Patterns of recovery from the 1998 coral bleaching event and MPA performance in the Maldives

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location
Figure 1.
Location of the Maldives.

Abstract
The global bleaching event of 1998 was particularly severe in the Maldives where up to 80% of hard corals were bleached down to 30m water depth. Initial survey data recorded by the Maldives Marine Resource Centre reported recovery of between 2 to 28% (n=15) live coral cover by 2004, but the difference in recovery between sites was extreme. Southern atolls fared best, with coral cover even reaching over 50% in some areas, showing distinct wide-scale latitudinal differences in bleaching impact. The Boxing Day tsunami of 2004 had very limited effect on the coral reefs of the Maldives. Advanced Reef Check surveys carried out between 2005 and 2008 by the Marine Conservation Society in collaboration with Maldives Scuba Tours have recorded coral cover of between 5 and 67% (depending on location) in shallow waters, with a mean of 22% (n=10) in summer 2008. The site with the highest coral cover (67%) in shallow Maldivian waters was where the coral assemblage was almost entirely dominated by Acropora corals. Most typically however, surveyed reefs were dominated by much higher diversity of young corals (acroporiids, poritiids, agariciids, pocilloporiids) and non-coral lifeforms (ascidians, sponges and carpet anemones). Further monitoring of reefs in the Maldives' central atolls is required to assess reef health. Creation of new Marine Protected Areas should take into account reefs recovery rates since 1998.

Methods
MCS coral surveys were carried out using the Reef Check methodology (Point Intercept Transect), on reefs at between 3 and 5m, and between 10 and 15m. The survey was slightly modified to gather information on coral lifeform to find trends in lifeforms within and between reefs, as there is evidence that more ephemeral families such as acroporids have recovered faster than slower-growing poritids and other massive corals since 1998 on Maldives reefs (Solandt and Wood, 2008).

Fish species, family number and size were recorded 2.5m either side and 5m above a 50m transect in June 2008 to gain an indication of the relative density and biomass of major predatory reef species, as well as trophic levels both inside (4 sites) and outside (5 sites) MPAs. All surveys were carried out at 10m depth. Fish size was recorded within 10cm size intervals for subsequent conversion to biomass (www.fishbase.org).

Results – reef fish populations inside and outside MPAs
Fish densities were generally greater inside than outside MPAs for omnivores and lower carnivores (Figure 7). The most abundant 'lower carnivore' group was represented by snappers and emperors, principally the red snapper (Lutjanus bohar), blue-lined snapper (Lutjanus kasmiri) and goldspot emperor (Gnathodentex aurolineatus).
Where off-transect sightings were taken into account, apex predator biomass (jack, tuna and shark) was significantly greater inside MPAs compared to outside MPAs (one-way ANOVA,P=0.040).

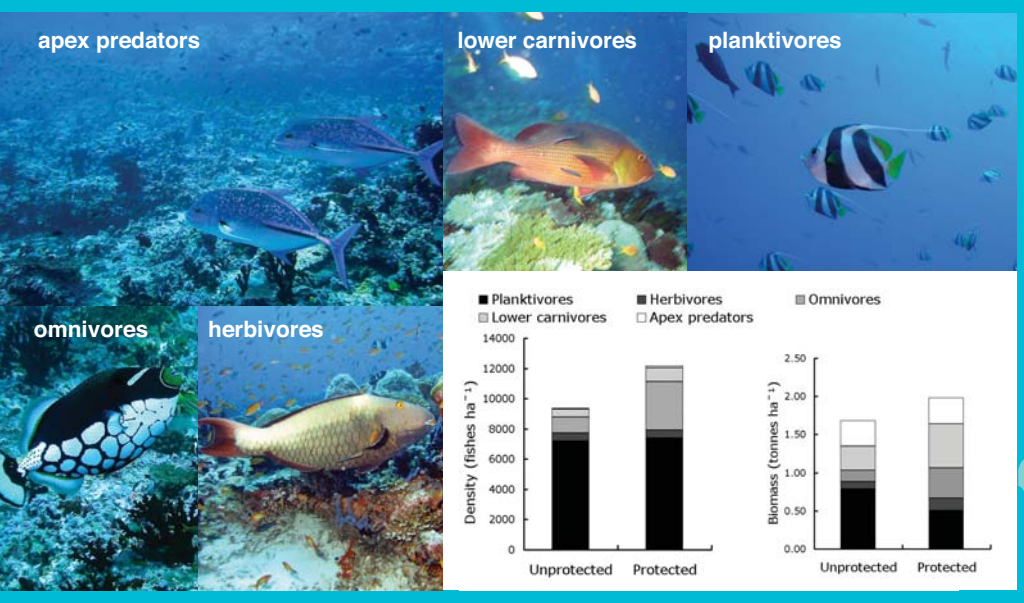
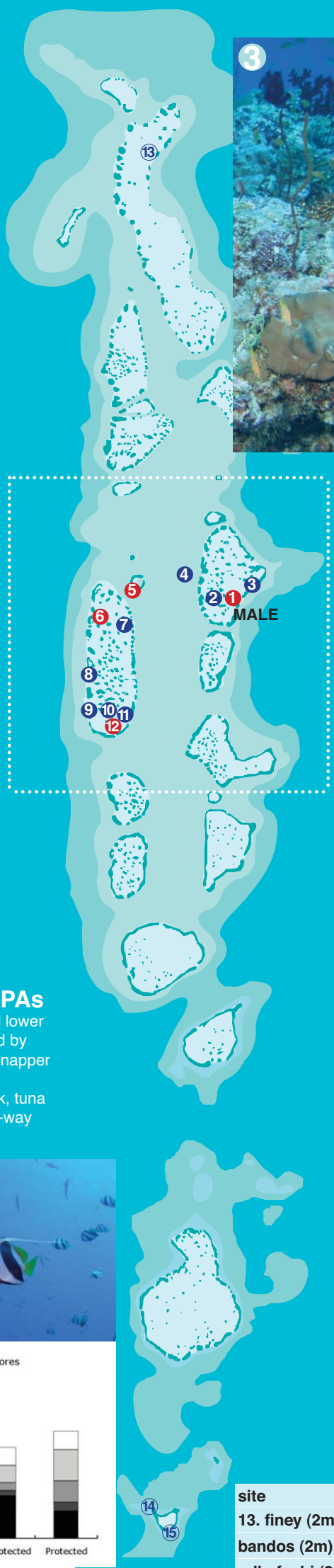


