

Assessing the Status and Improving Management of Coral Reef Resources: Experiences and Achievements in South Asia

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INTRODUCTION

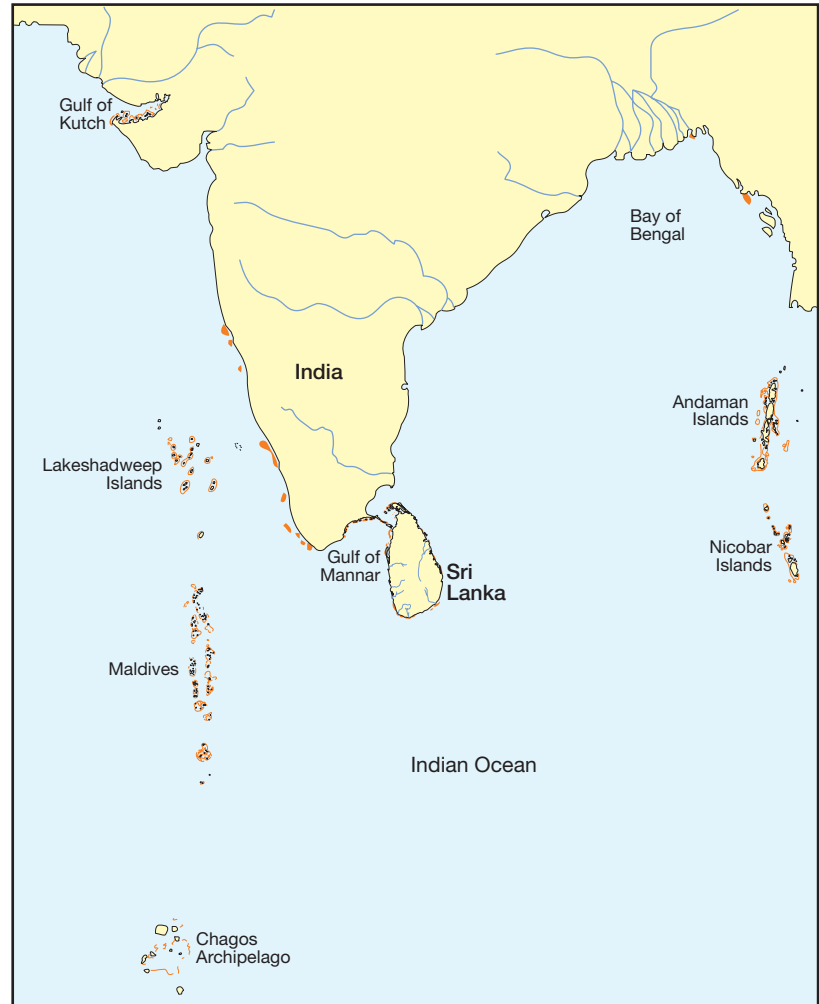
Close to half of the world's poor people live in South Asia (UNICEF, 2001; Samarakoon, 2004). Ramachandran (2002) identified population growth, insufficient food production, and underdevelopment as the major problems in the region. Open access to the sea, poverty, and an increasing demand for fishery products has escalated pressure on coastal resources (e.g. James, 1994; Devaraj & Vivekanandan, 1999; Bhattacharya & Sarkar, 2003; Perera *et al.*, this volume). For example, in India, the number of fishermen in coastal villages increased from two million to six million between 1980 and 1997 (Meenakumari, 2002). Moreover, growing commercial fleets operating in near-shore waters to supply expanding export markets cause habitat destruction and deprive local communities of fish products and a cheap source of nutrition (Jayashree & Arunachalam, 2000; Bavinck, 2003; Bhattacharya & Sarkar, 2003). About 10% and 15% of the total fish catches in India and Sri Lanka respectively are derived from coral reefs by small-scale fishermen (Wafar, 1986; Rajasuriya *et al.*, 1995). Although this is a considerable proportion of the national fish catches, these statistics do not adequately illustrate the actual situation in many areas in the region where hundreds of thousands of poor people depend solely on the products of coral reefs for food and livelihood (e.g. Berg *et al.*,

1998, Kannan *et al.*, 2001; Shanthini *et al.*, 2002; Hoon, 2003; Singh & Andrews, 2003; Whittingham, 2003; Patterson *et al.*, this volume).

During the last few decades, most coral reefs in South Asia have been progressively degraded by destructive human impacts, such as coral mining, blast fishing and the use of other destructive fishing methods, overexploitation, increased sedimentation due to poor land use practices, pollution, anchor damage from boats and tourism related activities (Öhman *et al.*, 1993; Rajasuriya *et al.*, 1995; Bakus *et al.*, 2000; Dharmaretnam & Kirupairajah, 2002; Patterson, 2002; Rajasuriya, 2002; Rajasuriya this volume). By 1998, almost half the coral reefs of South Asia were severely degraded, with the greatest impacts recorded on those reefs fringing the densely populated mainland coasts (Hinrichsen, 1998).

