All of the SIDS regions expressed the need for continuous inventory of coral reef areas and species (Wilkinson 2002). Specifically, the Pacific region recommended that taxonomic training is provided and guides prepared to enable researchers to identify coral species and other associated species. Mapping, utilising geographical information systems is becoming a useful interface for the analysis of coral reef data. Software have also been developed which can allow, based upon input data, sites based upon ecosystems and species representativeness and risk to be mapped for management purposes (Margules & Pressey, 2000).

Education and awareness programmes exist in all regions, however the effectiveness

of these programmes in changing people behaviour in the short term is not known. Capacity building in the development of media programmes and activities in schools is clearly lacking. Many SIDS have developed coral reef packs, which can be used as part of the curriculum or as a science activity. Integrating coral reef education in government and education bodies through the development of specific programmes have been shown to be very effective, as motivation to protect coral reefs is well accepted when there is collective agreement. Meaningful linkages between Government, Non-Governmental Organisations (NGOs) and the Private sector are critical challenges in many SIDS. For example, monitoring of coral reefs by the private sector in some islands in the Pacific, engages the entire organisation in the process.

Policy and Institutions

A number of island states have developed and adopted a number of legal instruments and policies aimed at managing fisheries, for example the prohibition of use of destructive fishing practices such as dynamite (Wilkinson, 2002). However, stronger political will is needed so that such bans can be extended regionally. Regulations to establish standards for pollution emissions is also lacking in the majority of SIDS although there has been considerable effort done within regional programs such as within the SPREP. The adoption of mandatory Environmental Impact Assessments for tourism projects is also not uniformly implemented within SIDS. Consequently, a review and adequacy of existing legislation and policies aimed at the protection and management of coral reefs may be required at national and regional levels.

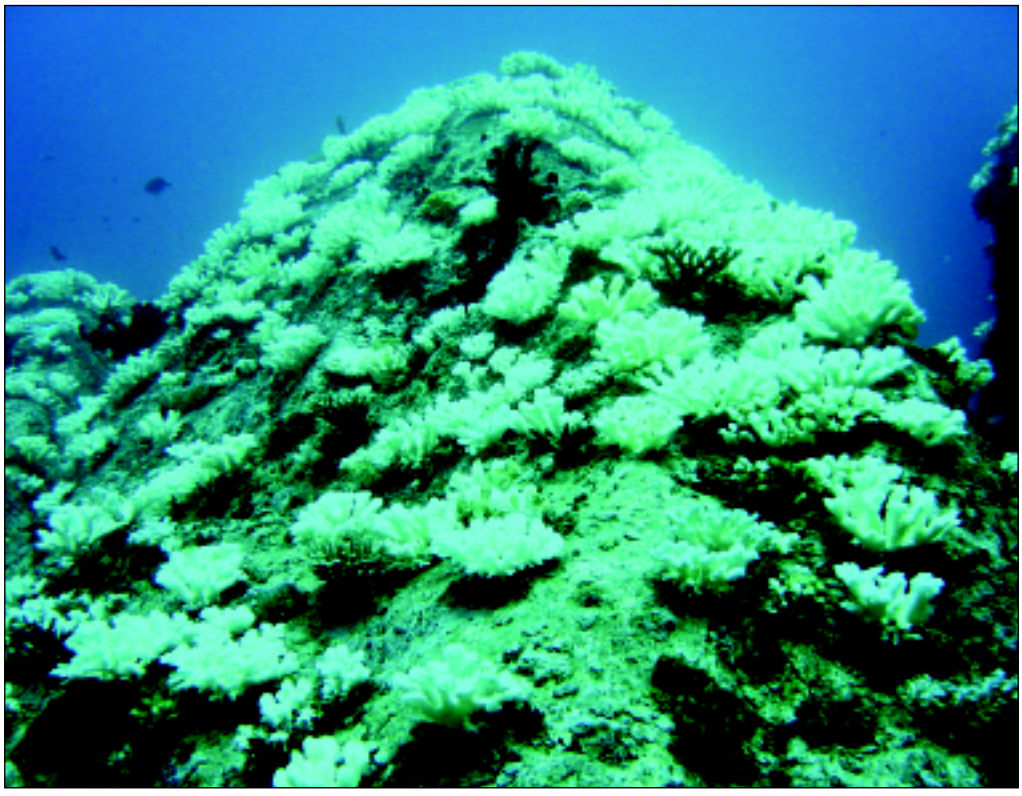
Enforcement and other command-and-control approaches, seems to remain to be one of the most critical aspects of management of coral reefs, although other attempts such as community-based management approaches and economic incentive-based mechanisms are being explored. Enforcement capacity is extremely weak across SIDS and specific strategies needs to be developed to ensure better surveillance and convictions of offenders. Convicting fishermen is a very delicate political issue in many SIDS, resulting in the continuous decline of many reef ecosystems.

