Project Update: April 2016

The overarching aim of this study was to investigate variation in the size structure of six dominant groups of corals with highly contrasting life history characteristics and test whether size structure varied spatially with depth and among reefs with different typology (oceanic versus lagoonal reefs). Importantly, historical data on coral cover from 1998 onwards from the literature are available for the studied reefs, providing an opportunity to better understand the recovery patterns of the monitored reefs. Knowledge of disturbance regimes and of subsequent changes in coral cover can greatly increase the ability to infer demographic processes and contrast life histories. Understanding variations between locations and among species can give insights on which species and what locations are likely to have a greater recovery capacity in order to enhance their conservation.

Results

A total of 1966 of colonies were surveyed during the present study. Colony surface area ranged from 0.05 cm (± 4.93 SE) in *Porites* to 3846.45 (± 17.66 SE) in *A. muricata.*

Within taxa, size-frequency distributions did not vary among depths and among different island exposure (KS test, P > 0.01). Since colony size did not increased consistently with increasing depth in any coral taxa, all colonies were pulled together to have a more robust analysis. Size-frequency distributions for all coral taxa were negatively skewed, with a preponderance of colonies in the largest size-classes (Fig 1 Table 1). Size-frequency distributions were also leptokurtic, peaked and highly centralised around the mean, indicative of slower population growth (Fig 1, Table 1). When using the untransformed data, there was a prevalence of smaller colonies in all coral taxa except for *A. muricata*, resulting in positively skewed size-frequency distributions (Fig 1). *A. muricata* had a larger percentage (62%) of colonies in the largest class size (>10.000 cm^2) compared to the other species (Fig. 1).

In *Porites* spp, *Acropora* plate and *A. muricata* percentage of partial mortality increased as the colonies became larger (Fig 1), while in *Pocillopora* spp and *A. humilis* percentage of partial mortality increase with increasing size but then decrease in the largest size classes (Fig 1). Mean percentage of dead tissue was highest in *A. muricata* and *Porites* (27.1% ±2.3 and 11.3% ±0.6 respectively) while it was lowest in A. plate (3.1% ±1.3) (Fig 1).

Except for *A. muricata* , colony surface area varied significantly among the study sites in all coral taxa (Table 2) with all the sites differing one from another (Tukey test >0.005).

Table 1 Size frequency distribution parameters.

Species	n	Mean colony size (cm2)	CV	Kurtosis	Skweness
Acropora muricata	221	4.07	22.9	3.15	-0.21
Acropora humilis	174	3.22	20.4	2.57	-0.01
Acropora	83	4.57	25.9	2.38	-0.1

plate					
Pocillopora spp	525	3.34	27.1	2.34	-0.49
Porites	968	3.35	19.9	3.59	-0.41