In addition, most coral reef areas of South Asia, including those in remote areas with few local human impacts, suffered extensive coral bleaching and subsequent mortality during the severe El Niño event of 1998, which caused significant increases in sea surface temperatures. While the deeper reefs, below ~10 m, generally recovered from bleaching, between 50% and 90% of the corals in many shallow areas were killed (Rajasuriya *et al.*, 1999; Wafar, 1999; McClanahan, 2000; Rajasuriya & Karunarithna, 2000; Zahir, 2000). In addition, the tsunami that

Figure 1.



hit the coasts bordering the Andaman Sea and Bay of Bengal in December 2004 also caused some damage to the coral reefs.

Coral reef destruction has led to decreased production of ecosystem services with adverse effects on people's food security and livelihoods, shoreline stability, and national economies (e.g. Spurgeon, 1992; Berg *et al.*, 1998; Westmacott & Rijsberman, 2000; Westmacott *et al.*, 2000; White *et al.*, 2000).

This paper provides a brief overview of the current status of coral reefs in India, the Maldives and Sri Lanka, reports the progress of CORDIO's activities in the re-

gion, and presents a number of recommendations for the future.

THE STATUS OF CORAL REEFS AND MAJOR THREATS

India

All major coral reef areas in India, including the Gulf of Mannar, Lakshadweep, Andaman and Nicobar Islands, and the Gulf of Kutch are under threat from human activities (Arthur, 2000; Muley, 2000; Rajasuriya, *et al.*,

2004). In addition, the coral bleaching event in 1998 caused a significant decline in the cover of live coral in most areas (Wafar, 1999; Arthur, 2000; Muley *et al.*, 2002; Rajasuriya, 2002; Wilhelmsson, 2002). Bleaching of extensive areas was recorded also during 2002 in Palk Bay, the Gulf of Mannar, and the Andaman Islands (Kumaraguru *et al.*, 2003).

Venkataraman (2002) reiterated Pillai (1996) by stating that the magnitude of destruction of the marine environment in the Gulf of Mannar may be unprecedented. Destructive fishing methods (including blast fishing), near-shore trawling, sedimentation and pollution are causing considerable damage to the coral reefs, threatening the reef fisheries of the Gulf of Mannar (James, 1994; Bakus *et al.*, 2000; Deepak-Samuel *et al.*, 2002; Patterson *et al.*, this volume). Declines in the abundance of coral associated fish due to the bleaching in 1998 have been reported (see Kumaraguru *et al.*, 2003, for reference). Coral mining, which reduces the function of reefs as natural barriers and lead to increased beach erosion, has transformed the coast (Quazim, 1999; Ramanujam & Sudarsan, 2003), and is probably responsible for the submersion of two islands in the Gulf of Mannar (Venkataraman, 2002). The tsunami in 2004 caused little damage to the reefs of Gulf of Mannar (CORDIO, 2005).

The atoll reefs of the Lakshadweep Islands lost between 43% and 87% of their live coral cover during the 1998 bleaching event (Wafar, 1999) declining to only ~10%. Post-bleaching surveys suggested a subsequent increase in live coral cover (Arthur, 2004). The reefs provide an important source of baitfish for the tuna fishery. Food fish are caught on the reefs primarily when tuna catches are low (Bakus *et al.*, 2000). Most of the atoll islands are unpopulated, and human pressure on coral reefs is relatively low, although the population has tripled during the past 20 years (Muley *et al.*, 2002). Dredging and coral mining have damaged the reefs near several islands (Chandramohan *et al.*, 1993; Bakus *et al.*, 2000). A drop in reef fish catches due to coral bleaching or over-fishing has been noticed (Muley *et al.*, 2002).

In the Gulf of Kutch, less than 30% of the corals were

killed by coral bleaching in 1998 (Wafar, 1999; Pet-Soede *et al.*, 2000). Although the coral reef areas remain important for different fisheries, they are patchy and degraded by coral mining, sedimentation, coastal constructions and discharged waste (Bakus *et al.*, 2000; Muley *et al.*, 2002).

The majority of the coral reefs of the Andaman and Nicobar Islands are comparatively healthy (Turner *et al.*, 2001; Kulkarni & Saxena, 2002), but many reef areas are affected by sedimentation due to logging, sand and coral mining, poaching, blast and cyanide fishing (Bakus *et al.*, 2000; Sundarmoorthy *et al.*, 2004; Venkataraman, 2004). The tsunami in 2004 caused damage to several reef areas in the Andaman and Nicobar Islands (Peninsi, 2005). The population and intensity of development activities are growing rapidly. Also, a growing demand for live fish for export has increased the Indian fishing sector's interest in the coral reefs of the Andaman and Nicobar Islands (Sakthivel, 1999).

