Status of Coral Reefs in Northern, Western and Southern Coastal Waters of Sri Lanka

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ABSTRACT

Selected coral reefs were monitored in the northern, western and southern coastal waters of Sri Lanka to assess their current status and to understand the recovery processes after the 1998 coral bleaching event and the 2004 tsunami. The highest rate of recovery was observed at the Bar Reef Marine Sanctuary where rapid growth of *Acropora cytherea* and *Pocillopora damicornis* has contributed to reef recovery. *Pocillopora damicornis* has shown a high level of recruitment and growth on most reef habitats including reefs in the south. An increase in the growth of the calcareous alga *Halimeda* and high levels of sedimentation has negatively affected some fringing reefs especially in the south. Reef surveys carried out for the first time in the northern coastal waters around the Jaffna Peninsula indicated that massive corals dominate the reef habitats and that human threats are relatively low at present. Reefs are relatively undamaged in the north, while elsewhere they are heavily impacted by human activities due to poor management.

INTRODUCTION

The most common types of coral reefs in Sri Lanka are fringing and patch reefs (Swan, 1983; Rajasuriya *et al*., 1995; Rajasuriya & White, 1995). Fringing coral reef areas occur in a narrow band along the coast except in the southeast and northeast of the island where sand movement inhibits their formation. The shallow continental shelf of Gulf of Mannar contains extensive coral patch reefs from the Bar Reef to Mannar Island (Rajasuriya, 1991; Rajasuriya, *et al*. 1998a; Rajasuriya & Premaratne, 2000). In addition to these coral reefs, which are limited to a depth of about 10m, there are offshore coral patches in the west and east of the island at varying distances (15 -20 km) from the coastline at an average depth of 20m (Rajasuriya, 2005). Sandstone and limestone reefs occur as discontinuous bands parallel to the shore from inshore areas to the edge of the continental shelf (Swan, 1983; Rajasuriya *et al*., 1995). Granite or other types of rock reef habitats are also common especially where headlands and rocks are found along the coast (Rajasuriya *et al*., 1995; Rajasuriya *et al*., 1998b).

Rajasuriya (2005) reported on the status of coral reefs after the mass coral bleaching in 1998 and the 2004 tsunami, the highest impacts of which were seen on shallow coral habitats. The greatest impacts of the tsunami on coral reefs were observed on the east coast whilst the northwestern coastal reefs were undamaged (Rajasuriya, 2005).

Obura, D.O., Tamelander, J., & Linden, O. (Eds) (2008). Ten years after bleaching - facing the consequences of climate change in the Indian Ocean.CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa. http//:www.cordioea.org

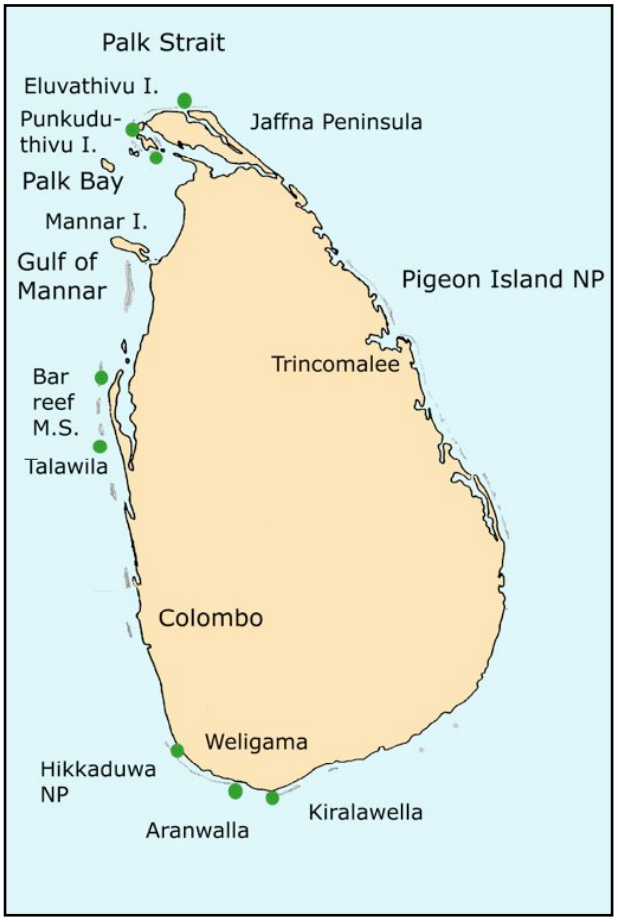

Figure 1. Map of Sri Lanka.

