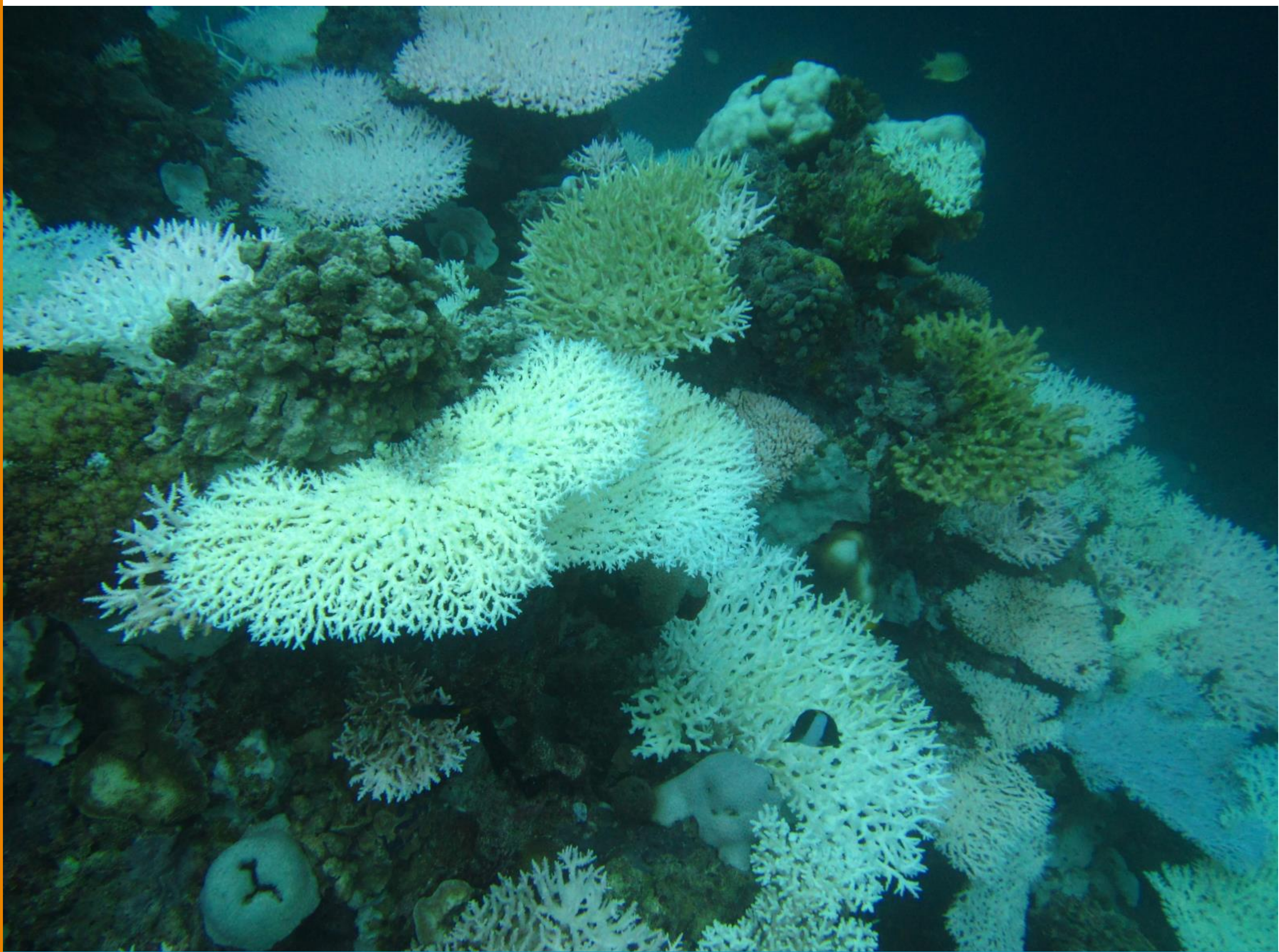
Maldives
Coral Bleaching Response Plan



Republic of the Maldives

Coral Bleaching Response Plan

2017

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Acronyms

BRAT- Bleaching Response Assessment Tool

BT- Belt Transect Benthic Surveys

CBRP- Coral Bleaching Response Plan

DCA – Department of Civil Aviation

DGs- Director Generals

DHW- Degree Heating Weeks

EPA- Environmental Protection Agency

GBRMPA- Great Barrier Reef Marine Park Authority

GoM- Government of the Maldives

IATFCB- Inter Agency Task Force on Coral Bleaching

IUCN- International Union for Conservation of Nature

MNDF- Maldives National Defence Force

MNU- Maldives National University

MoEE- Ministry of Environment and Energy

MoFA- Ministry of Fisheries and Agriculture

MoT- Ministry of Tourism

MRC- Marine Research Centre

NCRMF – (Maldives) National Coral Reef Monitoring Framework

NGOs- NonGovernmental Organisations

NOAA- National Oceanic and Atmospheric Administration

PIT- Point Intercept benthic Surveys

SST- Sea Surface Temperature

UNEP - United Nations Environmental Program

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Executive summary

There are a multitude of threats to coral reefs, but the increased frequency and severity of coral bleaching events under a changing climate is among the most pressing. The Maldives is world-famous for its spectacular marine environment, and coral reefs are the foundation of both the economy and culture of the country. In response to the alarming increases in risks from coral bleaching, the Government of the Maldives has established an Inter-Agency Task Force on Coral Bleaching (IATFCB; "The Task Force") with direct guidance from Minister of Fisheries and Agriculture, Dr. Mohamed Shainee. The Task Force consists of representatives from the Ministry of Fisheries and Agriculture (MoFA), Marine Research Centre (MRC), Ministry of Environment and Energy (MoEE), Environment Protection Agency (EPA), Ministry of Tourism (MoT) and Coast Guard of the Maldives National Defense Force (MNDF).

