

Implementation of the
Holistic Approach to Reef Protection (HARP)
Program in Dhigu (South Malé Atoll)
and Kihavah (Baa Atoll), Maldives: Phase I

Field Report

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Summary

In January 2016 we established 10 permanent sites in South Malé Atoll and Baa Atoll, Maldives that will be revisited over time to document changes to coral reef communities as a result of global and localized disturbances. Sites were selected to allow 1) comparisons of sites which have recently been hit by a crown of thorns starfish outbreak with sites where there have been no reports of crown of thorns starfish damage; 2) determine impacts of a predicted bleaching event; 3) identify corals that are stronger and more tolerant of high temperatures; and 4) evaluate patterns of recovery from disturbances. Permanent sites included photo-transect plots and tagged corals. Each photo-transect is a 10 m x 1 m belt, marking the beginning and end with an iron rebar, with two transects established per site; tagged corals are marked with a plastic numbered cattle tag. The sites were fully characterized in January, prior to the bleaching event, through quantitative fish transects (each 30 m x 4 m, with a minimum of 4 per site) and benthic transects (each 10 m long, with 100 points per line and 4 transects per site), and photo-documentation of permanent transects. Selected branching corals of two genera, *Acropora* and *Pocillopora*, were tagged within each site and sampled to establish a "baseline" of their health and to characterize symbiont (zooxanthellae, algae living within their tissue) composition. All permanent sites were between 4-7 m depth and include lagoonal, channel and fore reef locations.

Reef fish communities within the 10 permanent sites had a similar composition of species, although South Male sites had a slightly higher diversity (163 species) than Baa Atoll (151 species). There were notable differences in the numbers of reef fish recorded within transects, with Baa Atoll having a two to three-fold higher density (53,375 - 161,417 individuals/ha) than sites on South Malé (16,653 - 57,167 individuals/ha) and a higher biomass (total mean biomass at Baa Atoll was 1,308.3 kg/ha vs 833.54 kg/ha at South Malé Atoll). On both atolls schooling fusiliers and anthias and the redtoothed triggerfish were the most common fish. Other common families included surgeonfish, butterflyfish, wrasse and damselfish, which are all small bodied fish. The largest fish recorded on these reefs were red snapper (*Lutjanus bohar*), bigeye trevally (*Caranx sexfasciatus*), giant sweetlips (*Plectorhinchus obscurus*), and dogtooth tuna (*Gymnosarda unicolor*). The two atolls also exhibited some interesting differences in the dominant functional groups. In both locations, planktivores were the most abundant fish, making up nearly half of the fish at South Malé Sites and over 80% at Baa Atoll. South Malé sites also had a higher proportion of benthic feeders, omnivores and herbivores, while all locations had a very low abundance of piscivores.

Coral communities were in good condition, with exception of two sites that had been badly impacted by crown of thorns starfish. On fore reef locations, several species of table acroporids were often dominant, but many of the colonies were small to medium-sized indicating they were only 3-5 years old. Baa Atoll had several sites with very high (>50%) coral cover consisting of

large stands of foliaceous *Echinopora* as well as lagoonal reefs with high abundance and cover of small *Porites* colonies.

Stressors present included crown of thorns starfish damage (two sites on South Malé), coral disease (isolated cases of white syndrome), snail predation (primarily on branching corals), overgrowth by sponges (on staghorn coral). Substrates had low amounts of fleshy seaweed. There were high numbers of ascidians and sponges in some locations. No bleaching was noted.



Fig. 1. Overgrowth by an encrusting sponge, *Terpios*.

Methods

Permanent sites were selected off two atolls, South Malé Atoll and Baa Atoll, to document the condition of coral reefs prior to the predicted 2016 mass bleaching event, the extent of bleaching during April 2016 reassessments, and changes to these sites through future monitoring. We established five permanent sites on each atoll, including fore reef, channel reef and lagoonal patch reef sites. On South Malé Atoll, sites included areas where crown of thorns starfish (COTS) removals had been done, as well as sites that were not affected by COTS in 2015. Baa atoll sites served as controls, as no outbreaks of COTS have been reported as of March 2016.

Set-up

At each monitoring site, two permanent transects were established on the reef flat at 5-8m depth. The transects were marked using iron rebar inserted into dead reef substrate, to identify the beginning and end of each line and allow divers to reassess the identical area over time. A total of four rebars were inserted on each reef. A temperature meter was attached to one rebar at each site to measure changes in temperature on a daily basis (one reading per hour). A minimum of 10 corals in the vicinity of each line were tagged to follow and sample over time.



Fig. 2. One of the rebars used to mark the beginning of a permanent transect.

Assessments

A lead line marked in 10 cm intervals was extended between each pair of rebar and a continuous 1m wide strip of overlapping photographs was taken along the line. Within the surrounding area additional coral reef data were collected including: 1) assessment of reef fish community structure and biomass using a minimum of two 30 m fish belt-transects at 5 to 8 m, and two at 10 to 12 m depth; 2) assessment of benthic cover of corals, algae and other organisms by recording the taxa and substrate type under each of 100 points along a 10 m lead line, with a minimum of two transects completed per site at 5 m and at 10 m depth.



Fig. 3. Deploying a 10 m lead line at 10 m depth. Each line is marked with 100 points.

