Patterns of Benthic Recovery in the Lakshadweep Islands

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ABSTRACT

The atoll reefs of the Lakshadweep are recovering from a catastrophic mortality of coral following the El Niño-related bleaching of 1998. This event resulted in more than 90% loss of coral, a subsequent loss of structure, and significant alterations of fish communities. Although most reefs showed signs of recovery from 2000 to 2007, the pace of benthic recovery varied considerably between atolls. Additionally, there was a clear difference in the patterns of recovery between eastern and western aspects of the island, driven by local hydrodynamic conditions and post-settlement mortality of hard coral. The cover of macroalgae remained low at all reefs, controlled by abundant herbivore fishes. While benthic recovery appears to be progressing well on the Lakshadweep reefs, it is unclear if the reefs will withstand future mass bleaching events of the magnitude of 1998. The summer of 2007 was unusually hot, and bleaching progressed significantly with time as the summer progressed. Post-monsoon surveys will be needed to confirm what impact this warming had on benthic communities in the Lakshadweep.

INTRODUCTION

An archipelago of 12 atolls in the central Indian Ocean, the Lakshadweep coral reefs are characterised by clear, relatively nutrient-poor waters with high coral and fish diversity. The recent ecological history of these reefs is dominated by the El Niño of 1998, which resulted in a major mass mortality of corals in the Lakshadweep, and a subsequent loss of benthic structure (Arthur 2000), as was reported from atoll complexes further south (McClanahan 2000; Sheppard et al. 2002). Reefs are still recovering from this event, and while the pace of coral regrowth is remarkable at some locations, recovery at other locations is patchy at best. The pace of recovery appears to be dependent on interactions between post-recruitment survival, monsoon-generated hydrodynamics and other local-scale processes (Arthur et al. 2006). Fish community composition also changed in apparent response to benthic recovery, and several trophic groups, including herbivores and corallivores changed significantly with time (Arthur 2005). A relatively healthy fish community was perhaps an essential factor in determining benthic recovery, possibly preventing macroalgae from becoming a dominant element in the recovering reefs.

Much of the observed resilience of the Lakshadweep coral reefs can be attributed to the fact that the local population does not heavily exploit these reefs. With upward of 60,000 people, Lakshadweep has among the highest rural densities in India (more than 2000 individuals.km^{-2}). Although the main protein source for this population is fish, most of the fish caught, traded and eaten consists of skipjack tuna,