Maldives

Most direct human impacts on the coral reefs of the Maldives are localised to certain atolls or islands. The development of the country since the 1970s, through the expansion of the tourism and fishing sectors, has increased the demand for corals for construction of ports and houses (Naseer, 1997). Extensive reef areas bear the scars of coral mining, and a loss of reef-associated fish at these sites has been recorded (Dawson-Shepherd *et al.*, 1992). Land reclamation projects have also damaged reefs near densely populated islands. Although coral mining still occurs, there is now a certain degree of governmental regulation.

In the Maldives, the collection of bait fish on coral reefs sustains the traditional pole and line fishing for tuna, which is "highly appreciated on the international market for its perceived sustainability and high quality products" (MRC, 2003). Tuna fishers have, however, reported a scarcity of baitfish in recent years that they believe is a result of habitat degradation due to the mass mortality of corals in 1998 and high fishing pressure

(MRC, 2003). Further, the growing tourism and enhanced export facilities have expanded the market for reef fisheries. The grouper, sea cucumber, ornamental fish, giant clam, shark and turtle fisheries have expanded rapidly in the Maldives and signs of overexploitation of some reef resources were recognised in the early 1990s (Naseer, 1997; Shakeel & Ahmed, 1997; Flewwelling, 2001) and is a growing concern (Risk & Sluka, 2000; MRC, 2003).

In terms of live coral cover, the reefs of the Maldives are recovering at varying rates after the mass bleaching



Figure 2. Coral reef monitoring in the Maldives.
Photo: HUSSEIN ZAHIR.



Figure 3. Mined corals in Batticaloa, Sri Lanka.
Photo: DAN WILHELMSSON.

and mortality in 1998, when 90–95% of the corals on the shallow reef flats died (Zahir, this volume). New recruitment has been noticed at all sites. However, studies indicate a relatively poor supply of larvae of the genus *Acropora*, which was once the most abundant on these reefs, while other corals, such as *Pavona*, dominate the assemblage of new recruits (Zahir *et al.*, 2002). Results suggest that recovery of coral communities to pre-bleaching levels will be slow or that a change in the coral species composition of these reefs is underway (Zahir, 2002; Zahir, this volume). The deeper reefs are in better condition. Further, the relatively high coral cover recorded during surveys conducted in the Addu region in 2002, suggests that the most severe impacts of the bleaching of 1998 may not have been as geographically widespread as initially thought (Zahir, 2002a). The tsunami in 2004 had a negligible direct impact on overall coral cover, but sediment build up that may make the substrate unsuitable for coral growth, as well as solid waste on the reefs, poses subsequent threats to several reef areas (UNEP, 2005; Zahir, this volume).

Sri Lanka

Destructive fishing methods, such as the use of bottom-set nets and blast fishing, continue to damage coral reefs in Sri Lanka (Öhman *et al.*, 1993; Rajasuriya *et al.*, 1998; Perera *et al.*, 2002; Rajasuriya this volume). Coral mining is still practiced resulting in extensive beach erosion, especially along the south-western and eastern coasts. Even the marine protected areas in Sri Lanka are unmanaged and increasing human activities continue to degrade their condition (Rajasuriya & Karunaratna, 2000; Rajasuriya 2002; Rajasuriya *et al.*, this volume). Declines in catches of reef fishes have been reported in several areas in Sri Lanka (Rajasuriya & Karunaratna, 2000; Perera *et al.*, 2002; Wilhelmsson *et al.*, 2002). A significant decrease in the number of butterfly fish (Chaetodontidae), many of which are usually associated with live coral, has been observed on several reefs (Rajasuriya & Karunaratna, 2000; Wilhelmsson *et al.*, 2002).

Uncontrolled tourism has caused considerable dam-

age to coral reefs in Sri Lanka. For example, in Hikkaduwa National Park, the glass-bottom boats and their anchors break the corals, and local visitors trample corals on the reef flats (Rajasuriya, 2002).

Most of the dominant forms of reef building corals in many of the shallow coral habitats (<8 m) were destroyed during the bleaching event in 1998. The dead coral reefs are largely dominated by algae, tunicates, and corallimorpharians (Rajasuriya & Karunaratna, 2000; Rajasuriya, 2002). However, survival among corals growing in deeper waters (>10 m) was greater, providing a potential source of new recruits. Recovery of bleached corals in shallow reef habitats has been variable between sites but has in general been slow (Rajasuriya, 2002). Recent surveys indicate that there is better recovery on some patch reefs. In the Bar Reef Marine Sanctuary, *Acropora cytherea* and *Pocillopora damicornis* are replacing areas that were previously dominated by branching *Acropora* spp. (Rajasuriya, this volume).

The tsunami caused considerable damage to coral reefs in Sri Lanka. Although there was no discernible damage to coral reefs in the Gulf of Mannar or Palk Bay in Sri Lankan waters, all other areas were affected by the tsunami. Damage was evident on shallow water coral habitats; damage to sandstone and rock reef habitats was negligible. The damage was very patchy even within a single reef. Coral habitats in areas where the seabed configuration appears to have focussed energy into specific locations along the coast, and reefs in these areas were the most affected.