Reef surveys have been carried out from the Bar Reef in the northwest to Kiralawella in the south. In addition, coral reefs that were not previously surveyed by the monitoring programme were examined briefly along the coast of the Jaffna Peninsula and adjacent islands in October and November 2005 to gather preliminary data on their condition and biodiversity based on a recommendation by the Sri Lanka Advisory Group on Sethusamudram Ship Channel Project which is being constructed between India and Sri Lanka (SSCP, 2007). Reef surveys could not be carried out in the eastern coastal waters in 2006 and 2007 due to the ongoing internal conflict.

STUDY SITES AND METHODS

Study sites were located in the northern, western and southern coastal waters (Fig. 1). Permanent monitoring sites at the Bar Reef Marine Sanctuary, the Hikkaduwa National Park and Kapparatota - Weligama reef were surveyed to assess their status. In addition, reef surveys were conducted at Talawila in the northwest, and Aranwala and Kiralawella in the south (Fig. 1). Fringing reef sites at Aranwala, Kiralawella, and sites along the shores of the Jaffna Peninsula and islands were surveyed for the first time.

All reef sites except the northern reefs around Jaffna Peninsula and islands were surveyed using the 50m Line Intercept Transect (LIT) method for benthic cover (English *et al.* 1997). Eight to ten 50m LIT were used for larger reef areas such as Bar Reef, whilst a minimum of four 50m LIT were carried out on reefs with a linear extent of about 1km such as in Aranwala and Kiralawella. Five 50m LIT were used at Hikkaduwa National Park and at Kapparatota, Weligama. Point Intercept Transects (PIT) and Manta Tows (Hill and Wilkinson, 2004) were used for rapid reef surveys in northern coastal waters off Jaffna peninsula. Benthic categories recorded were live hard coral (HC), soft coral (SC), dead coral (DC), sponges (SP), coral rubble (CR), all types of algae (ALG), limestone or sandstone reef substrate (SUB), sand (SA), silt (SI) and other (OT, including e.g. tunicates and corallimorpharians). Hard corals and reef fish diversity around the Point Intercept Transects were assessed using the roving diver technique whereby a diver records species of hard corals and reef fishes in the vicinity of the transect during a 30 minute period.

RESULTS

Status of Corals

Bar Reef Marine Sanctuary

The Bar Reef Marine Sanctuary has an extensive area of patch reefs. The level of recovery has been variable among these patch reefs as they are subject to different oceanographic conditions. The results reported here

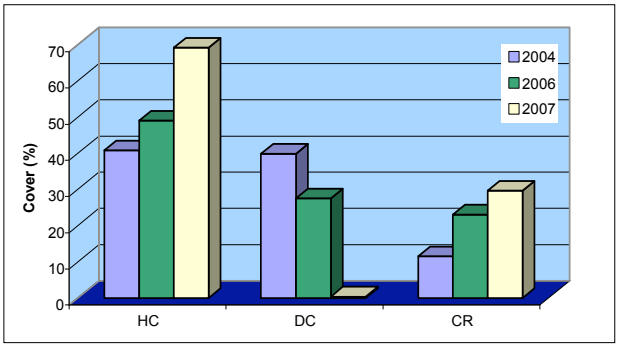

Figure 2. Comparison of cover of the most abundant substrate types in 2004, 2006 and 2007 in the Bar Reef Marine Sanctuary.

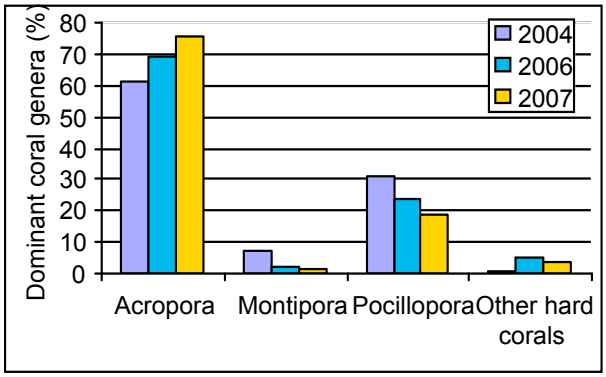

Figure 3. Comparison of the composition of live hard coral cover in 2004, 2006 and 2007 using the most abundant coral genera on the shallow reef flats in Bar Reef Marine Sanctuary.