Table 2 One way anova comparing mean colony size between the 7 studied sites

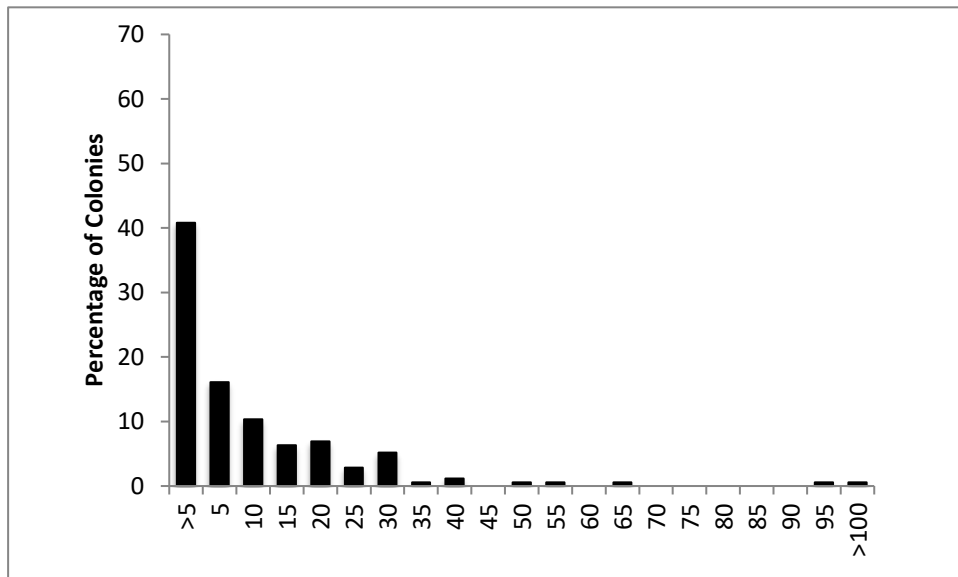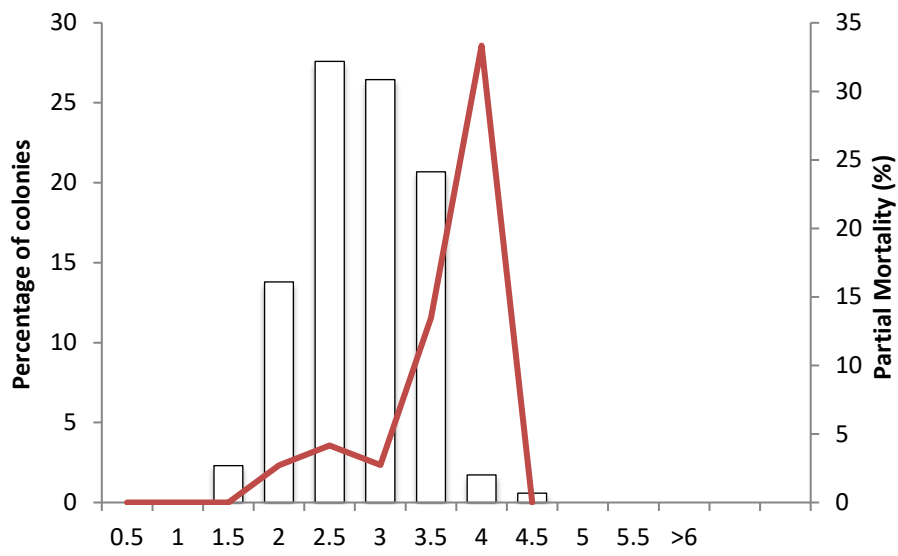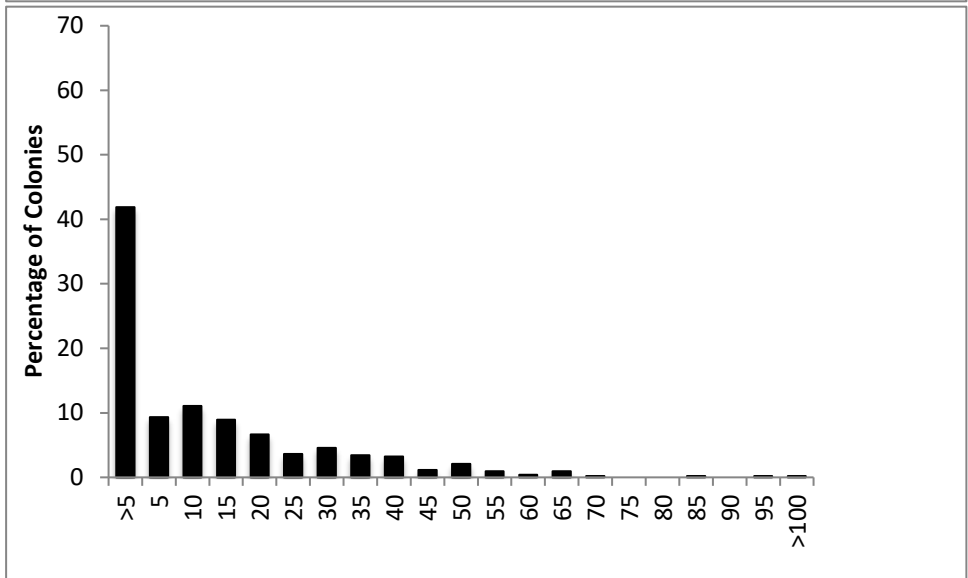