THE CORDIO PROGRAMME IN SOUTH ASIA, 1999–2004: OBJECTIVES

The CORDIO programme has worked towards improving management of coral reefs in South Asia since its initiation in early 1999. The programme, supported primarily by the Swedish International Development Cooperation Agency (Sida), has included a number of projects and activities in India, Maldives and Sri Lanka.

The objectives of CORDIO's South Asia Programme have been:

- Enhance coral reef related bio-physical and socio-economic research and monitoring;
- Raise public awareness of issues relating to the use and conservation of coral reef resources;
- Investigate the feasibility of restoration of damaged coral reefs;
- Provide alternative livelihoods for people dependent on coral reefs.

The following sections provide an account of the progress of CORDIO's activities in the region.

ACHIEVEMENTS AND EXPERIENCES

Coral Reef Related Bio-Physical and Socio-Economic Research and Monitoring

Knowledge of ecological and socio-economic processes, existing problems and risks are essential pre-requisites for making informed decisions and developing appropriate policies and responses to manage coral reefs and their resources effectively. The generation of relevant data is also important to conduct cost-benefit analyses to justify and continuously evaluate management measures. The institutional capacity in South Asia to collect such data is improving but substantial improvements are still to be made.

Ecological Research and Monitoring

CORDIO supports the monitoring carried out by the national governmental institutes, National Aquatic Research and Resources Agency (NARA) in Sri Lanka (Rajasuriya & Karunaratna, 2000; Rajasuriya, 2002; Rajasuriya, this volume) and Marine Research Centre (MRC) in the Maldives, (Zahir, 2000; 2002; this volume). The environmental data generated by these institutes contributes directly to the National Development Plan (NDP) and National Biodiversity Strategy Plan (NBDSAP) in the Maldives, and the government organisations respon-

sible for the management of fisheries and related activities (Department of Fisheries and Aquatic Resources), implementing integrated coastal zone management (Coast Conservation Department), and conservation of biodiversity and management of protected areas (Department of Wildlife Conservation) in Sri Lanka. The collaboration between CORDIO and NARA in Sri Lanka builds on previous capacity development and support provided by Sida/SAREC between 1989 and 1998. In addition, since 1999, CORDIO has funded a M.Sc. study investigating the spatial and temporal patterns of coral recruitment in the Maldives (Zahir *et al.*, 2002). The degree of erosion of reefs following the extensive coral mortality has also been investigated through field experiments (Zahir, 2002b). The CORDIO programme has also trained several people at MRC in methods to conduct general coral reef surveys and assessments of recruitment and erosion of reefs.

Further, the first comprehensive surveys of the reefs of the Tuticorin Coast in India were conducted by Suganthi Devadason Marine Research Institute (SDMRI) as part of the CORDIO Programme (Patterson, 2002; Patterson *et al.*, this volume). Through the institutional capacity building within the programme, SDMRI has established a research group equipped for repeated monitoring of coral reefs along the Tuticorin Coast (Patterson *et al.*, this volume). Several of the projects carried out by SDMRI provide students with Ph.D. degrees. CORDIO further supported SDMRI in the preparation of proceedings of two coastal management workshops, and the production of *A field guide to stony coral (Scleractinia) of Tuticorin in Gulf of Mannar, Southeast Coast of India* (Patterson *et al.*, 2004) for distribution among researchers entering the field of coral reef research.

With assistance from the National Aquatic Resources Research and Development Agency (NARA) and the Sri Lanka Sub-Aqua Club, CORDIO provided training and basic equipment to students at Eastern University, Batticaloa, on the east coast of Sri Lanka. Eastern University completed the first surveys of the reefs of Passichuda during 2003–2004 (Dharmaretnam & Ahamed, this vol-



Figure 4. Transplanted corals, Tuticorin, India.
Photo: SDMRI.

ume). It is anticipated that this will form the basis of expanded coral reef and socio-economic monitoring along the east and north-east coasts of Sri Lanka. Upon request, CORDIO also organised a training course in coral reef monitoring at Colombo University in 2000. Moreover, CORDIO has provided support for a number of researchers from India, Sri Lanka and the Maldives to attend international coral reef training courses and conferences.

Socio-Economic Monitoring of Household Parameters

Sen (1995) challenged the activist call ‘think globally, act locally’ with ‘analyse locally before acting globally’, emphasising the need to combine macro-system approaches with appropriate micro-system socio-economic analysis particularly to ‘identify the distribution of policy benefits and costs’ in the coastal communities. Using this approach, SDMRI has conducted socio-economic surveys in five villages along the Tuticorin Coast as a basis for subsequent management projects in the area (Patterson *et al.*, this volume). Further, in the Lakshadweep Islands, the Centre for Action Research on Environment, Science and Society (CARESS) has established a community based monitoring programme to map the coral reef related activities and resource use with CORDIO support (Hoon

& Tamelander, this volume). The data obtained and the enthusiasm generated among community members during a pilot project initiated by the Global Coral Reef Monitoring Network (GCRMN) in 2001 resulted in the perpetuation and expansion of this monitoring programme. This programme can facilitate the development and implementation of future management actions, through the generation of data and information and the successful involvement of the broader community.