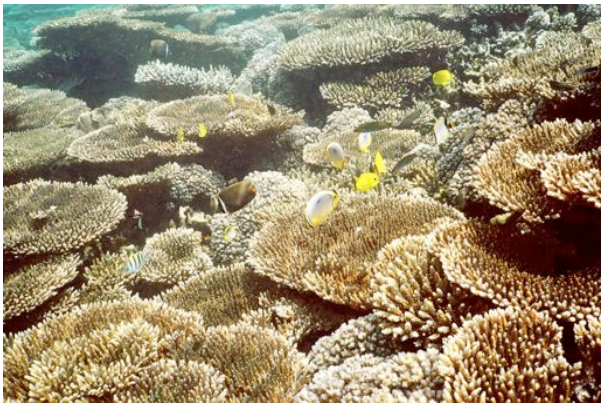

Figure 4. Coral recovery at the Bar Reef Marine Sanctuary by *Acropora cytherea* which now makes up 75% of the coral community.

are from the same group of coral patches that were monitored for recovery since 1998. They are located on the leeward side of a larger group of patch reefs.

Live hard coral (HC) cover has increased from 40% in 2004 to about 70% in early 2007 (Fig. 2). This increase can be attributed to the rapid growth of *Acropora cytherea* which constituted 75% of live hard corals in 2007 (Figs. 3, 4). Other common hard coral genera were *Pocillopora, Montipora, Echinopora, Favia, Favites, Platygyra* and *Podabacia*. Dead coral (DC) cover was less than 1% in 2007 indicating that there are few natural threats to the reef. However coral rubble (CR) had increased from 11% in 2004 to 29% in 2007 (Fig. 2).

Hikkaduwa National Park

The fringing coral reef at Hikkaduwa National Park is about 1km in length and has a reef crest parallel to the shore at a distance of about 75m. The seaward slope extends about 100m from the reef crest and has only a few encrusting coral colonies due to wave action and rapid movement of sand. The main hard coral area is located within the reef lagoon, which was dominated by branching *Acropora* species prior to 1998.

The live hard coral cover at the Hikkaduwa National Park had increased from 12% in 2005 to 26% in 2007 (Fig. 5) mainly due to the rapid settlement and growth of *Pocillopora damicornis* which had risen from 6% of the total live hard coral cover in 2004 to 35% in 2007 (Fig. 6). However, the

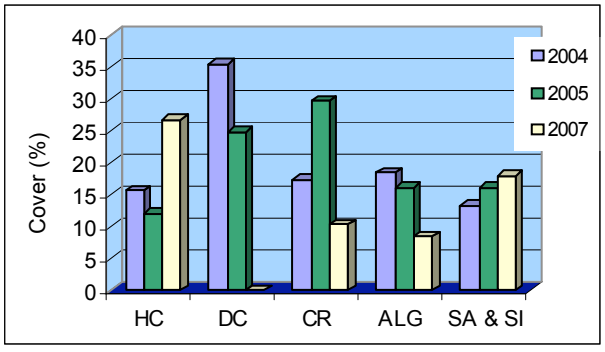

Figure 5. Comparison of cover of the most abundant substrate types in 2004, 2006 and 2007 in the Hikkaduwa National Park.

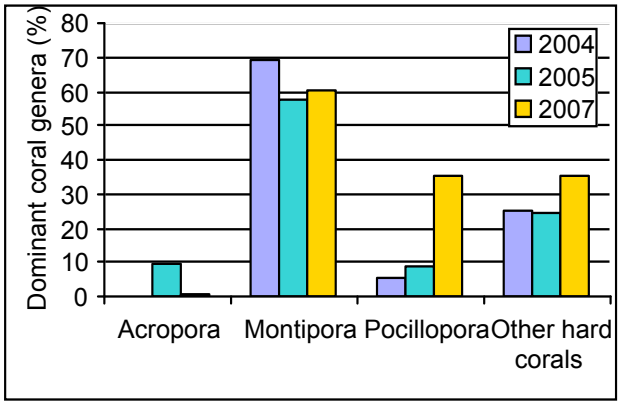

Figure 6. Comparison of the composition of live hard coral cover in 2004, 2005 and 2007 using the most abundant coral genera in the Hikkaduwa National Park.

dominant species at this site was *Montipora aequituberculata,* which had colonized most of the dead branching coral areas (Fig. 6). Other hard coral genera were *Acropora*, *Favia, Platygyra, Goniastrea, Leptoria, Goniopora, Porites, Pseudosiderastrea,* and *Psammocora*. The percent cover of *Acropora* was negligible (0.6%) as natural recruitment and growth of *Acropora* species have been adversely affected by high levels of sedimentation. The percent cover of dead corals, coral rubble and algae has been reduced while an increase was detected in sand and silt accumulation within the national park (Fig. 5).

