ASSESSMENT OF MALDIVIAN CORAL REEFS IN 2009 AFTER SEVERAL NATURAL DISASTERS

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Introduction

In this report we examine a commonly accepted group of biological indicators of coral reef health from a geographically diverse set of lagoon, shallow Maldivian reefs from northern Haa Dhaalu to Addu Atoll based on field work undertaken by Marine Research Centre (MRC), from February – October 2009.

Clearly the health of coral reefs, which are the physical basis for the Maldives, are of national strategic concern. President M. Nasheed called the plight of the Maldives to the world in his September 2009, address to the United Nations. He stated that failure to come to a meaningful agreement in the International Convention on Global Climate Change would be suicidal for the Maldives.

About 193 of the islands are inhabited by Maldivians, 93 islands have tourist resorts, and 55 islands are reserved for industrial and agricultural use. Only 33 of the inhabited islands have a land area of >1km^2 and only three islands have an area >3 km^2. Coral reef statistics produced by the United Nation Environment Programme (UNEP) in 2003 ranked the Maldives as having the seventh largest coral reef system within its territorial boundaries. The Maldives is estimated to contain 3.14% of the total coral reef area of the world (UNEP 2003).

The historically low population densities resulted in a large area of coral reefs where the influences of humans were low. For many centuries Maldivians preferred to eat pelagic fish instead of reef fish so fishing impacts on reef fish populations were slight (Sheppard and Wells 1998). Mining of the reef for rocks and sand for building materials depleted many lagoons and faros of corals and reduced fish biomass. However, human impacts on reefs are increasing. Recently, nutrients from the capital city/ island Male' combined with shark fishing, aquarium fish and sea cucumber collection (Adam et al. 1997) and harbor construction and island modification have been changing the reefs.

Although the Maldives is completely founded on the remains of living coral reefs, it has only been towards the end of the 20th century that systematic quantitative surveys of reefs, from the northern atolls to the most southern atolls were conducted by the government of the Maldives through MRC. The expanses of reefs in the Maldives are enormous and the human and logistical resources available for monitoring them are small.

Early surveys were limited to a few atolls. On the "Xaifa" expedition at Fadifolu, Rasdhoo, Ari and Addu Atolls, Scheer (1974) conducted some of the earliest detailed "coral sociology" studies, using the plant sociology techniques of line intercept and

quadrat methods. He reported coral cover ranged from 50–80% from his observations from Addu, Ari and Fadiffolu atolls. The health and beauty of Maldivian reefs was further confirmed during the establishment in the 1970s of the multimillion dollar tourist industry when scores of dive schools were included in resort developments to cater to the diver seeking to “dive in one of the last paradises on earth.”