Sampling

Each tagged coral was photographed (both whole colony and macro-photograph) and small tissue/skeletal samples were removed for laboratory analysis. Samples were immediately placed into *RNA Later* for analysis of coral DNA and into *DMSO* for analysis of coral symbionts.



Fig. 4. Conducting a fish survey along a 30 m x 4 m belt transect.



Fig. 5. Sampling a digitate *Acropora* colony for laboratory analysis.

Locations of Permanent Stations

Station Code	Atoll	Reef Name	Latitude	Longitude	Reef Type	Exposure
MAL01	South Malé	Small Sand Bank	3.95585	73.46486	Lagoonal Patch	Leeward
MAL02	South Malé	Raaebundi Reef	4.00945	73.4833	Lagoonal Patch	Leeward
MAL03	South Malé	Veli House Reef	3.96379	73.50127	Channel	Leeward
MAL04	South Malé	Stage	3.99394	73.52503	Forereef	Windward
MAL05	South Malé	Maafushi	3.94026	73.49776	Forereef	Windward
MAL06	Baa	Vinaneiyfaruhuraa	5.34531	73.08234	Forereef	Exposed
MAL07	Baa	Kashidupper	5.29653	72.93749	Lagoonal Patch	Semi-Sheltered
MAL08	Baa	Kashidhoogiri	5.29505	72.96262	Lagoonal Patch	Semi-Sheltered
MAL09	Baa	Gaagadufaruhuraa	5.37614	73.04385	Forereef	Exposed
MAL10	Baa	Gaagadufaruhuraa	5.37615	73.04425	Forereef	Exposed

Table 1. Site names, coordinates, and reef characteristics of the permanent sites.

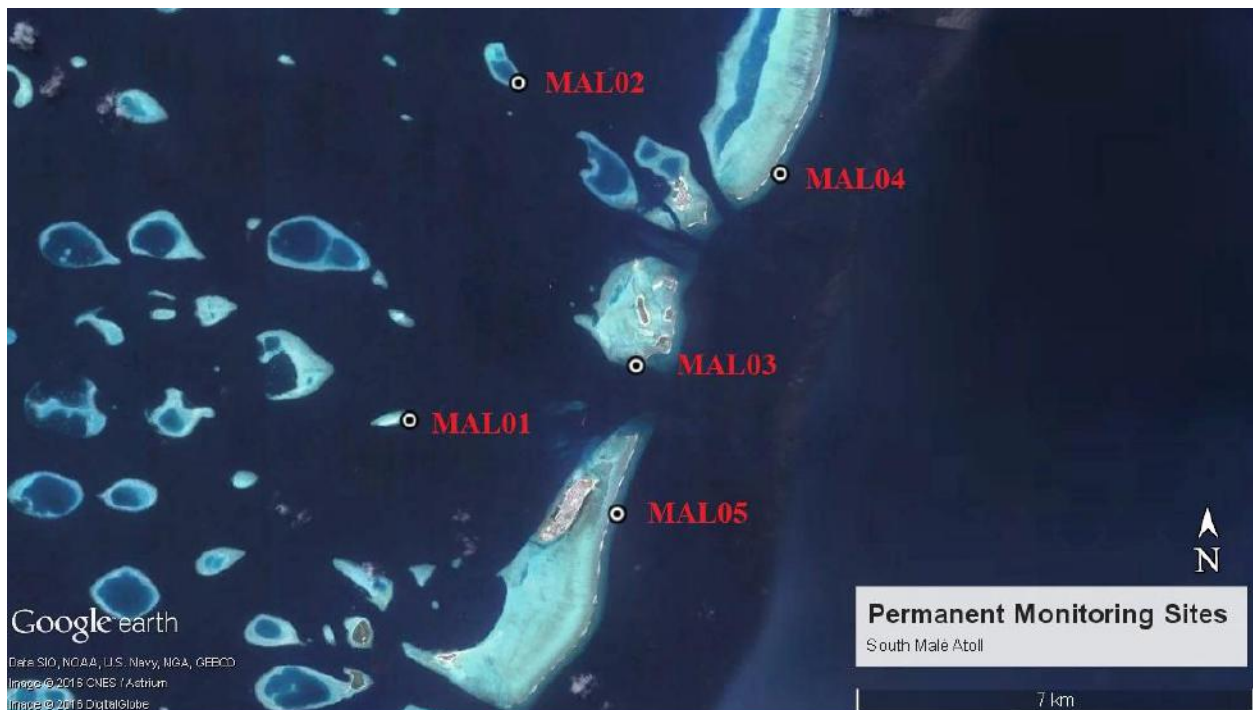


Fig. 6. Location of permanent monitoring stations near Dhigu, South Malé Atoll.