Kapparatota, Weligama

The fringing coral reef at Kapparatota, Weligama lies on the eastern side of a headland and its reef lagoon is protected from strong wave action. The main coral area lies within its reef lagoon which is about 1 km in length and about 150m wide. The reef was dominated by branching *Acropora* species, *Montipora aequituberculata* and *Pocillopora damicornis* prior to 1998. Reef recovery has been affected by shifting coral rubble after the 1998 bleaching event by the 2004 tsunami and due to human actions such as use of destructive ornamental fish collecting methods.

There was an overall decline in the live coral cover from 52% in 2004 to 22% in 2006 at Kapparatota, Weligama (Fig. 7). Percentage of coral rubble had

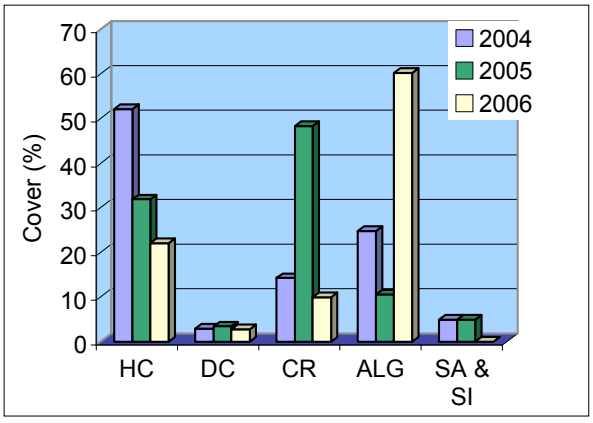

Figure 7. Comparison of cover of the most abundant substrate types in 2004, 2005 and 2006 in Kapparatota, Weligama.

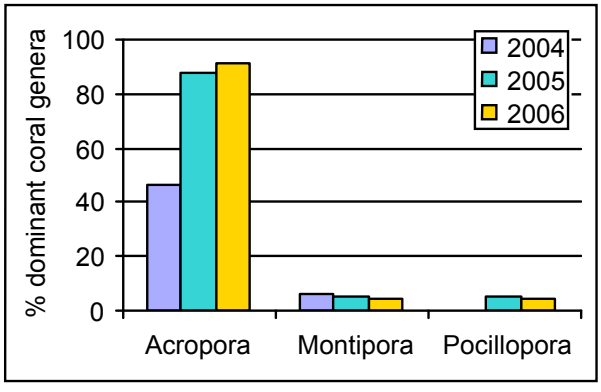

Figure 8. Comparison of the composition of live hard coral cover in 2004, 2005 and 2007 using the most abundant coral genera in Kapparatota, Weligama.

decreased while algae had increased from 10% in 2005 to 60% in 2006 primarily due to an increase in the growth of *Halimeda* spp (Fig. 7). Only three hard coral genera (*Acropora, Montipora* and *Pocillopora*) were common at this site where branching *Acropora* was the most abundant (Fig. 8).

Talawila

The coral reef at Talawila is located about 500m offshore and is parallel to the shoreline. The length of this shallow reef is about 1km and it has no reef lagoon. Most of the living corals are on the reef crest and on the seaward reef slope.

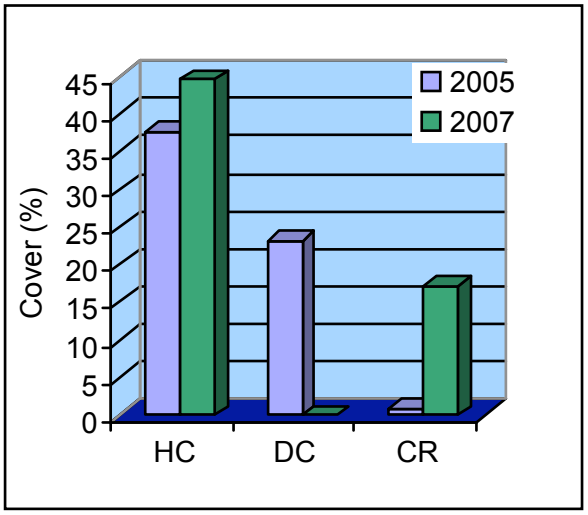

Figure 9. Comparison of cover of the most abundant substrate types in 2005 and 2007 in the Talawila coral reef .