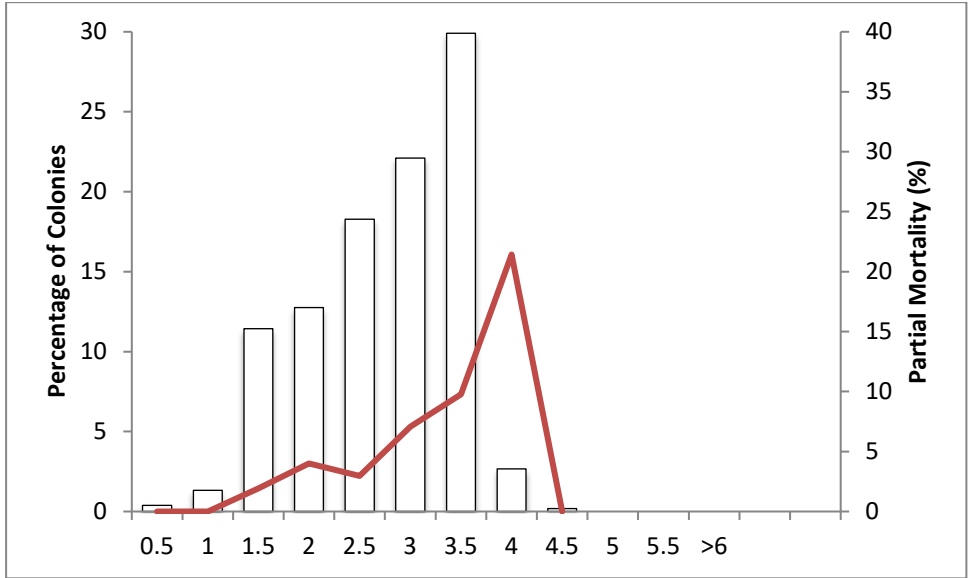| Coral species	Df	F	p
Acropora muricata	3/196	2.01	0.11
Acropora humilis	5/156	10.74	***
Acropora plate	3/78	23.99	***
Pocillopora spp	6/513	17.32	***
Porites	6/960	9.77	***