Furthermore, CORDIO has co-funded some GCRMN initiatives such as pilot socio-economic surveys in Sri Lanka in 2000 (by NARA), and a training course on socio-economic monitoring for coral reefs, in the Andaman and Nicobar Islands, India, in 2001.

Reef Fisheries and Tourism

The catches obtained in small-scale coral reef fisheries are often not recorded by governmental fishery institutes, or cannot be disaggregated from the national fishery statistics. Therefore, NARA, with support from CORDIO, initiated a programme of monitoring of reef fisheries in three areas in Sri Lanka (Perera *et al.*, 2002). Further, a database to collate and store information describing the collection and trade of marine ornamental fish was developed at NARA (Wilhelmsson *et al.*, 2002). These programmes will hopefully serve as useful tools in the management of the reef fisheries industry in Sri Lanka.

Coral reef related tourism is of particular importance in the Maldives, where about half of the visitors are scuba divers and travel and tourism contribute around 56% to the national economy (Westmacott *et al.*, 2000). In Sri Lanka, the reef related tourism is increasing, particularly in the newly accessible north-eastern and eastern areas. The effects of coral reef degradation on tourism were therefore investigated within the CORDIO programme in both the Maldives and Sri Lanka between 1999 and 2002 (Cesar *et al.*, 2000; Westmacott *et al.*, 2000; Amaralal, 2002). These governmental monitoring efforts of reef fisheries and tourism unfortunately came to a halt in 2002, but the intention is that these activities will resume during 2005.

Increases in Public Awareness

Attempts to reduce the destructive exploitation of coral reefs in South Asia through legal measures are often short-lived and localised, having little effect at larger scales or over longer periods (e.g. Premaratne, 2003; TCP, 2004). In order for a law or regulation to be generally complied with, it has to be firmly established and accepted in the broader community through the creation of awareness and education. In addition, these measures need to be supplemented with firm law enforcement to avoid a situation where individuals successfully evade the law and thereby discourage voluntary compliance (Flewelling, 2001). A strong awareness among the public often influences both the local stakeholders and politicians. Further, prospects of financial gains inevitably generate political and social acceptance of a certain strategy of exploitation of natural resources (Ludwig *et al.*, 1993). Thus, the overall as well as long-term economic benefits of non-destructive practices need to be better communicated to policy makers and coastal communities.

In 2001, CORDIO co-funded an educational and awareness project entitled *A tomorrow for our reefs* implemented by the World Conservation Union (IUCN) in Sri Lanka. The awareness campaign started with an eight-day exhibition in Colombo, followed by a mobile exhibition in Hikkaduwa and Tangalle in the south. The number of visitors per day in Tangalle averaged 4 000 resulting in recommendations for the implementation of similar projects in other areas of South Asia (IUCN, 2001). Furthermore, during the educational exhibitions, school teachers often asked for resource material to assist them in teaching subjects related to the marine environment. Thus, CORDIO assisted IUCN in producing educational packages, in Sinhala, Tamil and English, for school children in Sri Lanka during 2003. The resource material was distributed to over 1000 schools in Sri Lanka (IUCN, 2004), enabling secondary school teachers to enhance the knowledge of issues affecting coral reefs among a large number of young people. The distribution of this material to schools in Tamil Nadu, India by SDMRI is planned for 2005.



Figure 5. Vermi-compost in Vellapatti village, Tuticorin, India. *Photo: SDMRI.*



Figure 6. Crab fattening tanks in Vellapatti village, Tuticorin, India. *Photo: DAN WILHELMSSON.*

During 2002 and 2003, SDMRI conducted a series of awareness raising programmes on the importance of sustaining reef productivity in a number of villages along the Tuticorin Coast. Fisherwomen organised in 'Self Help Groups', who play a vital social role in these communities, constituted the main target group. Surveys investigating the degree of awareness of coral reef related issues conducted in the villages before and after the campaign showed a substantial increase in knowledge among the community members (Patterson *et al.*, this

volume). Moreover, coral mining activities at Vellapatti and blast fishing at Thirespuram have ceased completely as a direct result of this and earlier education campaigns. Also, in Tharuvaikalam, the fisherwomen are now strongly opposing coral mining (Patterson *et al.*, this volume).



Figure 7. Fisherman in Vellapatti village preparing gastropods. *Photo: DAN WILHELMSSON.*

At Rekawa in southern Sri Lanka, coral mining is extensive, and mangroves are harvested for firewood for the production of lime from the mined corals. In an attempt to reduce these highly destructive activities, the Turtle Conservation Project (TCP) organised five workshops during 2003 to educate and raise awareness of issues affecting coral reefs and associated ecosystems among the community members of Rekawa.