The live hard coral cover has increased from 37% in 2005 to 44% in 2007 (Fig. 9). Coral rubble had increased from a low level of 0.8% in 2005 to 17% in 2007. The Talawila coral reef was dominated by massive corals. The most abundant genera were *Favia, Favites, Galaxea, Porites, Goniastrea, Leptoria, Platygyra* and foliose *Echinopora lamellosa*. Other live hard coral genera present were *Acropora, Hydnophora, Acanthastrea, Montastrea, Oulophyllia, Symphyllia, Turbinaria, Podabacia*, *Pachyseris* and *Pavona*.

Aranwala

The fringing reef at Aranwala is located within a relatively narrow and shallow coastal indentation which is about 20m wide with a sand bottom in the center. The coral areas are located on either side of this coastal indentation. The depth of the reef crest on both sides is about 1m and the reef is subject to strong wave action especially during the southwest monsoon as the wave energy is channeled into the center of the coastal indentation due to the reef structures on either side. The depth of the reef varies from 1m at the shallow shoreward edge to about 7m on the seaward

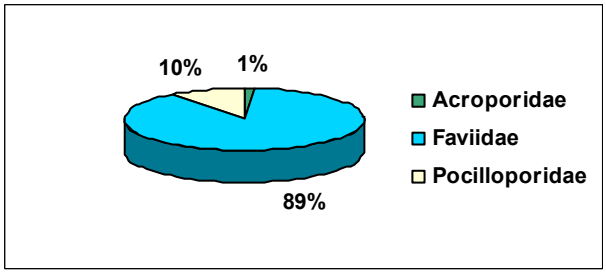

Figure 10. Percent composition of hard coral families at Aranwala, 2007.

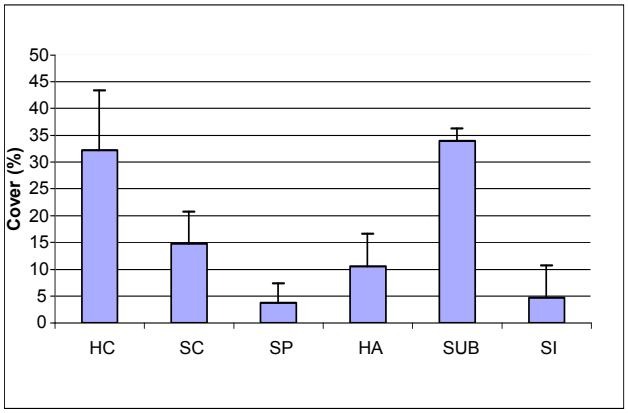

Figure 11. Comparison of the most abundant substrate types in the coral reef at Aranwala, 2007.

margin. The total length of the area surveyed was about 150m which includes reef sections on both sides of the coastal indentation.

Most of the living corals were found on the reef crest and on the seaward reef slope. Due to strong wave action massive corals of the family Faviidae (89%), comprising *Favia, Favites* and *Platygyra,* dominate the hard coral cover (Fig. 10). Live hard coral cover in 2007 was 32%, the limestone substrate amounted to 34% and the soft coral cover was 15% consisting of *Sarcophyton* and *Sinularia* species (Fig. 11).

Kiralawella

The fringing reef at Kiralawella is located in a small bay on the eastern side of the Dondra Headland which is the southernmost point in Sri Lanka. The shoreward

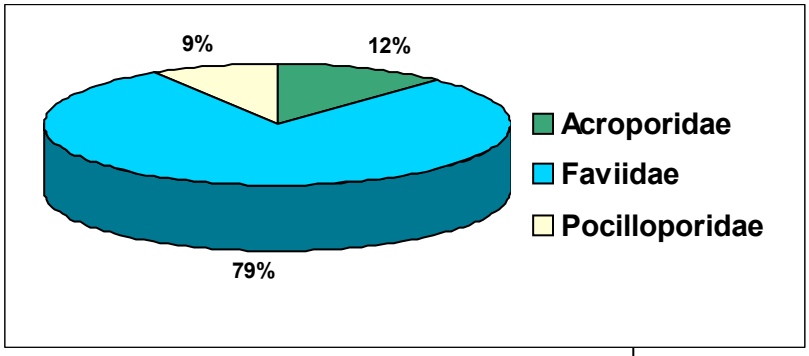

Figure 12. Percent composition of hard coral families at Kiralawella.