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

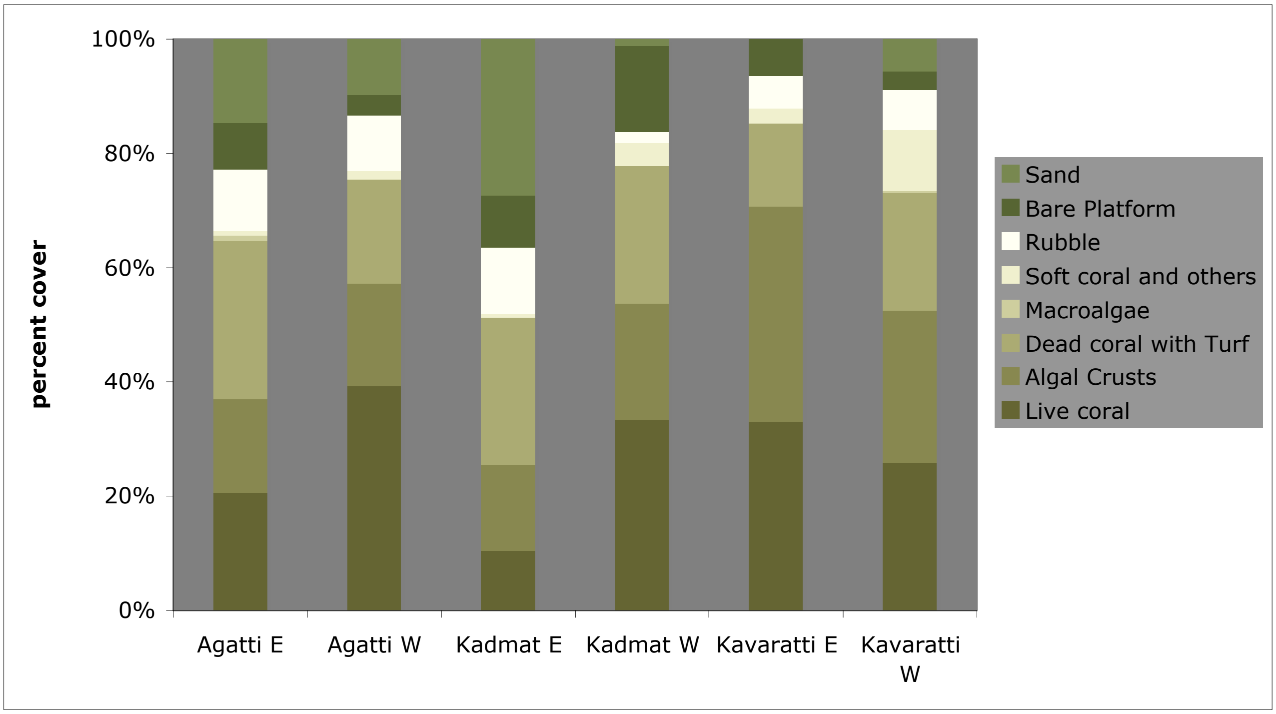

Figure 1

caught in the pelagic waters around the islands. A hook-and-line tuna fishery is the main economic livelihood here apart from coconut cultivation. This fishery was introduced to the island group in the 1970s, promoted by the Fisheries Department as an economic development activity, and it has practically replaced more traditional forms of reef and lagoon fishery, which earlier used to support the local population. An upshot of this promotion was to considerably reduce the amount of fishing pressure on the outer reefs of the Lakshadweep (Arthur 2005). This in turn could have contributed, albeit epiphenomenally, to the reef's recovery potential after the mass bleaching of 1998.

Few reliable studies exist from the coral reefs of the Lakshadweep before 1998, making it difficult to determine the impact of the bleaching event, or to comprehensively understand trends in post-bleaching recovery. Three atolls were monitored for benthic condition from 2000 to 2003 (Arthur et al 2006), but there have been no systematic surveys since then. The present survey was conducted to revisit the sites last sampled in 2003 and assess benthic status, and to establish these sites as annual monitoring stations. Sampling was conducted to coincide with a potential bleaching event before the onset of the summer monsoon, to track potential impacts of this event on the reef.

METHODS

Methods employed follow closely those detailed in Arthur et al. (2006). Six sites were located on three atolls (Agatti, Kadmat and Kavaratti). Agatti and Kadmat were the worst affected by the coral mass mortality of 1998, while Kavaratti was relatively less affected. At each atoll, a site was located on the east and west, reflecting important differences in hydrodynamic conditions caused by the summer south-west monsoon. These sites had been monitored annually from 2000 to 2003.

At each location the percent cover was estimated in

1m^2 quadrats located at fixed intervals along a random 50 m line. The 50 m tape was laid between 8 and 12 m depth. Benthic cover was estimated for the following benthic elements: live coral cover, dead coral with turf algae, macroalgae, crustose coralline algae, soft coral and other invertebrates, rubble, sand and bare reef platform. Live coral was identified to the species or genus level. However, for this report, only broad trends in live coral cover are presented. To determine trends in benthic cover, average percent cover values were compared with data from 2000 to 2003.

Sites were sampled at the peak of summer, just before the onset of the summer monsoons, with the possibility of unusually high sea surface temperatures in relation to a developing El Niño in the Indian Ocean. To estimate the potential impact of elevated ocean temperatures, signs of bleaching were recorded in each quadrat. In addition, temperature gauges were installed at each site to determine local-scale variation in ocean temperatures over the late summer and monsoon. Other ad-hoc observations on reef condition were made in extensive free swims at several sites on all three atolls. In addition, I spoke to fishers and community members about trends in reef resource use to determine if this had changed considerably since earlier studies (Arthur 2005).

RESULTS

Recovery patterns between reef sites continued to be variable, and while coral cover was relatively high at some monitored sites, other locations still had low values of coral cover (Fig. 1). Coral cover at west-facing sites continued to recover faster than eastern sites in Kadmat and Agatti; in Kavaratti however, live coral was not different between aspects. The difference in live coral between eastern and western sites was confirmed in spot surveys at several locations in Kadmat and Agatti, and was most clearly evident in Kadmat reefs. Eastern sites in Kadmat continued to show low levels of coral cover in comparison with western locations. Recovery across the sites surveyed