In Batticaloa, Sri Lanka, CORDIO assisted in the organisation of a seminar on environmental issues held

over two days in July, 2000. During the first day, local school children and teachers were invited to participate in discussions and, on the second day, governmental officers, NGO's, and different stakeholders contributed their views. One of the major topics discussed was the extensive coral mining taking place in Batticaloa.

The Feasibility of Restoration of Damaged Coral Reefs

The natural recovery of reefs damaged by coral mining or dynamite fishing is often inhibited by unconsolidated substrata that are unsuitable for settlement and, as a consequence, is very slow (Brown & Dunne, 1988). Natural recolonization can be facilitated by transplantation of corals, similar to reforestation programmes used to restore terrestrial habitats (Auberson, 1982). However, transplantation techniques used in one area may not be applicable to other areas since both physical and biological conditions for survival and reef development vary greatly among localities and species (Guzman, 1991; Smith & Hughes, 1999). Also, when considering transplantation of coral, there is a trade-off between costs, in terms of labour and material, and the survival rate of transplants, which in turn affects the amount of damage caused to donor sites. Thus, CORDIO supported SDMRI in investigating the feasibility of low-cost community driven reef restoration through coral transplantation on the Tuticorin Coast. Results obtained to date are presented in Patterson *et al.* (this volume). A valuable spin-off of the involvement of the local community is an enhanced awareness of environmental issues among local fisher folks.

Alternative Livelihoods for People Dependent on Coral Reefs

“Resource problems are not really environmental problems. They are human problems that we have created at many different times and in many places, under a variety of political, social, and economic systems” (Ludwig *et al.*, 1993). The increasing pressure on coastal resources and the continuous degradation of coral reefs threatens

the food supply and incomes for many people. Therefore, CORDIO seeks to make coastal communities in selected pilot areas less dependant on the coral reef resources by providing opportunities for income diversification and alternative livelihoods. This also reduces the pressure on reefs.

In order to optimise the outputs of CORDIO projects, and other efforts at a larger scale, the South Asian Co-operative Environment Programme (SACEP) has reviewed past, present and planned efforts to establish alternative livelihoods in Sri Lanka and other parts of the world. This resource guide, targeting policy makers and ground level managers has analysed the lessons learned and presents a set of recommendations for future initiatives in promoting additional income generating activities (Perera, 2004). It has incorporated the findings of various institutions, such as the Asian Development Bank, universities and governmental departments, as well as individuals with experience in this field. Moreover, there is scope for a regional co-operation on these issues through the inter-governmental mandate of SACEP. The recommendations of this review are outlined in Perera *et al.* (this volume).

In Tuticorin, several village communities are solely dependent on fish resources obtained from the coral reef areas off the coast (Shanthini *et al.*, 2002). Crowded fishing grounds, increasing demand for fisheries products, and declining catches compel fishermen to use more effective and destructive fishing methods (Deepak Samuel *et al.*, 2002). Further, coral mining and blast fishing, which has already destroyed a significant portion of many reefs, still occurs despite increased law enforcement (Deepak Samuel *et al.*, 2002; Patterson, 2002). The Tuticorin Coast is one area that should be given high priority for management interventions providing alternative livelihoods for artisanal fisher families.

Thus, SDRMI, with support from CORDIO, has trained fisherwomen from four villages in preparation, maintenance and harvesting of earthworm composts for the production of eco-friendly fertilizers for the agricultural sector. SDMRI assisted in the installation of facilities, provides technical backup, and organizes the mar-

keting and sale of the products among local farmers. Today, hundreds of fisherfolk in the area are making considerable financial gains from these activities.

Also, in 2002, groups of fisherwomen were trained in crab fattening where recently moulted crabs are maintained in tanks until the shell hardens before selling them at market for higher prices (Patterson *et al.*, this volume). The project has attracted attention from local authorities and the District Administration provided funds for the construction of a shed with tanks for crab fattening. Today, around 60 women in Vellapatti are engaged in this activity, with continuous technical support provided by SDMRI through the CORDIO Program. A strong interest in expanding this project within the Tuticorin region and eventually throughout the Gulf of Mannar has been shown from other villages as well as from governmental and international agencies. The provision of supplementary incomes to coastal populations through development of crab fattening has been encouraged by the Bay of Bengal Programme (BOBP), due to the fast turnover rate, low operating costs, and reliable market demand for the end products (Pramanik & Nandi, 2002).

Further, at Vellapatti, large quantities of gastropods are landed as by-catch from the crab fishery but the meat from the gastropods was not used due to lack of knowledge of its nutritional value. Thus, 25 women in Vellapatti were trained by SDMRI in processing the gastropods for consumption and today it is part of the diet in the village. Nearby villagers are now asking for similar training. The gastropods could also be locally marketed although additional support for facilities, logistics and promotion would then be needed (Patterson *et al.*, this volume). The activities of SDMRI have contributed to a more efficient utilization of marine resources and to some extent reduced poverty in villages of the Tuticorin Coast.