Regional cooperation provides a critical platform for exchange of experience and the opportunity to develop regional agreements such as those under the regional seas. Through regional programmes, countries can seek to implement various CBD and ICRI resolutions on coral reefs in a more cost-effective manner, since island states typically suffer from problems of financing and human capacity. Regional cooperation also allows for the exchange of information and expertise which can provide systems of early warning and adaptation in cases of extreme storm events and mass coral bleaching. Existing regional networks should therefore be strengthened with a view to develop regional coral reef task forces with mandate to address at political and technical levels a number of management priorities discussed here.

Conclusions

SIDS have very strong dependence on coral reefs, but increasing pressures threatens not only the reefs but also the livelihood and sustainability of island people. Since SIDS depends upon coral reefs for tourism, recreation and fish (as the main source of protein) any negative will lead to potential losses in revenue, employment as well as basic necessities such as food. Evidence from the global monitoring reports strongly indicates that many reefs within SIDS are in serious decline as a result of direct human exploitation. In much the same way as droughts affects many parts of Africa; coral mortality as a result of episodic elevated sea surface temperatures constitutes, has lead to widespread mortality of reefs in SIDS.

It is therefore imperative that the international community and SIDS governments take urgent action to address those declining trends, and consider the development of implementable coping measures. Ideally, a proactive process should be engaged to further develop the recommendations presented in this paper with a view to address on the ground concerted and participatory actions to reverse the current trend.



The Stork patch reef in the Seychelles: after 1998 mass coral bleaching (Photo Courtesy of Riaz Aumeeruddy)

References

ADAMS, T JH. and DALZELL, P. 1996 Management of Pacific Island Inshore Fisheries. Proceedings of the third Australasian Fisheries Managers Conference: pp 225-237. (Ed.) 'Tricia Summerfield. *Fisheries Management Paper* 88. Fisheries Department of Western Australia, Perth.

AHAMADA, S., BIGOT, L., BIJOUX, J., MAHARAVO, J., MEUNIER, S., MOYNE-PICARD, M., PAUPIAH, N. 2002, Status of the Coral Reefs in the South West Indian Ocean Island Node. In: C.R. Wilkinson (ed.), Status of coral reefs of the world:2002. GCRMN Report, Australian Institute of Marine Science, Townsville. Chapter 5, p 79-100.

AHMED, M. 1988. Extraction et utilisation des matériaux coralliens aux Comores. Le Journal de la Nature, Bourbon Sciences 1(1): 24-26.

ANTONIUS, A. and BALLESTEROS, E. 1998 Coral reef health problems in the Caribbean. *Revista de Biologia Tropical* 46 (Supplement 5).

CESAR, H., (Ed.) 2000. *Collected Essays on the Economics of Coral Reefs*, CORDIO, Sweden. 242 pp.

COMMONWEALTH SECRETARIAT, 2000 *Small states: Meeting challenges in the global economy*. Report of the Commonwealth Secretariat/World Bank Joint Task Force on Small States. Commonwealth Secretariat Report, March 2000. 127 p.

CONAND, C, CHABANET, P., QUOD, JP, BIGOT, L. 1999 Guidelines for Coral Reef Monitoring in the South-West Indian Ocean. Indian Ocean Commission - Regional Environment Programme, Mauritius. 27 p.

COP3 (3rd Conference of the Parties), 2001 COP 3 Report of Parties to the Nairobi Convention. Nairobi Regional Coordinating Unit, Seychelles & UNEP, Nairobi.

EDMUNDS, PJ., ROBERTS, DA, SINGER R., 1990. Reefs of the north-eastern Caribbean I. Scleractinian populations. *Bulletin of Marine Science* 46(3):780-789.

ENGELHARDT U., RUSSEL, M., WENDLING, B., 2002 Coral Communities around the Seychelles Islands 1998-2002. In 'Coral Reef Degradation in the Indian Ocean- Status Report 2002', Linden, O., Souter D., Wilhelmsson, D., Obura, D. (eds.) CORDIO, Kalmar, Sweden, p212-231.

GARZON-FERREIRA, J., CORTES, J., CROQUER, A., GUZMAN, H., LEAO, Z., RODRIGUEZ-RAIREZ, A., 2002, Status of the Coral Reefs in Southern Tropical America: Brazil, Colombia, Costa Rica, Panama and Venezuela. In: C.R. Wilkinson (ed.), *Status of coral reefs of the World:2000*. GCRMN Report, Australian Institute of Marine Science, Townsville. Chapter 18, pp 331-348.