Figure 1

A. *Ac. muricata*
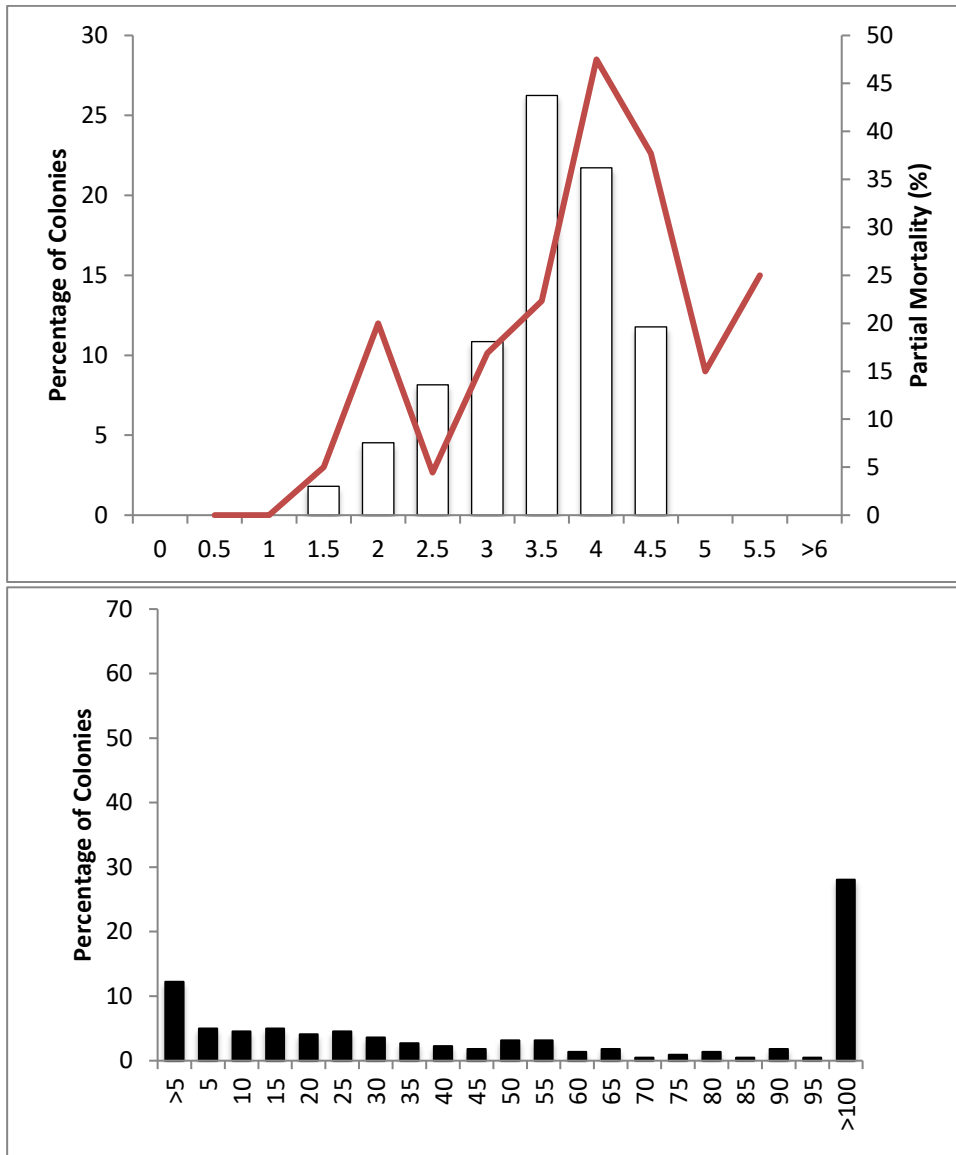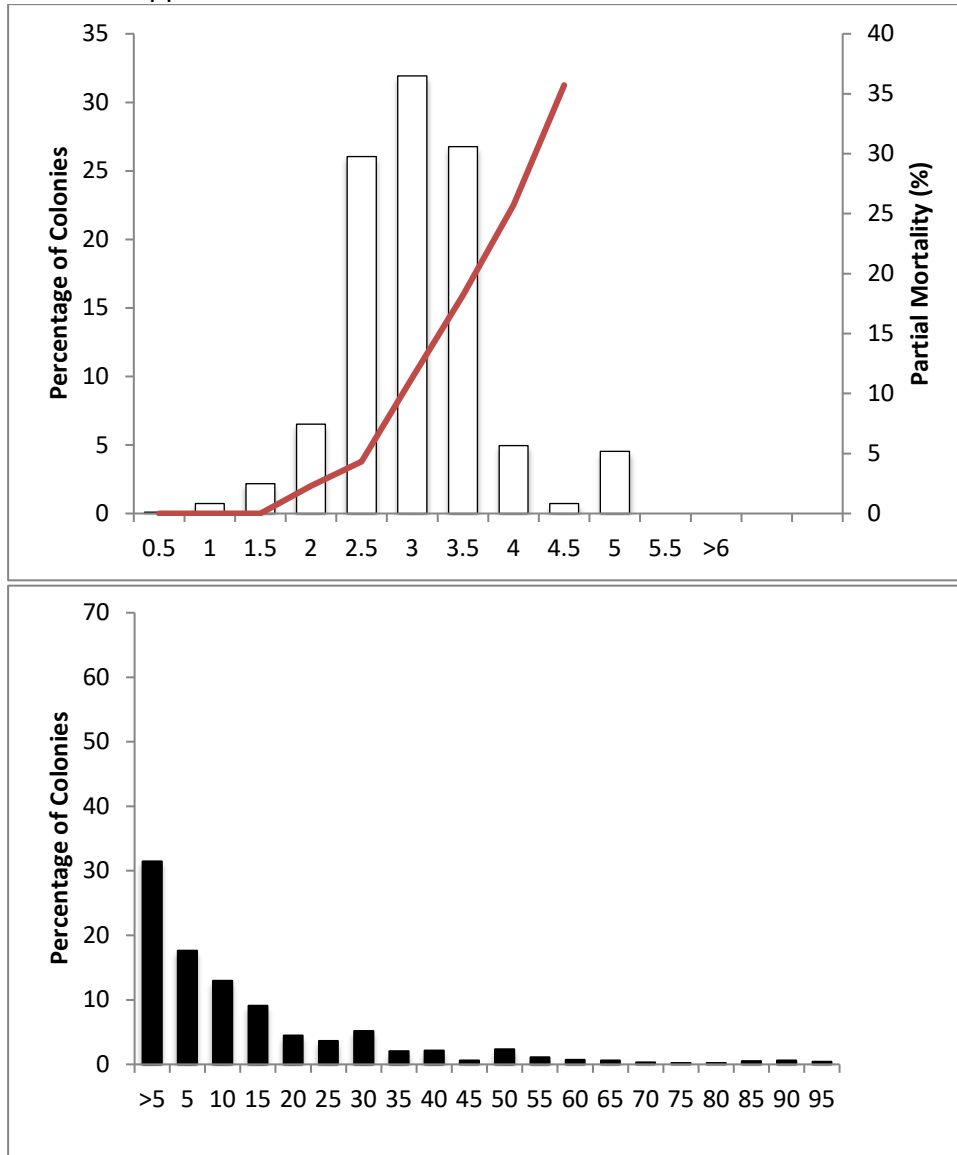