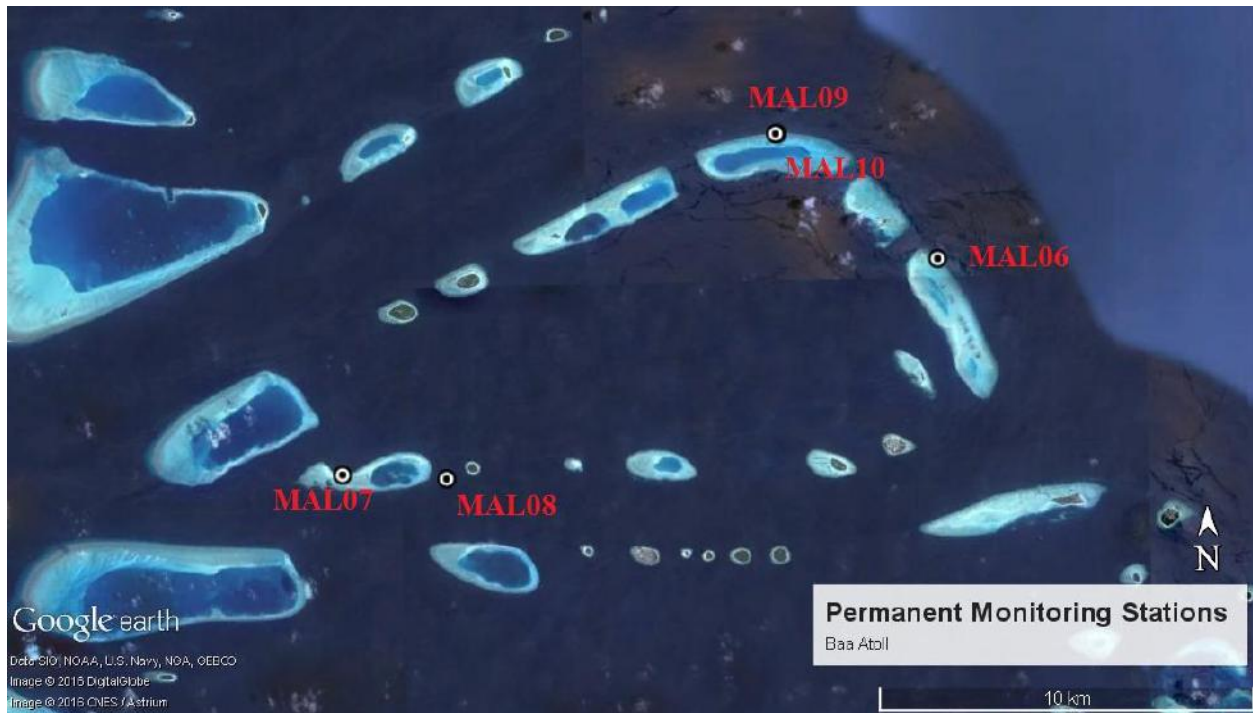


Fig. 7. Location of permanent monitoring stations near Kihavah, Baa Atoll.



Fig. 8. Shallow reef community at Kihavah, Baa Atoll with large foliaceous colonies of *Echinopora*.

Condition of permanent sites

Sites varied in species composition, coral cover and health. These differences were attributed to exposure and location, as sites included lagoonal patch reefs, channel reefs and exposed fore reef communities. Live coral cover was also considerably lower at sites on South Male where previous COTS outbreaks had been documented, especially Stage Reef and Raaebundi Reef. These sites also had a high number of dead coral skeletons. Low numbers of COTS were still present on Raaebundi Reef and some continued damage to coral was noted. No COTS were seen at any sites on Baa Atoll.

The dominant corals in shallow fore reef and channel reef sites were table acroporids, digitate acroporids, *Pocillopora*, and plating *Montipora*. Lagoonal sites had higher numbers of small massive *Porites* and smaller massive faviids such as *Goniastrea*. On Baa atoll some very large stands of foliaceous *Echinopora* were identified (Fig. 8).

A small number of diseased corals were present but no severe disease outbreaks were noted. There was no bleaching noted in any of the permanent sites during January. Water temperatures were approximately 29° C, which is below the threshold for bleaching (Fig. 17).

Reefs had relatively high cover of crustose coralline algae, a positive sign, and also had very little macroalgae, cyanobacteria or other pest species. There were several colonies being overgrown by an encrusting sponge. There were high numbers of coral eating snails (*Drupella*) on isolated corals, but mortality from these snails was minimal.

Reef fish

South Malé

Over the 28 belt transects performed in South Malé, 163 species of reef fish (32 families and 83 genera) were recorded (Fig.10). An average of 82 species was recorded at each station. Acanthuridae (surgeonfish), Chaetodontidae (butterflyfish), Labridae (wrasse) and Pomacentridae (damselfish) were some of the most regularly observed families. The four most commonly recorded genera were *Pterocaesio*, *Odonus*, *Pseudanthias* and *Pomacentrus* and accounted for 55% of these stations' total density. *Odonus niger*, *Pterocaesio tile*, *Pseudanthias evansi* and *Pomacentrus philippinus* were the most common species at these reefs.

Total mean density for these five stations was 34,530 individuals/ha, with the greatest mean density observed at MAL 04 (57,167 individuals/ha) and the lowest at MAL 05 (16,653 individuals/ha; Fig. 11). The largest schools of fish observed were anthias, fusiliers and the redtoothed triggerfish (*Odonus niger*). Total mean biomass was 833.54 kg/ha and was fairly consistent at all stations (Fig.12). Biomass ranged from 602.4 kg/ha (MAL 01) to 1,024.26 kg/ha

(MAL 02). The two largest species recorded were the red snapper (*Lutjanus bohar*) and the bigeye trevally (*Caranx sexfasciatus*).