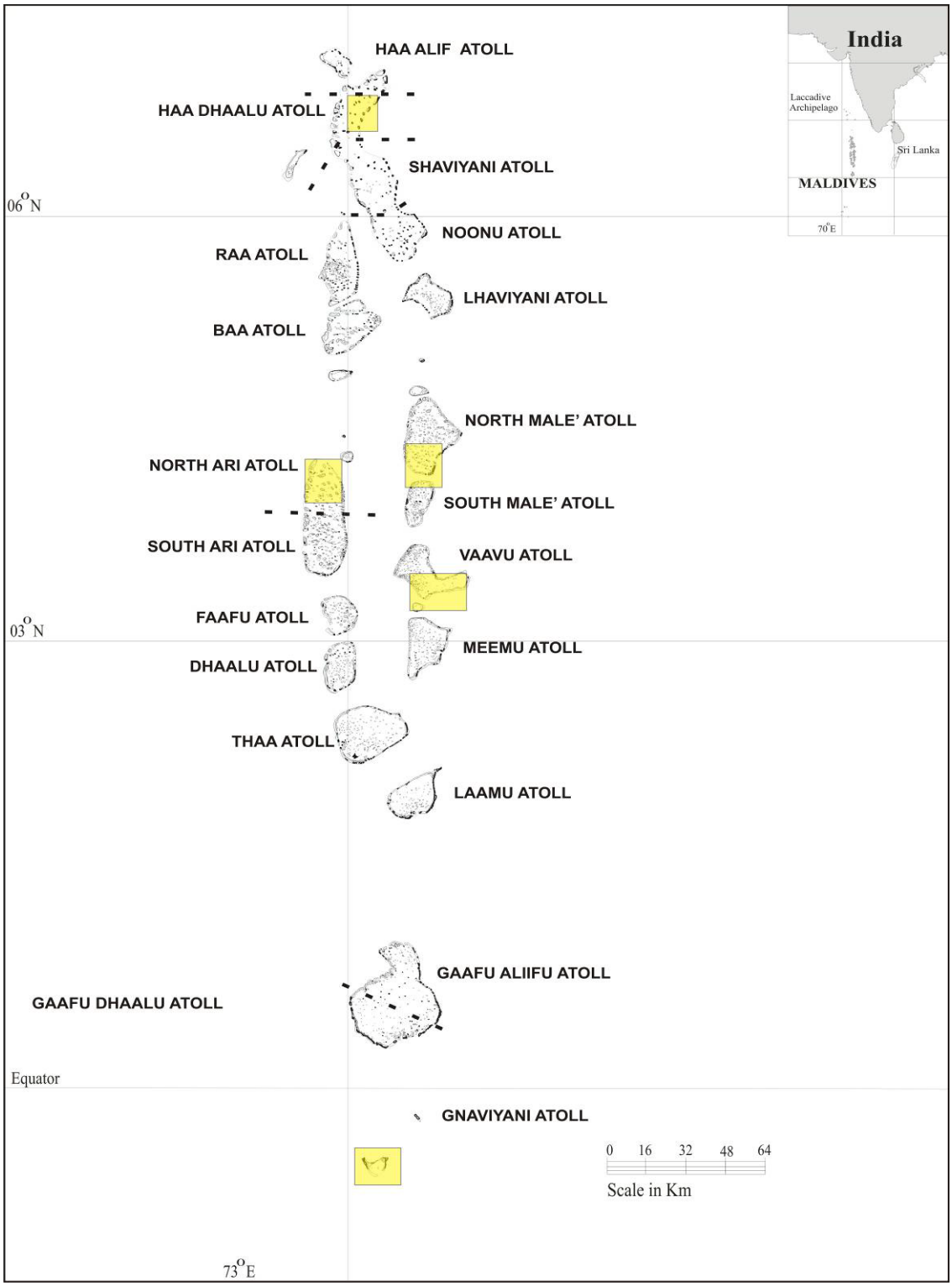

Figure 1 Map of Maldives with colored areas showing areas with NCRMS sites sampled in 2009.

Maldvian reefs have a high species diversity and many are threatened. Pichon and Benzoni (2007) reported that there were 248 coral species from 57 genera, although they stated that the taxonomic status of some of the earlier described species were doubtful. According to the International Union for Conservation of Nature (IUCN) Red List Categories and Criteria: 1% -10% of the total species in the Maldives are Critically Endangered and Endangered species, 10% - 20% are Critically Endangered, Endangered, and Vulnerable and 40% - 50% are threatened or near threatened. The threats are from both global climate change and local impacts.

Initial Reef Check Surveys and the 1998 Bleaching Event

Although there were previous surveys that MRC staff participated in, quantitative surveys of the coral reef community organized by MRC began in 1997 using the Reef Check coral reef monitoring protocol (Zahir et al 1998). These surveys yield a scientifically based estimate of several parameters commonly used to assess coral reef community health and resilience.

The unprecedented coral bleaching in 1997-1998 around the world including the Maldives, resulted in extensive mortality to reef building corals (Zahir 2000). During this event the living coral animals expelled their commensal living plant called zooxanthellae exposing the unpigmented coral tissue and underlying skeleton. Prior to 1998 an isolated bleaching event occurred on the three central atolls in the Maldives was reported. While the 1998 bleaching may not have been the first, it was the most intense and sustained in recent history in the area. The NCRMS surveys clearly detail the death of live coral in Anbaraa reef, Vaavu Atoll, Thuvaru reef, Meemu Atoll and the high mortality of corals in Maduvvari reef, Meemu Atoll (Figure 2).