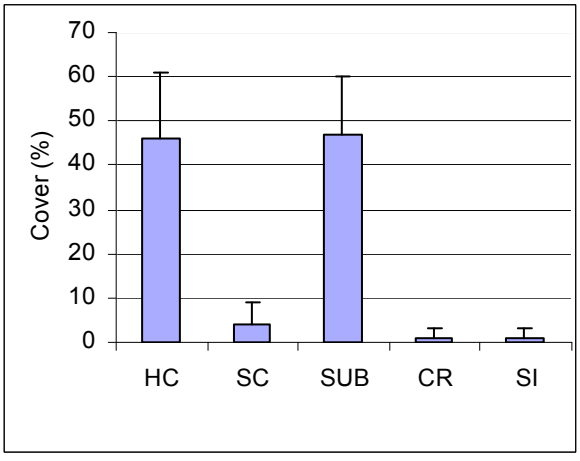

Figure 13. Comparison of the most abundant substrate types in the coral reef at Kiralawella, 2007.

edge of the reef is against the rocky shore and the seaward margin lies about 50m offshore at a depth of about 10m. The reef is about 200m in length and is subject to strong wave action during the northeast monsoon.

The most abundant live corals belonged to the family Faviidae (79%) comprising *Echinopora*, *Favia, Favites, Platygyra, Goniastrea* and *Leptoria* (Fig. 12). Extensive patches of *Echinopora lamellosa* and several large *Porites* domes were present on the lower reef slope at a depth of 6m. Overall live hard coral cover was 46%, with 47% bare limestone substrate (Fig. 13).

Coral Reefs of the Jaffna Peninsula

Fringing coral reefs are located along the northern coast of the Jaffna Peninsula and along the western shore of the islands (Swan, 1983; Rajasuriya & White, 1995). They could not be surveyed during the past two decades due to lack of access to the area as a result of the internal conflict in the country. Most fringing reefs were narrow belts without a reef lagoon with a reef crest of about 15m in width and a reef slope of about 75m. Punkuduthivu and Mandathivu Islands in the southwest corner of the peninsula had relatively larger reefs that extended about 1km into the Palk Bay. Punkuduthivu Island had a relatively narrow reef lagoon of about 30m (SSCP, 2007). The shoreward margin of most fringing reefs was against the limestone shoreline whilst the seaward edge was at a depth of about 6m.

Substrate cover was determined at four reef sites. Two sites were located in the Palk Strait along the northern coast of the peninsula, whilst the other two sites were located to the west of Eluvathivu Island and on the southern side of Punkuduthivu Island respectively (Fig. 1).

Due to similarity of the reefs surveyed and limited sampling effort (four 50m PIT at each location) the data from all four reef sites was pooled. The combined

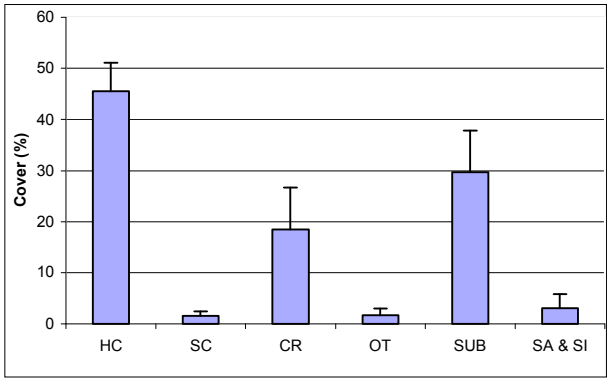

Figure 14. Percent cover of substrate types on coral reefs of Jaffna Peninsula in 2005.

Figure 15. Coral communities of the Jaffna Peninsula study sites.

live hard coral cover for all four reef sites was 45%, with 29% limestone substrate (Fig. 14).

All reef sites were characterized by abundant massive corals of the families Faviidae (*Goniastrea, Platygyra, Leptoria, Favia and Favites*) and Poritidae (*Porites lutea* and *Porites lobata*) (Fig. 15). There were extensive banks of dead branching *Acropora* at Punkudithivu Island and large living *Porites* domes of about 7m in diameter near the seaward margin of the reef. Forty species of hard corals were recorded from the reef sites (Appendix 1). Soft coral (*Sarcophyton*) was common on the lower reef slope of the northern coast of the peninsula. Seventy four species of reef fish were recorded during the survey (Appendix 2), with most records from Punkuduthivu Island. Large schools of *Scarus ghobban* and *S. rubroviolaceous* and Siganids were also present at this site. The most common species of butterflyfish was *Chaetodon octofasciatus* which is restricted to the Gulf of Mannar, Palk Bay and Palk Strait in Sri Lanka (SSCP, 2007).