Baa Atoll

Over the 23 belt transects performed Baa Atoll, 151 species of reef fish (31 families and 85 genera) were recorded (Fig. 13). Despite a lower total number of species recorded in Baa, the same average diversity was found at each station (82 species). The most common genera observed were *Pterocaesio*, *Pseudanthias* and *Caesio*, accounting for 50% of total density. The most frequently recorded species within these genera included *Caesio xanthonota*, *Pseudanthias squamipinnis* and *Pterocaesio tile*. The triggerfish, *Odonus niger*, was also common.

Total mean density for these five stations was 88,736 individuals/ha, with the greatest mean density recorded at MAL 08 (161,417 individuals/ha) and the lowest at MAL 09 (53,375 individuals/ha; Fig. 14). Total mean biomass was 1,308.3 kg/ha and ranged from 949.2 kg/ha (MAL 10) up to 2,401.5 kg/ha (MAL 08; Fig. 15). The largest fish observed at these stations were the giant sweetlips (*Plectorhinchus obscurus*), dogtooth tuna (*Gymnosarda unicolor*) and *L. bohar*.



Fig. 9. Oriental sweetlips (*Plectorhinchus vittatus*) at a cleaning station.

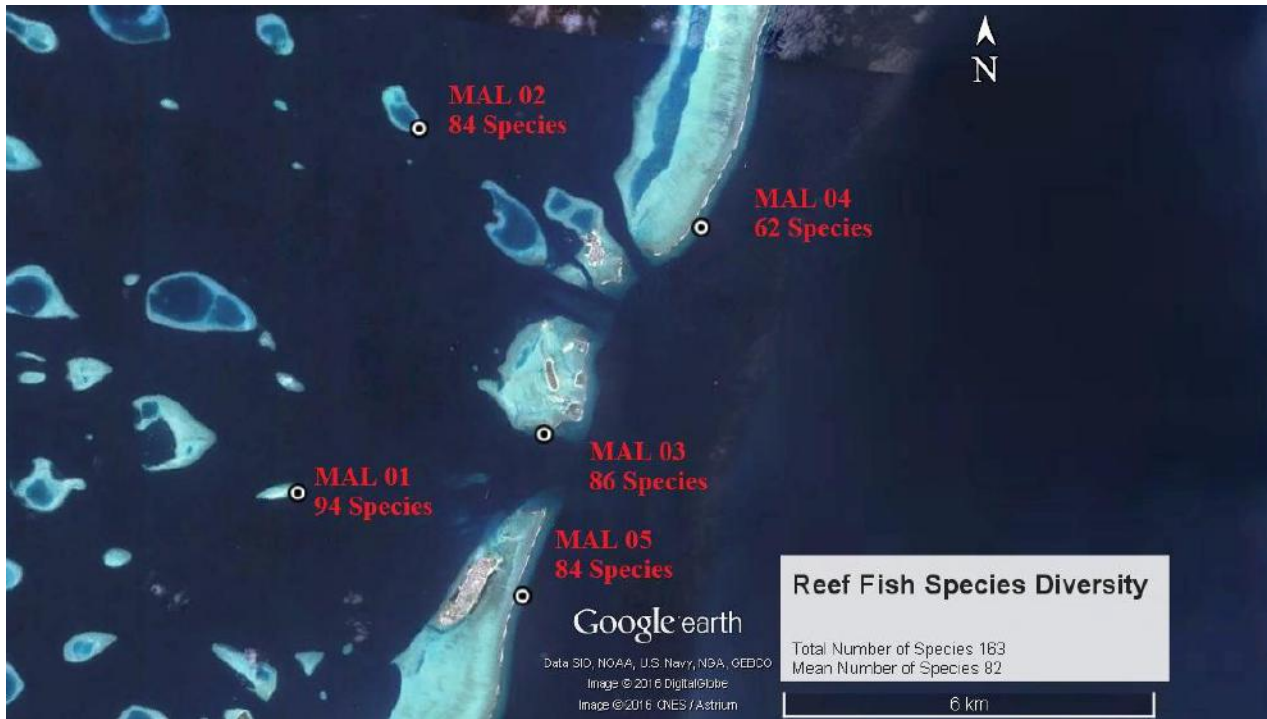


Fig. 10. Total numbers of species of fish recorded at each permanent site in South Malé Atoll.