GOREAU, T., HAYES, R., CLARKE J., BASTA, D., and ROBERTSON, C. 1993 Elevated sea surface temperatures correlate with Caribbean coral reef bleaching, in '*A global Warming Forum: scientific, economic, and legal overview*'. Geyer R. (Ed.), CRC Press, Florida.

GOREAU, T., McCLANAHAN, T., HAYES, R., and STRONG, A. 2000 Conservation of Coral Reefs after the 1998 Global Bleaching Event. *Conservation Biology*, Vol. 14(1):5-15.

HAQ, B.U., HAQ S.M., KULLENBERG, G., and STEL, J.H. (Eds.) 1997 *Coastal Zone Management Imperative for Maritime Developing Nations*, Kluwer Academic Publishers, Netherlands.

HATZIOLOS, ME., HOOTEN, AJ., and FODOR, F. 1998 Coral Reefs: Challenges and Opportunities for sustainable management. In *Proceedings of an associated event of the fifth annual World Bank Conference on Environmentally and Socially Sustainable Development.* World Bank, Washington DC, 224 p.

HAYES, RL. and GOREAU, NI. 1998. The significance of emerging diseases in the tropical coral reef ecosystem. *Revista de Biologia Tropical* 46: 173-185.

HOEGH-GULDBERG, O., 1999 Climate Change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research*, 50:839-866.

LINCOLN, J.M., and SCHLANGER, S.O., 1991, Atoll stratigraphy as a record of sea-level change: Problems and prospects. *Journal of Geophysical Research*, Vol. 96, p. 6727-6752.

LINDEN, O., and SPORRONG, N. (Eds). 1998 Coral Reef Degradation in the Indian Ocean- Status Reports and Project Presentations, CORDIO Publication, Sweden. 108 p.

LINDEN, O., SOUTER D., WILHELMSON, D., OBURA, D. 2002 *Coral Reef Degradation in the Indian Ocean. Status report 2002*. CORDIO, Sweden.

MACKAY, K. 2003 Community Managed Marine Protected Areas in the Pacific Islands: Summary of Case Studies. Retrieved from: www.icriforum/itmems/. Accessed: 10/11/03

MARGULES, C.R. and PRESSEY, RL., 2000 Systematic conservation planning. *Nature*, 405:243-253.

McCLANAHAN, TR., SHEPPARD CRC, and OBURA DO, (Eds.) *Coral Reefs of the Indian Ocean*. Oxford University Press.

MHAHE 2001 *First National Communication of the Republic of Maldives to the United Nations Framework Convention on Climate Change*. Published by the Ministry of Home Affairs, Housing and Environment (MHAHE, Male, Maldives. pp.127.

NUNN, PD. 1994 *Oceanic Islands*. Blackwell Publishers, UK. 413 p.

NURSE, L., SEM., G., HAY, J., SUAREZ, A., POH POH, W., BRIGUGLIO L., RAGOONADEN, S. 2001 Small Island States, *In 'Climate Change 2001- Impacts, Adaptation and Vulnerability*', McCarthy et al. (Eds). Cambridge University Press, UK, p843-875.

PAYET, R.A., SOOGUN, N., RANAIVOSON, E., PAYET, R.J., ABDALLAH, F.A. 2003 Indian Ocean Islands – GIWA Regional Assessment 45b. *Global International Waters Assessment (GIWA) Report Volume 1.* PREPRINT. Kalmar, Sweden. 150pp.

PAYET, RA. 1999 *Environmental Impact Assessment: East Coast Phase III*. Ministry of Land Use and Habitat. Government of Seychelles, Seychelles. 125 p.

PETERS, EC., OPRANDY, JJ., and YEVICH, PP. 1983 Possible cause of "white band disease" in Caribbean corals. *Journal of Invertebrate Pathology* 41: 394-396.

POTTS, A. 2003 Conflict Resolution between Inter-Sectoral Stakeholders for the Bucco Reef Marine Park Coastal Zone in Tobago: The Pigeon Point Case Study. Retrieved from: www.icriforum/itmems/. Accessed: 10/11/03

RICHMOND, R., R. KELTY, P. CRAIG, C. EMAUROIS, A. GREEN, C. BIRKELAND, G. DAVIS, A. EDWARD, Y. GOLBUU, J. GUTIERREZ, P. HOUK, N. IDECHONG, J. MARAGOS, G. PAULAY, J. STARMER, A. TAFILEICHIG, M. TRIANNI and N. V. VELDE, 2002, Status of the Coral Reefs in Micronesia and American Samoa: US Affiliated and Freely Associated Islands in the Pacific.. In: C.R. Wilkinson (ed.), Status of coral reefs of the world:2002. GCRMN Report, Australian Institute of Marine Science, Townsville. Chapter 12, pp 217-236.