figure 7
Fish density and biomass inside and outside Maldives MPAs by trophic group.

Conclusions
The recovery of Maldives reefs from the 1998 appears to be patchy, but is generally considered to be increasing. Wilkinson (2008) reported that recovery of western atoll reefs appears to be more highly developed than eastern atolls. This patchy recovery is probably caused by differences in site specific oceanographic conditions such as current, weather and the number of available larvae in the months immediately after the bleaching event.

While the data reveals few differences in fish species, family and trophic level assemblages between protected and unprotected reefs, Maldivian MPAs appear to yield some increases in density of some fish species at certain trophic levels. Since the early 1990's there has been an increasing demand for reef fish to cater for the tourist industry (McClanahan et al. 2000) and it would be beneficial for the Maldivian government, tourism industry and fishing sector to further understand the role and application of protected area management in the sustainable exploitation of reef fish resources. MCS is working with the Maldives Research Centre to develop an integrated management plan for the reef fishery by 2013.



MCS survey area
Figure 2.
Central Maldives atolls. The locations of the coral surveys are numbered.
Red numbers are location of MPA sites where reef fishing is banned.

typical reef communities of the maldives
Figure 3-6.
3- HP reef, North Male atoll; 4- rare mature colony of Porites; 5 & 6 – shallow water reef community at Dega Giri in west Ari atoll.

Results - coral
Coral cover on central atoll Maldivian reefs surveys was low at some sites (Adhureys Rock, Angaga); moderate at others (Rasdhoo), and good at one (Dega Ghiri) (Table 1, Figures 5 & 6). Corals were dominated by Acroporid family corals, with most sites having a patchwork of colonies approximately 20-40cm in diameter. Mature old-growth massive corals were almost entirely absent from the surveys (see figure 4). Patchiness of recovery is observed within atolls and between depths, e.g. Adhureys Rock on the southeastern side of Ari atoll is covered in a layer of Discosoma ascidians, covering the shallow surface of the reef at 3-10m, yet further to the west within the same atoll, Dega Giri has a coral cover of 67%, dominated by Acropora corals in shallow waters (<5m). From 5-20m, however Dega Giri resembles many other reefs, with cover of less than 15%. Far southern atolls appeared to have been less affected by the bleaching event in 1998 (Table 2), and recent visits by Maldives Scuba Tours live-aboard dive trips report that the reefs and fish populations remain very healthy, with high coral cover and many apex predators seen at most sites (Rob Bryning, pers. comm.).

site	2005	2006	2007	2008
1.HP reef (14m)	n/m	17.5	n/m	19
2. okaboli (10m)	n/m	n/m	n/m	31
3. aquarium (10m)	n/m	n/m	n/m	20
4. boduhithi (10m)	n/m	n/m	n/m	13
5. rasdhoo (14m)	34.4	n/m	33.1	33
6. maaya thila (10m)	n/m	n/m	n/m	9
7. bathalaa (10m)	n/m	n/m	n/m	20
8. dega giri (2m)	n/m	n/m	n/m	66.9
9. angaga (10m)	n/m	n/m	n/m	5
10. adhureys (10m)	12.5	n/m	n/m	n/m
11. niumath (15m)	n/m	10	n/m	10.75
12. kudarah (10m)	n/m	n/m	n/m	20

Table 1. Percent coral cover at different central Maldives reefs recorded by MCS (2005-2008). Sites in red are MPAs.

site	1998	1999	2000	2002	2003	2004
13. finey (2m) far north	0.7	0.1	0.3	1.4	2.5	n/m
bandos (2m)	1.9	7.6	5.0	6.9	n/m	n/m
udhafushi (2m)	1.3	1.5	2.1	2.9	n/m	n/m
maayaa (2m)	0.6	0.9	1.5	2.7	5.0	4.8
wattaru (2m)	2.8	2.4	2.7	3.7	5.0	n/m
14. gan (2m) far south	4.0	4.5	5.0	12.9	n/m	n/m
15. hithadoo (10m) far south	n/m	n/m	n/m	40.9	62.6	51.7

Table 2 . Percent coral cover at different Maldives reefs recorded by Maldives Marine Research Centre (1998-2004).

References
McClanahan, TR, Charles, R, Shephard, C and D Obura (2000) Coral reefs of the Indian Ocean: Their ecology and conservation. Oxford University Press.
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