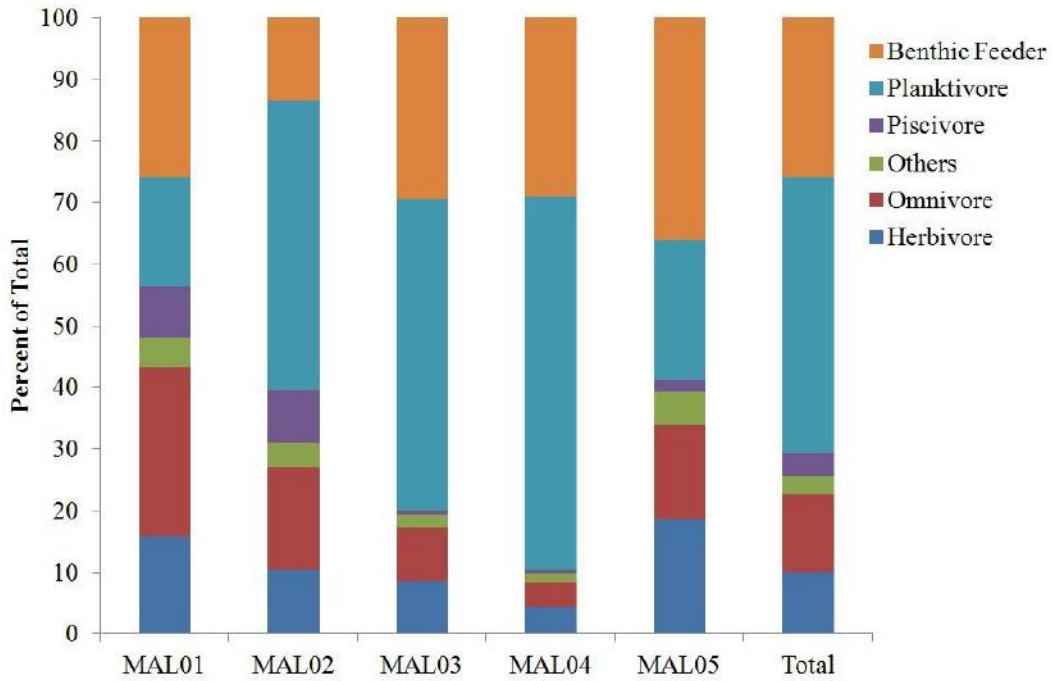


Fig. 11. Mean relative density of reef fish (no. fish per hectare) at permanent sites in South Malé Atoll by functional guild.

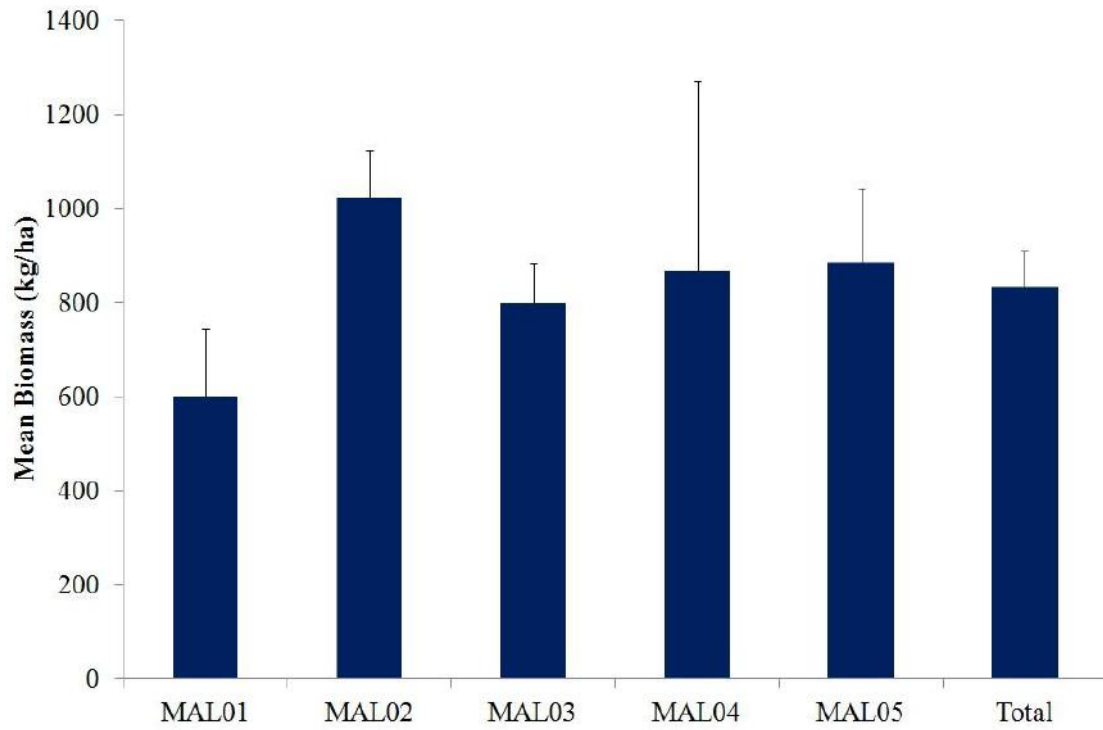


Fig. 12. Biomass (kg per hectare) of reef fish at permanent sites in South Malé Atoll.