Coral Bleaching

Extensive damage to reefs due to coral bleaching was not observed in Sri Lanka in 2007. Bleaching of a few colonies of *Leptoria*, *Platygyra*, *Favia*, *Favites* and *Acropora* spp was recorded from the Hikkaduwa National Park. Seasonal paling of a few colonies of branching *Acropora* were observed in the Bar Reef Marine Sanctuary in 2007 but all colonies returned to normal after one month. Paling of some massive corals (Faviidae and Poritidae) was reported in August 2007 from Pigeon Island in Trincomalee (N. Perera. pers comm.). Branching *Acropora* spp at a depth of less

than 2m had been killed in Dutch Bay in Trincomalee and was overgrown with filamentous algae in late September 2007. However branching *Acropora* in slightly deeper areas (> 3m) was healthy.

DISCUSSION

Results from the monitoring indicate long-term impacts on reef structures due to the 1998 bleaching event. For several years after 1998 the dead but mostly intact coral branches maintained the reef structure, providing habitat and allowing new corals to settle and grow. Due to variability in recovery (Rajasuriya, 2005), almost every reef area has sections that exhibit good recovery and sections with poor recovery. At present, reef sections where recovery has been poor have begun to disintegrate, leading to an increase in the percent cover of coral rubble, e.g. at Talawila and some parts of the Bar Reef Marine Sanctuary. However, both areas also exhibit good coral growth, although the dominant types of hard corals have changed since 1998. In the Bar Reef Marine Sanctuary the dominant hard corals are tabulate *Acropora* (mainly *Acropora cytherea*) and *Pocillopora damicornis* whilst at Talawila massive corals dominate. The dominance of *Acropora cytherea* and its contribution to live hard coral cover at Bar Reef indicate that the opportunities for rapid colonization of coral species that were dominant species prior to bleaching, such as a number of branching Acropora species and *Echinopora lamellosa*, is low. At Kapparatota, Weligama the live hard coral cover has been reduced by half due to a combination of overgrowth of *Halimeda*, movement of coral rubble, damage caused to the reef by anchoring of fishing boats and the use of destructive ornamental fish collecting methods. Although the calcareous algae stabilize the coral rubble it prevents recruitment of corals and thus it is a barrier to the growth of the reef. Moreover it traps sand and sediment and has thus contributed to reduction of the depth of the reef lagoon. The destruction of vegetation on a nearby headland for the construction of a hotel may exacerbate the problem by increasing sedimentation and nutrient loads within the reef lagoon.

The increase of live hard coral cover in Hikkaduwa National Park is mainly due to the increase of recently recruited *Pocillopora damicornis,* which is now growing relatively rapidly on the dead coral stands. However, due to many other stresses, primarily sedimentation (Rajasuriya, 2005), there is little growth of species other than *Pocillopora damicornis* and *Montipora aequituberculata,* which survived the bleaching in 1998 and have since taken over areas formerly dominated by *Acropora muricata* and *A. hyacinthus*.

Coral species found on the northern reefs around the Jaffna Peninsula are similar to inshore reefs in the southern coast, and are tolerant of relatively high sedimentation (SSCP, 2007). Two species of reef fish (*Liza cascasia* and *Abudefduf bengalensis*) not found elsewhere in Sri Lanka were recorded in the Palk Strait and Palk Bay. The extensive dead *Acropora* stands of Punkuduthivu Island in Palk Bay indicate that they may have been killed during the 1998 bleaching event. There was no indication of recent large-scale coral mortality among other genera. Although most reefs are located along the coast human impact was negligible on the coral reefs of the Jaffna Peninsula and islands. This is primarily due to low fishing pressure and lack of development along the coast.

As reported in the past (De Silva, 1985; 1997; Rajasuriya, et al. 1995; 2004, 2005), reefs in the south and on the west coast continue to be adversely affected by uncontrolled resource exploitation, use of destructive fishing methods, coastal development, land-based pollution, sedimentation and overall poor management of the marine and coastal environment (Kumara et al. this volume). The status of Marine Protected Areas also remains unchanged, with little active management by the responsible authorities. Over-harvesting of reef fish and semi-pelagic species in the Bar Reef Marine Sanctuary using a modified form of purse seine continues unabated, leading to severe overexploitation of Carangids, Lutjanids, Lethrinids, Sphyraenids and Scarids. Most of the periodic aggregations of *Caranx sem* and *Sphyraena jello* that used to be relatively common in the northern section

of the Bar Reef Marine Sanctuary have now become rare. Recently this fishing method has begun to utilize scuba diving equipment, with divers scaring the fish and driving them into the nets. Unlimited numbers of licenses are also issued to collectors of sea cucumber and chanks (a gastropod, *Turbinella pyrum*) by the authorities, and there is not sufficient capability to monitor the activities of the license holders. This has led to over harvesting sea cucumber and chanks resources in the Bar Reef Marine Sanctuary. As a result human pressures are likely to continue to increase in the future, and the ability of reefs to resist and recover from natural perturbations will diminish further.