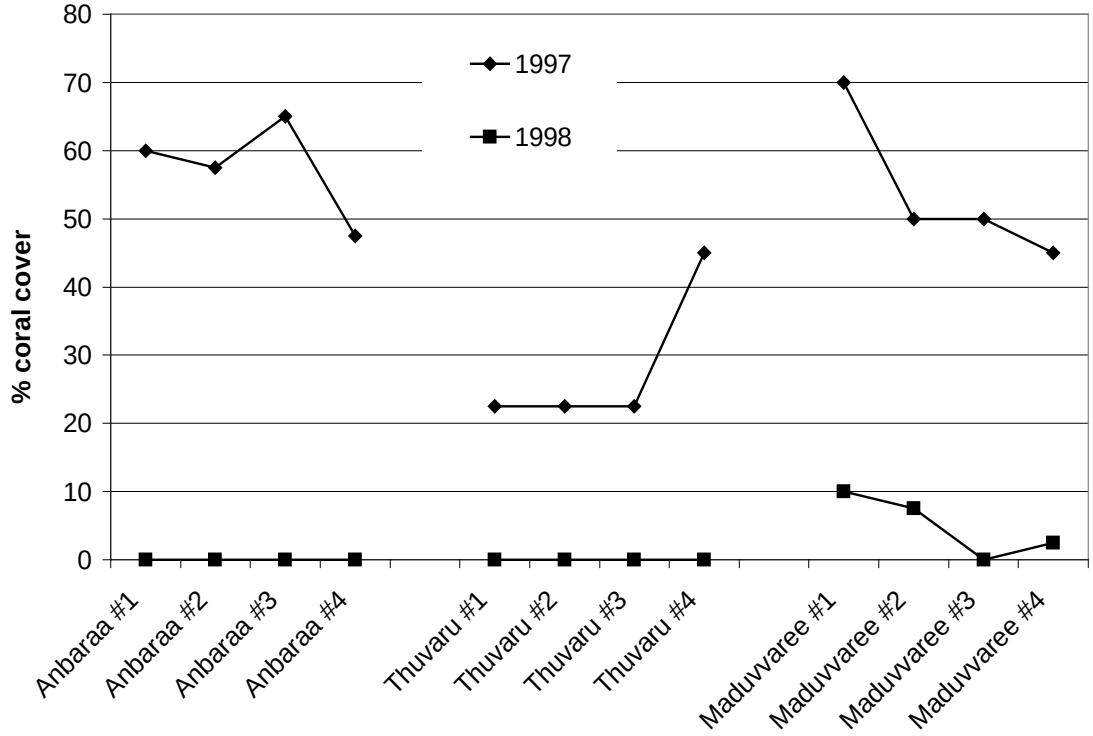

Figure 2 Comparison of NCRMS 150m point intercept transect percent live coral cover data at three sites in 1997 before and immediately after the bleaching in April – May 1998 bleaching event (after Zahir 2002 et al).

Prior to the bleaching event the reefs were considered luxurious at Anbaraa (Patch reef) and Maduvvari reef, with about 50 - 70% coral cover. Thuvaru reef was a moderately developed reef with less than a 30% coral cover prior to bleaching. Fast growing branching corals, such as A*cropora* spp., suffered greater mortality than slow-growing massive corals. Virtually all of the colonies of *Acropora* spp. in the study sites had died. Similarly the fast growing pocilloporids were highly susceptible to bleaching. In contrast agariciids and poritids were more resilient, although they too experienced a decrease in cover.

Other workers found the percentage of living coral cover on several shallow reef flats declined markedly immediately after the bleaching event. Coral cover was reduced, from around 22.5–70% pre-bleaching to 0–10% post-bleaching (Clark et al 1999). The reef flat at Vabbinfaru, North Male' Atoll exhibited very high mortality. The luxurious reef at this site gradually became rubble / sand (Figure 2) which increased the beach erosion on the island which the resort tried to mitigate by pumping sand from the reef flat, further destabilizing natural efforts for recolonization.

Coral reefs are critical to the Maldives as they maintain the integrity of atoll islands by providing erosion barriers and are sources of sand and rock. For centuries the coral reefs have adapted to changes in sea levels associated with climate change. Kench et al (2009) demonstrated by drilling through several reefs in South Maalhosmadulu Atoll that healthy coral reefs produced sufficient skeletal material to allow reef islands to accommodate rising sea levels on the order that is projected for the next century. The question today is: Are the reefs sufficiently healthy to continue to keep up with sea level rise and maintain the islands or are global and local stresses to the reefs so intense as to diminish the growth and reproduction of the corals resulting in submergence of all or some of the islands of the Maldives?

Tsunami Devastation

Another natural disaster impacted Maldivian coral reefs on 26th December 2004. Originating in an earthquake off the coast of Indonesia, a tsunami struck. In February 2005, a joint Maldivian and Australian research team surveyed 124 reefs sites in seven atolls, covering about 170km of reef margin looking for tsunami damage (AUSAID 2005). They observed localized damage to reefs near inhabited islands from debris from buildings and sand that had smashed and smothered corals when it had been swept into the ocean. Some of the damage was extensive enough to alter the reef framework. They concluded that there was minor direct damage to coral reefs by the tsunami, but only observed live coral cover in the range of about 4–12% (Figure 3). Although the reefs were not particularly luxuriant, they were recovering from the 1998 bleaching.