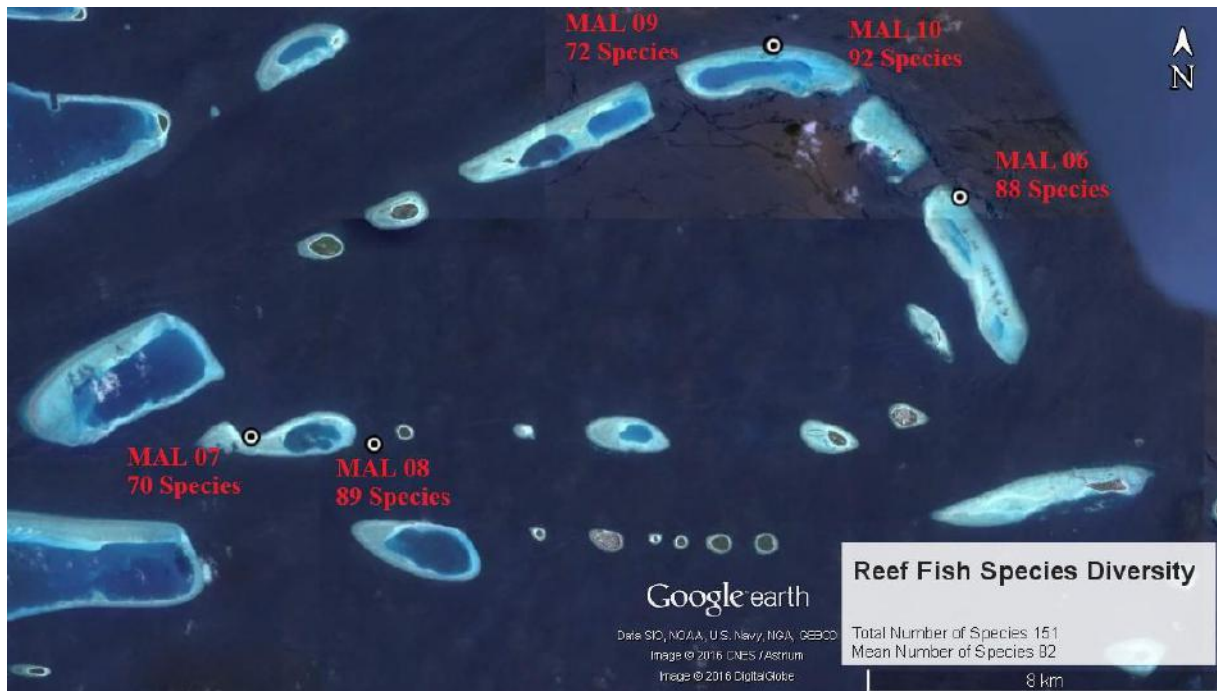


Fig. 13. Total numbers of species of fish recorded at each permanent site in Baa Atoll.

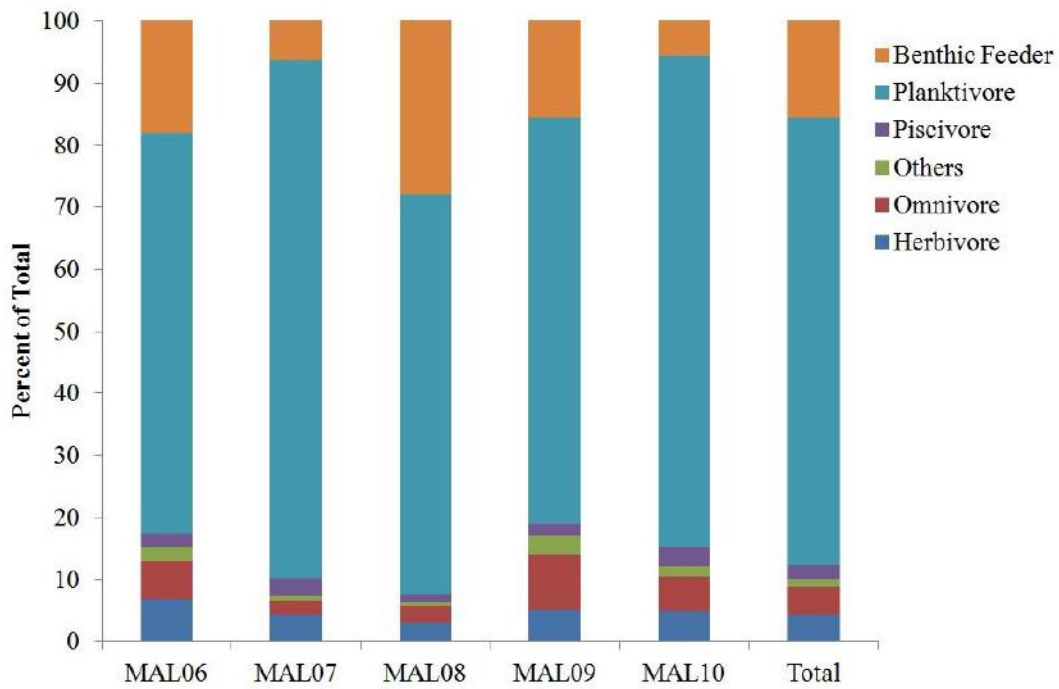


Fig. 14. Mean relative density of reef fish (no. fish per hectare) at permanent sites in Baa Atoll by functional guild.