ROBERTS, C., 1998 Source, Sinks and the design of marine reserve networks. *Fisheries* 23(7): 16-19.

SALM, R., MUTHIGA, N., MUHANDO, C., 1998 Status of coral reefs in the western Indian Ocean and evolving coral reef programmes, in "Wilkinson CR., (ed.), *Status of coral reefs of the world:1998.* Global Coral Reef Monitoring Network Report, Australian Institute of Marine Science, Townsville. 184 p.

SALVAT, B. (ed.) 2001 *Status of Coral Reefs 2000 in SouthEast and Central Pacific "Polynesia Mana" Network*. Fondation Naturalia Polynesia, Papeete, Tahiti. 217 p.

SHEPPARD, CRC., 2000 Coral Reefs of the Western Indian Ocean: An Overview. In 'Coral Reefs of the Indian Ocean, McClanahan, TR., Sheppard CRC, & Obura DO, (Eds.). Oxford University Press. p.3-34.

SPALDING MD, RAVILIOUS, C., GREEN E., 2001 *World Atlas of Coral Reefs*. UNEP-WCMC. University of California Press. 424 p.

STOBART, B., BUCKLEY, R., LeCLAIR, L., TELEKI, K., DOWNING, N., SOUTER, D., and CALLOW, M. 2002 Aldabra:Monitoring the Path to Recovery. In 'Coral Reef Degradation in the Indian Ocean- Status Report 2002', Linden, O., Souter D., Wilhelmsson, D., Obura, D. (eds.) CORDIO, Kalmar, Sweden, 284p.

STODDART, DR. 1973 Coral Reefs: the last two million years. *Geography*, Vol. 58, p. 313-323.

TOMCZAK, M., and GODFREY, J.S 2001 Regional Oceanography: An Introduction. PDF Version 1.0. http://www.es.flinders.edu.au/~mattom/regoc/pdfversion.html . Originally published by Pergamon (1994).

TURNER, JR 1999 Status Report Mauritius. In 'Coral Reef Degradation in the Indian Ocean- Status Reports and Project Presentations, Linden O., and Sporrong, N. (Eds). CORDIO Publication, Sweden. p.60-62.

UNEP 1999 *Assessment of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the Wider Caribbean*. UNEP Regional Seas Reports and Studies, No. 172. UNEP, Nairobi, Kenya.

UNEP, 2003 *Conventions and Coral Reefs*. A UNEP Coral Reef Unit and WWF Coral Reefs Advocacy Initiative. Kenya. 18 p.

UNESCO, 2001. *Wise coastal practices: Towards sustainable small island living.* Results of a workshop on 'Wise coastal practices for sustainable human development in small island developing states', Apia, Samoa, 3–8 December 2000. Coastal region and small island papers 9, UNESCO, Paris, 120 p.

UNESCO, 2002. *Wise practices for conflict prevention and resolution in small islands.* Results of a workshop on 'Furthering coastal stewardship in small islands', Dominica, 4–6 July 2001. Coastal region and small island papers 11, UNESCO, Paris, 70 p.

WABNITZ, C., TAYLOR, M., GREEN, E., RAZAK, T., 2003 *From Ocean to Aquarium-the global trade in marine ornamental species.* UNEP-WCMC, Cambridge, UK. 64 p.

WELLS, S. 1988 *Coral Reefs of the World*, Vols 1-3. UNEP, Nairobi and IUCN, Gland, Switzerland.

WENDLING B., ENGELHARDT U., ADAM P.A., ROSINE G., ALCINDOR R., ZIALOR V. and LOUANGE A. 2003. *A renewed coral bleaching event in the inner granitic islands of Seychelles (April – June 2002), impacts on recent hard coral recruits*. Unpublished Report. Ministry of Environment. Seychelles.

WESTMACOTT, S., TELEKI, K., WELLS, S., WEST., J. 2000 *Management of Bleached and Severely Damaged Coral Reefs.* IUCN, Gland. 36 pp.

WILKINSON CR., (ed.), 1998 *Status of coral reefs of the world:1998.* Global Coral Reef Monitoring Network Report, Australian Institute of Marine Science, Townsville. 184 p.

WILKINSON CR., (ed.), 2000 *Status of coral reefs of the world:2000*. Global Coral Reef Monitoring Network Report, Australian Institute of Marine Science, Townsville. 363 p.

WILKINSON CR., (ed.), 2002 *Status of coral reefs of the world:2002.* Global Coral Reef Monitoring Network Report, Australian Institute of Marine Science, Townsville. 378 p.