At Rekawa in southern Sri Lanka, coral mining is extensive (Perera, 2004; TCP, 2004). Large areas of the reef have been turned into plateaus of shifting sediments and, as a consequence, beach erosion in the area is severe. Coral mining was temporarily curtailed in mid-1990s through increased law enforcement, which resulted in



Figure 8. Coral miners receive training in batik production at Rekawa, Sri Lanka.
Photo: DAN WILHELMSSON.

the loss of income for a number of people, of which about 200 were women. Due to lack of alternatives, many coral miners turned their attention to another illegal practice, poaching sea turtle eggs (TCP, 2004). Further, the profitable coral mining resumed quickly once beach patrolling by the police ended and is currently continuing on a large scale.

During 2003/04, the Turtle Conservation Project, with support from CORDIO, trained 20 women who were engaged in coral mining to make coir mats, batiks and wood carvings in an attempt to provide them with an alternative livelihood within the tourism sector. After a series of training workshops, a gift house was constructed on the beach by TCP. The women receive assistance in selling the products in conjunction with the turtle-watching tourism that is conducted by TCP. TCP also promotes the outlet at hotels in the area. This is a first step of a long-term effort by TCP to involve coral miners in the community-based tourism industry at Rekawa. It is not expected that all the trained women will venture into the new occupation full time since coral mining is still more profitable. However, when the tourism industry in the area has been further developed, there is scope for shift at a larger scale from mining into tour-

ism, which can build on the experiences from this pilot project (TCP, 2004). Unfortunately, the tsunami on December 26, 2004, caused many casualties as well as damage to the infrastructure at Rekawa. This tragic event will have long-lasting and serious consequences for the development of the area, including the tourism sector.

DISCUSSION AND FUTURE PERSPECTIVES

The threat of global climate change to coral reefs has come to the world's attention relatively recently, but seems to be here to stay (IPCC, 2001). Increased sea surface temperatures and intensified El Niño events may cause mass mortality of corals and relatively rapid and significant losses in the extent, biodiversity and ecosystem functions of coral reefs in the next few decades (Hoegh-Guldberg, 1999, Stone *et al.*, 1999, Wilkinson *et al.*, 1999, Reaser *et al.*, 2000). So is there a point in trying to conserve reef functions through extensive local management efforts affecting large numbers of people? Indeed, first the susceptibility to bleaching and mortality vary among species and sizes of corals (e.g. Obura, 2001). Also, thermal adaptations among corals through alterations of the composition of symbiotic algae (*Symbiodinium* spp.) have been suggested (e.g. Rowan, 2004). Many reefs show a degree of resilience to bleaching, and there is "circumstantial evidence for an ongoing evolution of temperature tolerance" (Hughes *et al.*, 2003). Hughes *et al.* (2003) further suggest that the reefs will change rather than disappear entirely. However, no coral is tolerant to coral mining or dynamite fishing. Anthropogenic stressors and fragmentation of reefs undermine reef resilience (Nyström & Folke, 2001; Hughes *et al.*, 2003), and inhibit reef recovery, including the possible recolonisation by more tolerant corals (Loya, 1990; Connell, 1997). Thus, a dense network of effectively managed marine protected areas (MPAs), and an enhanced protection of other reef areas, to improve the prospects of re-colonisation of damaged areas through dispersal of corals from more intact reefs are now a high priority (e.g. Nyström

& Folke, 2001; Hughes *et al.*, 2003; West & Salm, 2003, Bellwood *et al.*, 2004).

Secondly, if development of enhanced resilience among coral reefs cannot keep up with the rate of the increase in sea temperatures, and most of the reefs are still doomed, the promotion of sustainable management of reefs will be part of a race against time. A collapse in reef resources can be postponed and more preparatory actions can be taken to mitigate the consequences for coastal communities. Thus, for either scenario, there is no reason to give up on the coral reefs and the people depending on them.

Pertaining to coral reef management in South Asia and elsewhere, repeated urges for enhanced Integrated Coastal Zone Management (ICZM) practices with law enforcement, fisheries management, environmental and socio-economic monitoring, collaboration between institutes, involvement of local communities, and public awareness have been made through a number of organisations and reports of meetings during the past 10 years. While echoing these recommendations, it is worth emphasising some points:

Enhanced Co-Ordination of Efforts among Donors and Implementing Agencies

There is a certain degree of progress at political and institutional levels in South Asia. A number of programmes and projects adopting the principles of ICZM and including coral reefs have been initiated in the region (e.g. Regional: Bay of Bengal Programme (BOBP) executed by FAO, UNEP Regional Seas Programme, implemented by SACEP in South Asia; Sri Lanka: Coastal Resources Management Project (CRMP) implemented by Coast Conservation Department; Maldives: Integrated Reef Resources Management (IRRM); India: National and State Coastal Zone Management Authorities) (see also Le Tissier *et al.*, 2004). External support has been provided by a number of organisations and governments. However, mitigating the problems affecting coastal communities and marine ecosystems in South Asia to any significant degree is an immense task, and a major breakthrough at ground level is yet to occur.