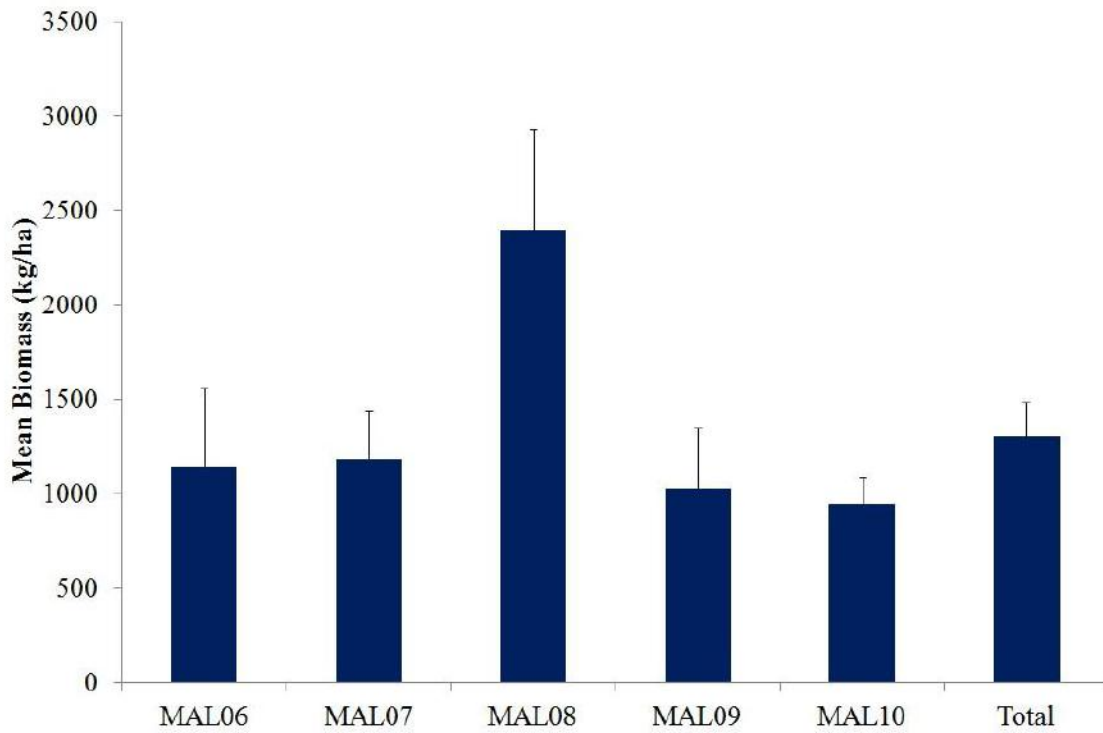


Fig. 15. Biomass (kg per hectare) of reef fish at permanent sites in Baa Atoll.

Sea water temperatures

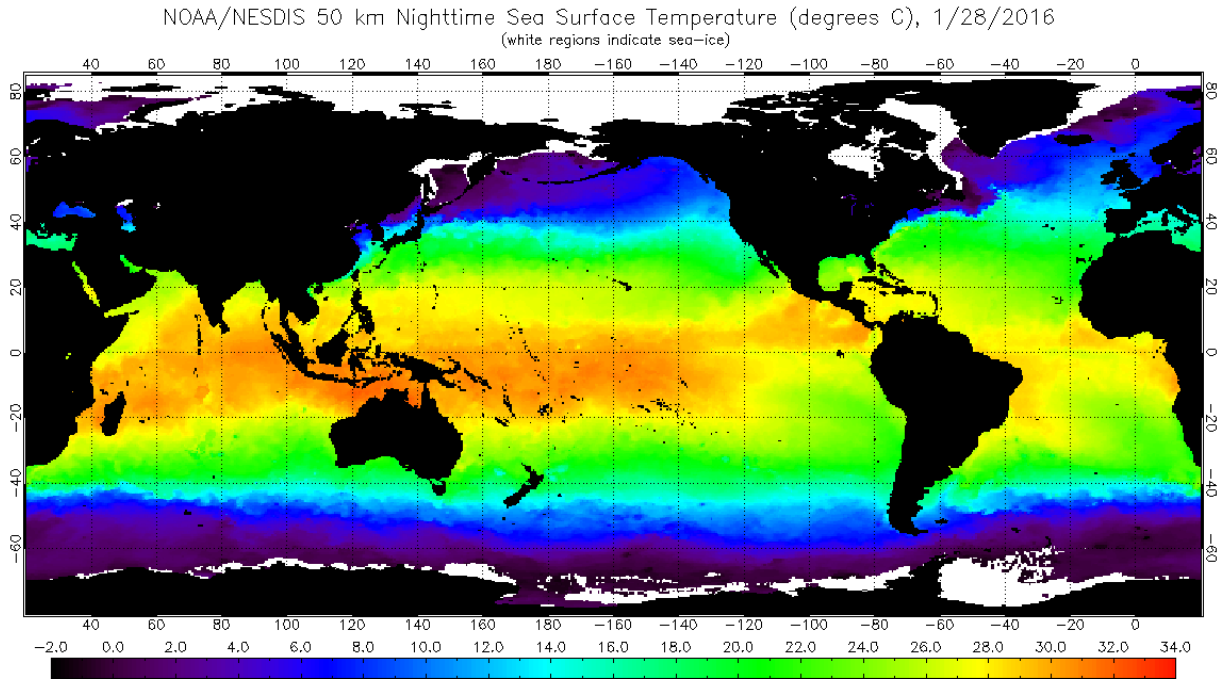


Fig. 16. NOAA sea surface temperature (global) on 1/28/2016.