ACKNOWLEDGEMENTS

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Appendix 1. Hard coral species recorded during reef surveys in Jaffna Peninsula, 2005.

Family	Species
Acroporidae	*Acropora cytherea*
	Acropora hyacinthus
	Acropora muricata
	Montipora aequituberculata
	Montipora foliosa
	Astreopora sp.
Dendrophyllidae	*Turbinaria mesenterina*
	Turbinaria peltata
	Turbinaria sp.
Faviidae	*Favia pallida*
	Favia speciosa
	Favia rotundata
	Favites abdita
	Favites chinensis
	Favites complanata
	Favites flexuosa
	Favites pentagona
	Montastrea valenciennesi
	Goniastrea retiformis
	Platygyra lamellina
	Platygyra sinensis
	Platygyra daedalea
	Platygyra pini
	Leptoria phrygia
	Leptastrea purpurea
	Echinopora lamellosa
Merulinidae	*Merulina ampliata*
	Hydnophora exesa
Mussidae	*Symphyllia agaricia*
	Symphyllia radians
	Symphyllia recta
	Symphyllia sp.
Pectiniidae	*Echinophyllia aspera*
Pocilloporidae	*Pocillopora damicornis*
	Pocillopra verrucosa
Poritidae	*Porites* sp.
	Porites lutea
	Porites lobata
	Goniopora spp.
Siderastreidae	*Pseudosiderastrea tayamai*

Appendix 2. Reef fish species recorded during reef surveys in Jaffna Peninsula, 2005.

Family	Species
Acanthuridae	*Acanthurus bariene*
	Acanthurus mata
	Acanthurus nigricauda
	Acanthurus xanthopterus
Apogonidae	*Apogon angustatus*
	Apogon aureus
	Cheilodipterus macrodon
	Rhabdamia gracilis
Caesionidae	*Caesio cuning*
	Caesio xanthonota
	Pterocaesio chrysozona
	Pterocaesio tile
Carangidae	*Caranx heberi*
	Caranx sp.
Centropomidae	*Psammoperca waigiensis*
Chaetodontidae	*Chaetodon auriga*
	Chaetodon collare
	Chaetodon decussatus
	Chaetodon octofasciatus
	Chaetodon plebeius
	Heniochus acuminatus
Echeneidae	*Echeneis naucrates*
Gerridae	*Gerres* sp.
Gobiidae	*Amblyeleotris* sp.
	Amblyeleotris steinitzi
	Amblygobius sphynx
Haemulidae	*Diagramma pictum*
	Plectorhinchus gibbosus
	Plectorhinchus schotaf
Holocentridae	*Sargocentron diadema*
Labridae	*Halichoeres nebulosus*
	Thalassoma janseni
Leiognathidae	*Leiognathus daura*
Lethrinidae	*Lethrinus lentjan*
	Lethrinus sp.
Lutjanidae	*Lutjanus ehrenbergi*
	Lutjanus fulviflamma
	Lutjanus fulvus
	Lutjanus rivulatus
	Lutjanus sp.

Appendix 2. ***continued.***

Family	Species
Mugilidae	*Mugil sp.*
	Liza cascasia
	Parupeneus indicus
Nemipteridae	*Scolopsis vosmeri*
Pomacentridae	*Abudefduf septemfasciatus*
	Abudefduf sordidus
	Abudefduf bengalensis
	Abudefduf vaigiensis
	Amblyglyphidodon leucogaster
	Chromis ternatensis
	Neopomacentrus asyzron
	Neopomacentrus taeniourus
	Pomacentrus chrysurus
	Pomacentrus indicus
Pseudochromidae	*Pseudochromis fuscus*
	Pseudochromis sp 1
	Pseudochromis sp 2
Scaridae	*Scarus ghobban*
	Scarus niger
	Scarus rubroviolaceus
	Scarus sp
Scorpaenidae	*Pterois volitans*
Serranidae	*Cephalopholis boenak*
	Cephalopholis formosa
	Epinephelus caeruleopunctatus
	Epinephelus malabaricus
Siganidae	*Siganus canaliculatus*
	Siganus javus
	Siganus lineatus
	Siganus stellatus
	Siganus virgatus
Sphyraenidae	*Sphyraena jello*
Tetraodontidae	*Arthron hispidus*
	Canthigaster solandri