B. Plate corals
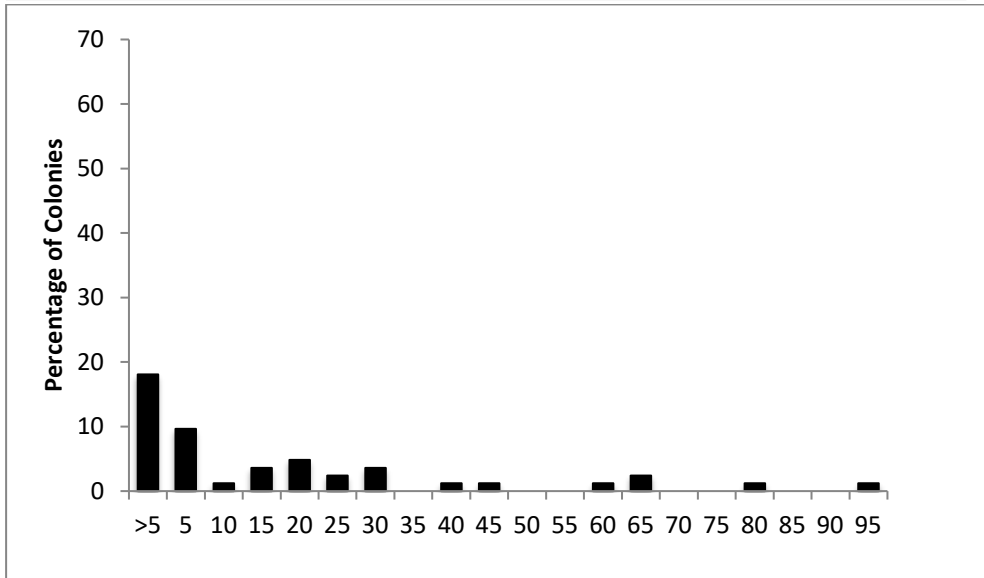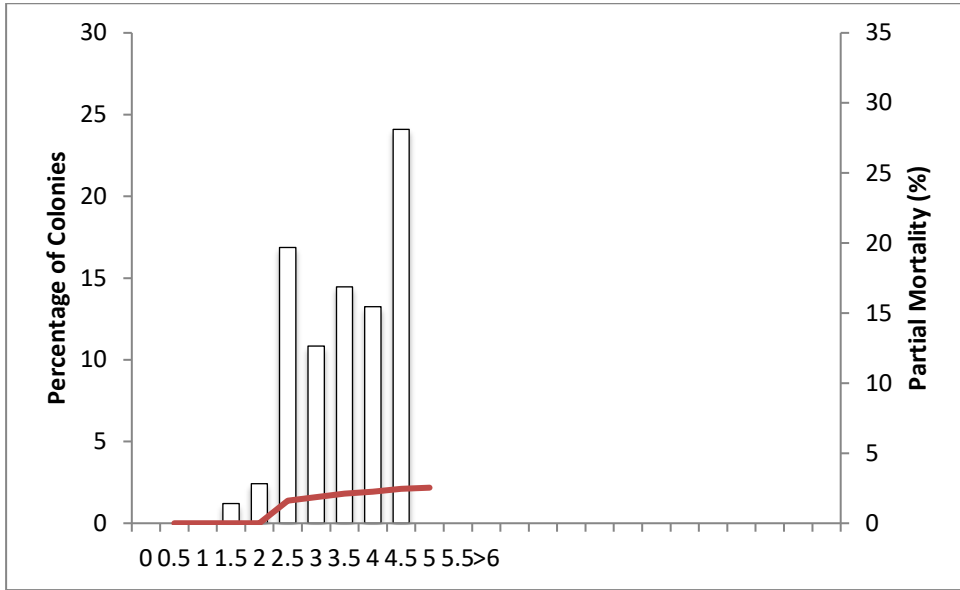
C. *Ac. humilis*