The CORDIO programme can fill some gaps in the process where national and international institutes and organisations with larger financial and human resources as well as formal authorities carry the main responsibility. CORDIO South Asia can also provide a number of path finding demonstration projects for others to build on. There are often advantages in starting with small-scale projects and building coastal management efforts at larger scales on the progress, trust and confidences gained among the local communities (e.g. Olsen & Christie, 2000; Torell, 2000). This is illustrated particularly in Patterson *et al.* (this volume), where an increasing interest from governmental agencies and donors is allowing the initial project to expand both geographically and financially.

In collaboration with the existing projects and programmes, assistance from additional organisations and institutes is much needed. However, better communication among national and international agencies is essential. For example, in order to promote the influx of new initiatives or strengthening of ongoing programmes, more transparent, concrete and specific reporting is required primarily from the supporting and co-ordinating organisations and institutes in the region. This would facilitate the identification of gaps and needs allowing ameliorative efforts to be more focused and co-ordinated. Moreover, the commitment from the governments needs to be improved to assure a long-term process rather than short-term fragmented interventions by donor driven projects (Perera *et al.*, this volume). Unfortunately, in some cases, the governmental dedication seems to be inhibited by the assumption that the donor driven programmes will succeed each other.

Reconstruction after the Tsunami

Large financial, human, and material resources are entering the region in the wake of the tsunami that devastated many coastal communities in south-eastern India, Maldives, and Sri Lanka. It is now of paramount importance that a holistic view is adopted so as not to recreate the pre-existing unsustainable situation in the coastal areas affected. The development of infrastructure, settlements,

and economic activities (e.g. aquaculture, tourism) has to a large extent taken place against policies, laws, and regulations, resulting in conflicts of interests, environmental degradation, economic losses and coastal erosion. Also, several governmental and donor driven, rather small-scale, attempts have been made to reduce the pressure on coastal resources, and to mitigate current and future poverty, through helping people into new livelihoods, such as agriculture, aquaculture, off-shore fisheries (e.g. Perera, 2004). Thus, aid resources must be used in accordance with the long-term development needs of the region, and establish economic activities and infrastructure where and how it should be rather than where and how it was previously.

Empower Governmental Agencies for More Efficient Surveillance and Law Enforcement

The number of laws and regulations pertaining to the use and protection of marine resources and the number of MPAs established in South Asia is misleading. Enforcement of laws and regulations is very weak (e.g. Rajasuriya, 2002; Premaratne, 2003; Perera, 2004; Rajasuriya *et al.*, 2004). As indicated earlier, in the long run, we will not succeed in promoting a change in behaviour among fishermen who use relatively effective but rather destructive seine nets on the reefs, while their neighbours use explosives. Thus, law enforcement needs to be strengthened urgently to primarily stop the people destroying marine habitats for profitable but short-term gains (e.g. Weerakody, 2004). However, this should be done concurrently with awareness raising activities among the broader public and policy makers, not only to influence the behaviour of more stakeholders, but also to create general support for law enforcement and supplement it with social pressure. One example, of many, that illustrates the need to influence public and political opinion is the event in Seenigama, Sri Lanka, in 2002, where the police had to release a number of coral miners after strong protests by fellow villagers and local politicians (Perera, 2004). For the segment of the people involved in illegal activities, such as coral mining and destructive reef fishing, that are poor with no

access to alternative income sources (e.g. Dharmarethnam & Kirupairajah, 2001), increased law enforcement needs to be accompanied by extensive development programmes providing other livelihood opportunities.

Consider Research Efforts as Only a Contribution to the Process, Not a Solution

The call for more resources for research and monitoring should only be made in the context of enhancing the capability to set priorities, continuously assess and optimise the decision-making processes and actions taken. Support to research and monitoring should not be seen as a way to show deed and replace or delay uncomfortable management measures. With fluctuating and complex ecosystems such as coral reefs, a scientific consensus that specifies in detail the levels or means of exploitation that are sustainable will take a long time to accomplish if we will ever get there other than through trial and error. Policy makers will have to live with some uncertainty in decision-making (Ludwig, 1993; Olsen & Christie, 2000), and we certainly know enough about the most urgent threats to the coral reef systems in South Asia (e.g. coral mining, blast fishing, overfishing, pollution and sedimentation) to take immediate action. Unequivocal results are already at hand from the 3–4 decade long large-scale experiment on the effects of uncontrolled human activities on coastal ecosystems in South Asia.

CORDIO will maintain the support to long-term monitoring in the region, and continue to develop demonstration projects for reef management. Also, in 2004, CORDIO, together with IUCN Regional Marine Programme, assumed the role of the GCRMN node in South Asia. This increases CORDIO's emphasis on networking, dissemination of information, and influencing coral reef stakeholders at local as well as policy-making levels.

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