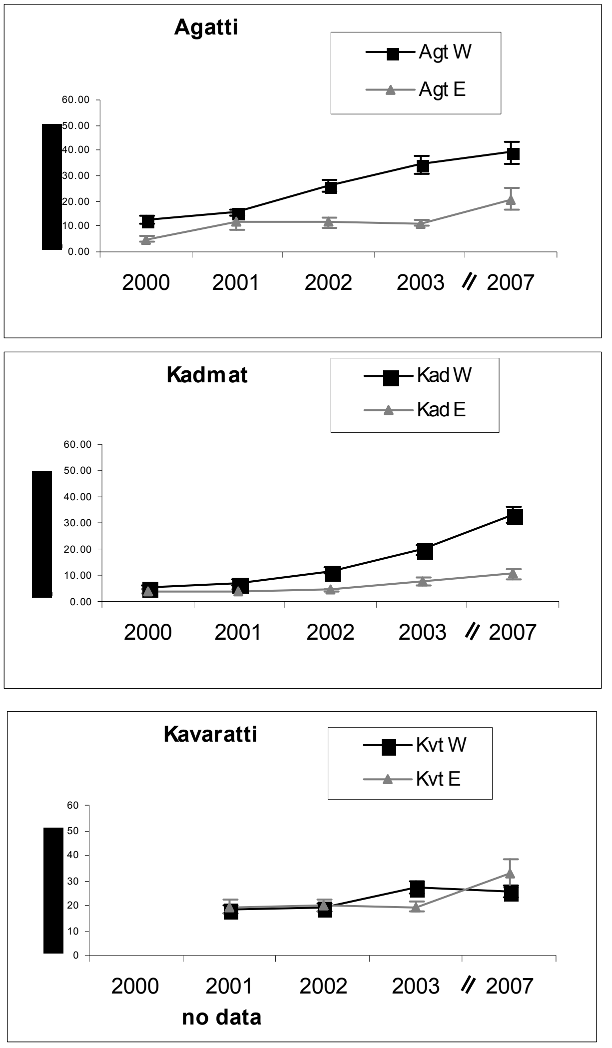

Figure 2.

was dominated by several species of tabular and branching *Acropora*, which, particularly at some western sites in Agatti, frequently grew to sizes in excess of 1m in width. In general, benthic cover showed signs of increasing at most sampled locations from 2000 to 2007, apart from Kavaratti West, where there was a mild, possibly insignificant decline in cover from the last sampling in 2003 (Fig. 2). There was considerable variability in the rate of recovery the last week of April. Bleaching patterns appear to follow this aWńqWId@.Epgpling tiWńqWId@.Epge, ń8WEWgWń%1In@.EWgb%qbId@EWEgb%wWI @.E8qgńp8abyhe a

between locations, and while some locations showed gradual increases in coral cover, eastern sites at Agatti and Kavaratti, and Kadmat West showe anadrke increase in benthic area occupie a by coral..EW%gEbwEI @TJ Upbgp88%G.pEg%EGTdUIT@.E%gw8W%Ih@.E%gbEń8Ie@.E1gqq1EI (locations Fig.). eef ites at gatti ere aWńqńEg88E1Ip@TJ UEwpgWń1GwGTdUIl@.ńwgEń%8Ie@.E1gqq1EI@.EWEgb%wWI @.1Egbb88a WId@.%EIa@.EWgWńqWIt@.pqgb1b1I @.Ewqgwb%Iw@.E%gw8W%Ia@.EWgWńqWIs@.E8g18EI @.Ewqgwb%Is@.E8g18EIa@.EWgWńqWIWńqńEg8 no comprehensive baselines exist documenting the status of benthic communities or fish populations of these reefs. The first reliable in-water studies document reefs already considerably changed by the coral mass mortality of 1998. Given this paucity of prior information, the best that is possible is to examine present trends in the light of conjectured consequences of the El Niño.

By and large, patterns of recovery described by Arthur et al. (2006) appear to be continuing in the reefs of the Lakshadweep. Briefly, coral cover is increasing at most reef sites (Fig. 2), while algal turf and macroalgae were both considerably reduced from earlier studies. As mentioned earlier, these reefs have seemingly healthy populations of herbivorous fish, particularly *Scarids* and *Acanthurids*, and they could play a significant role in keeping algal levels down, facilitating coral recovery (also see Arthur 2005). Many *Acropora* species, particularly *A. abrotanoides*, that were most probably part of the original reef framework are returning to dominance, and are mature enough to be contributing to the local recruitment pool (Wallace et al 2007)

Observations point to a clear increase in coral bleaching through the month of April 2007, at levels higher than normal summer bleaching (Fig. 3). Casual reports from divers diving in early May confirm that this pattern of bleaching was on the increase, with the possibility of some amount of bleaching-related mortality (Sumer Verma, personal communication). The south-west monsoons arrived at the Lakshadweep around the middle of May 2007, and the monsoon rains generally result in a rapid lowering of ocean temperatures, potentially ameliorating the effects of the ocean temperature anomalies on the coral. However, without post-monsoon surveys, it is difficult to predict the extent of bleaching damage. Rapid surveys are planned later in 2007, and will provide a clearer picture of bleaching impacts.