The researchers considered that the 1998 coral bleaching event, the on-going human damage to the reefs caused by coral rock and sand collection from reef flats and the dredge and fill operations associated with coastal development caused more overall damage to the reef community than the tsunami (AUSAID 2005). While the tsunamis did not cause significant damage it was likely that the tsunami slowed recovery from earlier damage caused by bleaching.

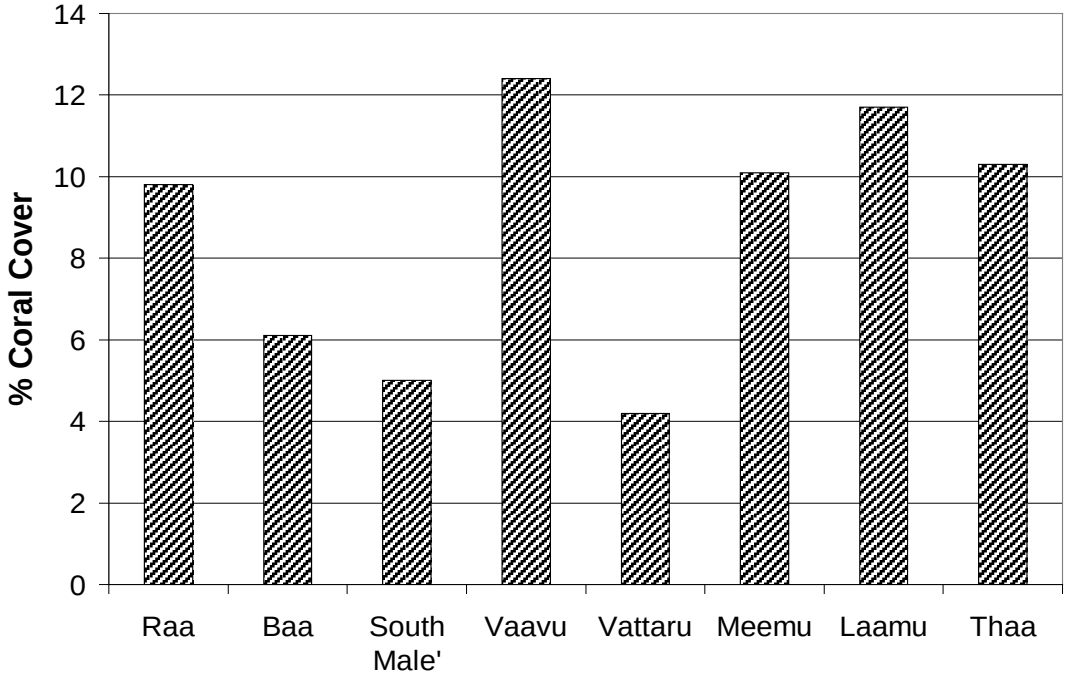

Figure 3 Percent live coral cover reported by surveys undertaken in January – February 2005, a couple months after the December 2004, tsunami (after AusAID, 2005).

The tsunamis focused attention on the need for better management of direct human pressures and inappropriate coastal development. It was noted that the assessment of the condition of the reefs was hampered by the lack of comparable prior quantitative surveys that covered the length and width of the country at several depths (AusAID 2005).

Recovery in 2009

In spite of the calamities that had happened to Maldivian reefs the results from our surveys were encouraging. The mean percent coral cover in 2009 ranged from 7.5% at Hirmaradhoo to 59.4% at Fesdhoo (Figure 4). There is a lot of variability in cover throughout the Maldives. Only four sites had a coral cover >50%: Fesdhoo, Kandholhudhoo (both Ari Atoll) and Vilingili and Hithadhoo (both Addu Atoll). The reefs in the narrow depth range sampled also are quite variable in there cover with the coefficient of variation ranging from 4.0% at Vilingili to over 100% at Hirmaradhoo and Maniya-fushi. There is considerable variation among reefs and among habitats within reefs. This variation is a function of the wide latitudinal range of the atolls, the structure of the atolls and chance. These factors create considerable variation in the abiotic factors that influence reef development.

Coral cover on the northern reefs of Haa Dhaalu Atoll was nearly 0% after the 1998 bleaching event (Zahir, 2000). In 2009, coral cover ranged from 14% - 29% (Figure 4). This was collectively the lowest coral cover for all the atolls surveyed. In South Male' Atoll, En'boodhoofinolhu had the lowest live coral cover in 2009. The reef has been used for sand mining for several decades.