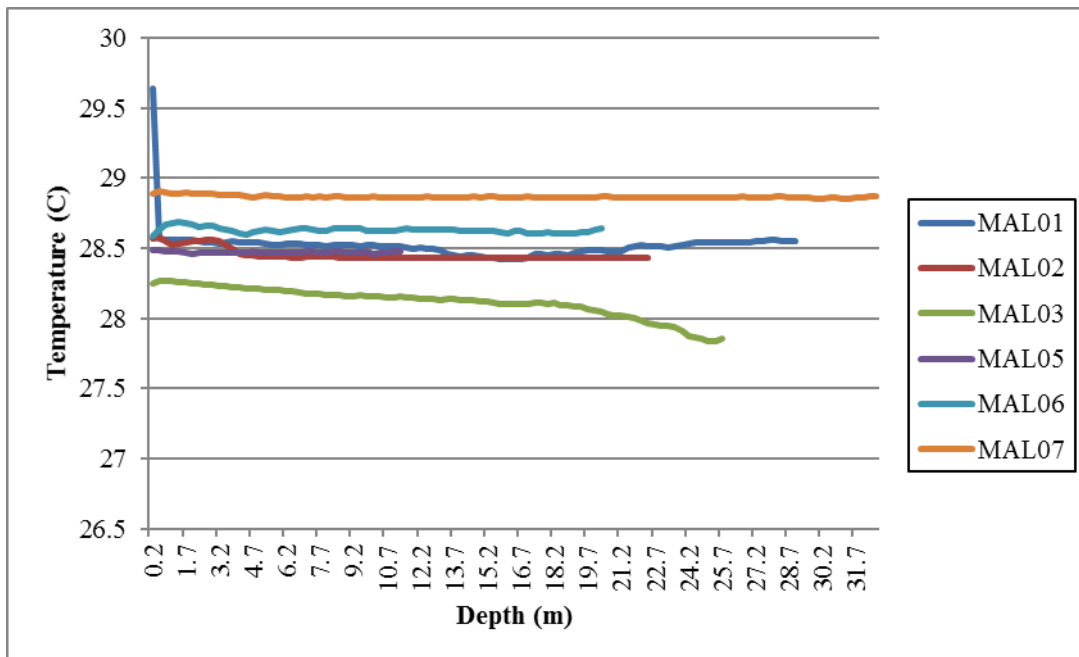


Fig. 17. Temperature profiles at 6 permanent sites when first established in January 2016. Temperature is from the surface (left side) to sea floor bottom (right).

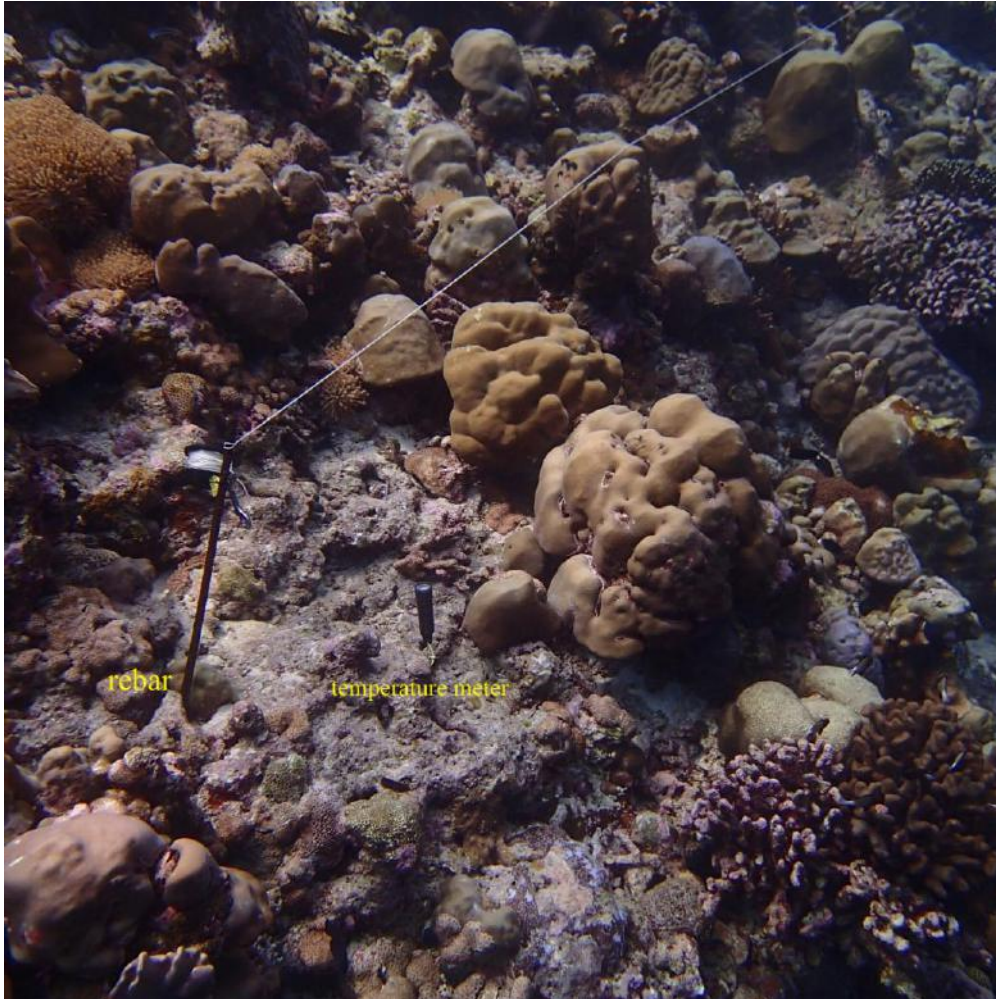


Fig. 18. A permanent site with a dominance of massive corals, especially *Porites*. The rebar used to mark the beginning of the transect and a temperature meter are shown.