It is perhaps equally difficult to conjecture on the resilience of the Lakshadweep reefs to repeated coral mass mortality impacts. The principal lesson of the 1998 mass mortality was that recovery patterns can often be the result of a complex interaction between local and regional-scale factors (Arthur et al 2006, Wallace et al. 2007), and contingency plays an equally important role in determining the paths each location takes to recovery or decline. The observed difference in recovery between east and west in Kadmat and Agatti is a case in point. These reefs suffered the highest mortality during the 1998 bleaching (Kavaratti was relatively less affected), and by the time the monsoons arrived, most of the bleached coral had already died. The western reefs are on the windward aspect of the approaching monsoon, and by the end of the rains, the strong monsoonal waves had reduced the dead *Acropora* tables and other branching species to rubble, which deposited in large amounts in the lagoon and lagoon mouths. In contrast, the eastern reefs still maintained their structure, and initial coral recruitment was high on both aspects of the island. Arthur et al. (2006) argue that the viability of settlement substrate was markedly different between the two aspects, and, while coral settled on bare platforms or old dead corals on the western lagoons, corals appeared to preferentially choose less structurally stable locations to settle on eastern reefs, where the majority of the settlement was on recently dead *Acropora* tables. These substrates became increasingly unstable with time, and post-recruitment survival was much lower on the east than the west.

What is difficult to know is whether the same processes will play themselves out in the wake of another catastrophic coral mass mortality. To list the unknowns that need to be addressed before a more complete picture can be obtained of the resilience of the Lakshadweep reefs is to outline a full-fledged research programme for the island group. For a start, the importance of long-term data sets on benthic and fish communities cannot be overemphasized. Impacts of unexpected events can only be correctly interpreted against a canvas of background trends, and regular and sustained monitoring is essential to understand these temporal changes. The Lakshadweep is also a region for which no information is available on seasonal trends in coral larval release, or on landscape-level patterns of recruitment. Unraveling the source-sink dynamics of this reef complex will be crucial to understanding how reefs will respond to large-scale mortality.

Recent discussions on managing reefs in the face of global change have focused on the need to identify sites that may be inherently vulnerable, resistant, tolerant or resilient to thermal stress (Obura 2005, West and Salm 2003). It is argued that oceanographic features, geographic position, and characteristics of the surrounding water can all interact to offer various degrees of protection to reef sites from thermal stress and UV radiation associated with increased sea surface temperatures. It is difficult to predict this gradient from a single anomalous temperature event, and only with a series of these events can a reliable gradient of resilience be established (Wooldridge and Done 2004). On the face of it, the Lakshadweep atolls appear to have few inherent protections against ocean warming events. With relatively high water transparency, the 1998 bleaching saw coral bleached even below 30m depth and the flat coral atolls do not provide any shading to the reefs during the hottest days of summer. Oceanographic conditions and local-scale water currents could offer some amount of protection, but these are not clearly understood as yet. We have currently established sampling sites at reef locations that reflect potential differences in water currents, and we are tracking these locations to determine if they respond differently to thermal stress. This may help us understand the patchiness of decline and recovery in bleached reefs.

The prospects of continued reef recovery in the Lakshadweep are closely linked to human resource use of the reefs. Currently, and for the last four decades or so, reef fish have formed only a marginal component of the community diet, and the dominant fishery has focused on fishing pelagic tuna. Interviews conducted recently however indicate that some fishers have begun to target reef fish once again, exclusively for south-east Asian markets. This nascent fishery focuses on bumphead parrotfish, Napoleon wrasse and several species of grouper. This fishery is, in the short term, much more lucrative than tuna fishing, and it may not be long before other fishers tap into this trade as well. This is a worrying prospect for the reefs of the Lakshadweep, since, without adequate controls on fishery in these waters, what resilience to global events that the reefs may possess thanks to these higher herbivores and carnivores could be very rapidly squandered by short-term prospectors.

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