D. *Pocillopora sp*

E. *Porites* spp

There is limited data on chronic disturbances affecting the study locations in Maldives (e.g., fishing pressure, sedimentation, and/or eutrophication), it appears that loss of corals is largely explained by the occurrence of acute disturbances, including bleaching, tsunami, and outbreaks of *A. planci*, all of which have contributed to significant coral depletion in other locations in the Indian Ocean and Pacific [Wilson et al 2006; Death et al 2012].

Coral reefs in the Maldives are some of the more diverse reefs of the western Indian Ocean, nevertheless they are highly vulnerable to climate change and are exposed to high levels of human stress but yet they are overlooked. In 1998 Maldivian reefs have been severely affected by an intense bleaching event that reduced coral coverage by more than 80%. The recovery rate after this event has been variable both in terms of coral cover and return to the original coral community composition (Zahir et al 2010; Morri et al 205; Rilwan et al. 2016). Given the observed variability in post disturbance recovery, and the logistical and economics constrains in relation to broad scale environmental management, understanding the potential of reef recovery is paramount for the appropriate management of Maldivian

reefs.

Outbreaks of *A. planci* are one of the principal causes of coral loss in the Indo-Pacific (Bruno and Selig 2007; Death et al 2012), often killing up to 90% of scleractinian corals (Done 1985). *A. planci* outbreaks were previously reported in the Maldives in the 90's (Ciarapica and Passeri 1993), however in 2014-2015 density of starfish was reported to be higher (Saponari et al 2014). Recovery of coral cover following outbreaks is typically very slow (Randal 1973) and it may take between 10 and 40 years (Randal 1973; Colgan 1981; but see Trapon et al 2011).

While there was significant spatial variation in mean colony size of all coral taxa (except *A. muricata*), this study did not detect any clear and consistent difference between depths and between exposed and less exposed locations. These findings may suggest that other factors including disturbance regime and life history processes further modify the structure of coral populations. Differences in recruitment, growth, partial and total mortality rates may also cause spatial variation in the size structure as they can vary with small spatial scale (Baird & Hughes, 1997).

Size structure of coral populations has important implications for the subsequent persistence and recovery of taxa (Done 1988). Fecundity is strongly and positively correlated to colony size (e.g., Hughes & Jackson, 1985; Babcock, 1991), populations comprised of larger colonies may then be highly likely to reproduce and persist through time due to the high reproductive output, compared to populations comprising entirely of smaller colonies. In the present study, some populations comprise many smaller colonies, and probably make a limited contribution to reproductive output, compared to other populations that are comprised mainly of larger colonies. However, the few larger colonies may contribute disproportionally to the reproductive output of a population and may provide sufficient larval supply to replenish coral losses after major stress events (Riegl 2002; Baker et al. 2008).

Material and Methods

Study site
The Maldives include 16 complex atolls with ca.1120 islands extending form the central part of the Chagos-Maldives-Laccadive ridge in the central Indian Ocean from about 7°07' N to 0°40' S in latitude and 72°33' E to 73°45' E in longitude. This study surveyed 7 islands in three atolls in the central Maldives archipelago. Three islands on the ocean-facing sides of the atoll rim and four islands on the lagoon-facing sides of the atoll rim were selected to investigate whether reef typology affected size structure. To better understand recovery trajectories of different islands, benthic cover and size classes were measured among depths and different reef typologies. *Acropora hyacinthus, Acropora cytherea, Acropora muricata, Acropora humilis , Pocillopora spp, and* massive *Porites.* These species were among the most abundant at the studied sites. *Isopora* was also suggested as common at the study site (Morri et al 2010), however no colonies were observed in the transects.

At each island, three replicate 10 x 2m belt transects, laid parallel to the reef edge, were surveyed on the reef crest (5 meters) and on the slope (10 meters). Percentage benthic

cover was measured using line transects, while all coral colonies contained within each transect were measured to determine colony size. For every colony sampled, the longest diameter was recorded. Partial mortality (percentage of tissue loss) was also visually estimated *in situ* for each surveyed colony and causes of injuries were also recorded when possible such as in case of fish bites or *Drupella*.

Historical data from other studies (Zahir et al 2009, 2010; Rilwan et al. 2016) were collected using three 50m line intercept transect. Initial surveys started in 1998 after bleaching and surveys were repeated at the same sites almost every year until 2005. Since 2009 data were collected with 50cm point intercept transect along four 20m transects, each separated by a 5m gap to ensure independency.