In Ari Atoll the shallow reefs of Fesdhoo, Maayafushi, Velidhoo in the NCRMS exhibited exceptional resilience. In 2009, Fesdhoo was among the most luxuriant reefs surveyed with about 65% coral cover. Velidhoo reef also demonstrated remarkable recovery from about 11% in 2005 to 50% in 2009. Sometime after the sampling in 2005, the hotel at Maayafushi reef had expanded constructing water bungalows over the reef flat, within 100m of the reef edge. It does not appear that the sedimentation associated with the construction of the bungalows greatly thwarted the recruitment of new corals by either smothering new recruits or covering suitable substrate with silt rendering then unsuitable for settlement. Much of the recovery in these sites is due to successful recruitment and growth of primarily fast growing acroporid colonies and to lesser extent pocilliporid colonies.

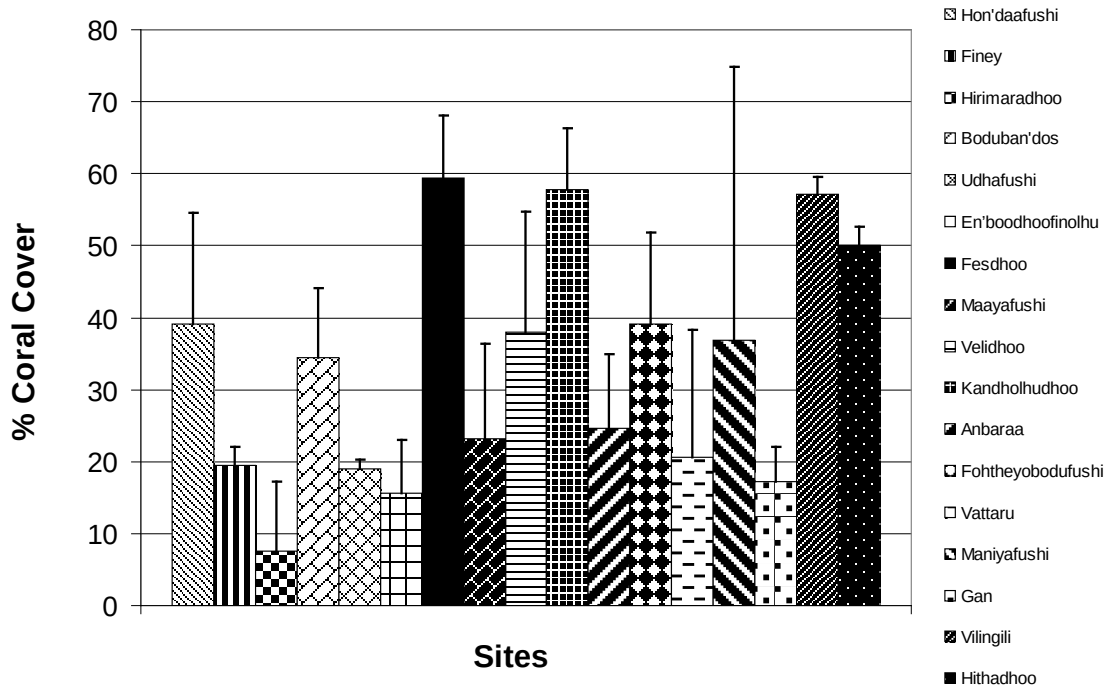

Figure 4 Mean (3m, 10m) percent coral cover of the NCRMS sites surveyed from March to October 2009. Error bars show standard deviation. n = 8 for each site.

Addu Atoll had the greatest recovery of live coral cover in sites distant from anthropogenic influences (Figure 4). After the 1998 bleaching, the reefs still had some living coral. In 2009, the coral cover had increased to 55% (Figure 4) in spite of its proximity of the development of resort water bungalows and beach restoration efforts. Recently killed coral was observed at Vilingili reef, but only covered 0.3% of the substrate. In May 2009, the sediment plume from the resort's beach restoration occasionally clouded the shallow parts of the site. The reef has survived the 1998 bleaching better than many other reefs as there were still large colonies of the slow growing *Porites lobata* coral (Figure 5). The reef was also one of the few reefs with the giant *Tridacna squamosa* clam present (Figure 6).

While this survey has expanded the depth at which reef transect data was collected (10 m), future surveys should include sites at depths of 15–20 m and include the outer atoll reef crest and slope habitats. The recovery of most of the reefs surveyed during the past decade is remarkable and suggests the question of where were the new recruits coming from. Recruitment was not a limiting factor for reef recovery (Zahir et al, 2002). It is

important to determine where the reefs are that provide the recruitment source and for them to be protected. With the protection of these reefs there is hope.

Figure 5 Large colonies of *Porites lobata* were common at Vilingili reef, May 2009.

Acknowledgements

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Figure 6 H. Zahir, photographing a large *Tridacna squamosa* (TL 45cm) at Hithadhoo reef, 10m, Addu Atoll, May 2009.