Background

This Coral Bleaching Response Plan has been developed to guide the Task Force and partners in detecting, assessing and responding to coral bleaching events in the Maldives. Primary responsibility for implementing the Coral Bleaching Response Plan (CBRP) lies with the Task Force, comprising the Marine Research Centre, Environmental Protection Agency and Coast Guard.

The Great Barrier Reef Marine Park Authority (GBRMPA) first developed a coral bleaching response plan (now the risk and impact assessment plan) in 2002, as part of a response to a bleaching event that occurred in the late summer (February and March) of that year. This plan is now central to preparations and response actions every summer in the Great Barrier Reef. The Maldives CBRP builds on this international experience to provide a best-practice framework for responding to coral bleaching events in the Maldives.

The Maldives has experienced two major bleaching events in recent years. The first recorded bleaching event in 1998 took the country by surprise, creating little opportunity for formal assessment of the severity of damage. However, a full monitoring program was put in place for the severe bleaching event in 2016, during which 73% of corals were bleached across the 71 sites surveyed (Ibrahim et al 2017). These events have highlighted the importance of a strategic framework to address and respond to mass bleaching in the country. As coral bleaching events can occur any year, the Coral Bleaching Response Plan (CBRP) will help government agencies and partners to detect the early warning signs of bleaching. To ensure that the Maldives is ready for future bleaching events, the Inter-Agency Task Force on Coral Bleaching (IATFCB) will coordinate implementation of the CBRP each bleaching season and review and refine it annually.

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Overview of the Coral Bleaching Response Plan

The CBRP outlines a strategic approach for preparing for bleaching events, monitoring bleaching risk, instigating response activities and assessing coral bleaching impacts when events occur. Within this document, the objectives of each of the three primary components of the CBRP are outlined and described in detail:

1. Early warning system
2. Incident response
3. Communications strategy

The Coral Bleaching Response Plan includes related routine and responsive tasks. When bleaching is either predicted or initially reported under the early warning system, the in-water monitoring and citizen science network ground-truths these predictions. MRC in conjunction with the EPA also conducts site inspections that determine the level of response required under the incident response component of the plan (based on the GBRMPA and Australasian Inter-service Incident Management System). Thresholds for response levels (1, 2, or 3) in the incident response component are based on the severity of bleaching impacts as well as the spatial extent of the event. More detailed monitoring during the incident response phase enables detailed reporting on reef condition and the severity of bleaching impacts, and works to target surveys to assess recovery. In the months and years that follow the disturbance, resilience-based management actions (e.g. continued improvement of water quality, litter management and dredging activities) can support the natural resilience of coral reef habitats in the Maldives, and increase the resilience of island communities reef users to any losses in ecosystem services that result from a bleaching event.

The Task Force will implement the plan throughout the bleaching season, rendering a transparency and consistency to management decision-making during bleaching events. The plan also serves to keep representatives from key partner institutions and the public aware of the technologies and protocols used to predict and monitor bleaching, and the criteria used to determine how to communicate about the severity of bleaching impacts when events occur. The plan is designed to complement other incident response frameworks in place or under development in the Maldives, including the Disaster Management Plan and other strategies overseen by the National Disaster Management Centre.

1. Introduction

The expected increases in the frequency and severity of coral bleaching events under a changing climate is among the most pressing threats facing the Maldives. While the coral reefs of the Maldives have a history of recovery from major disturbances, such as after the bleaching event of 1998, or the recovery following crow-of-thorns infestations in the later 1980s, the recovery capacity of the ecosystem is likely to diminish as disturbance frequencies and local stresses increase. Consequently, the risk of coral bleaching each year cannot be viewed in isolation. The legacy of impacts from previous years may render corals more susceptible to bleaching and disease. Since future bleaching events are inevitable, reef managers have a responsibility to monitor risk and assess the socio-ecological and economic impacts of coral bleaching. This expectation was outlined specifically in the Maldives Climate Change Strategy and characterised as the need to assess ecosystem health and manage for resilience. Assessing impacts ensures Maldives has an up-to-date understanding of the vulnerability of the coral reef ecosystem that the country depends on. The Government of the Maldives (GoM) can therefore distinguish between the effects of acute and chronic stressors (e.g. bleaching events and water quality, respectively) and target resilience-building management strategies and awareness raising communications efforts.

During the bleaching season, GoM can use this Coral Bleaching Response Plan (CBRP) to provide a transparent and consistent decision-making framework during bleaching events. The plan serves to keep representatives from key partner institutions, stakeholders (NGOs, fishermen, divers), as well as the public, aware of the technologies and protocols used to predict and monitor bleaching. It also describes the criteria that determine how we communicate about bleaching events when they occur.

The plan includes linked routine and responsive tasks, as outlined in the Response Framework in Figure 1 and Appendix A. When early warning system tools predict bleaching, monitoring network participants ground-truth the predictions and report to managers. Managers and researchers confirm reports of bleaching by conducting site inspections that determine whether the level of bleaching exceeds one of three thresholds defined within the Reef Health Incident Response System (RHIRS) (based on GBRMPA standard incident response protocols) section of the plan. Thresholds for response levels 1, 2 and 3 (Figure 1) are defined by the severity and spatial extent of the impacts. More detailed monitoring during the incident response enables detailed reporting on reef condition and the severity of bleaching impacts, and works to target survey efforts to assess recovery.

An effective management response to bleaching depends on clear and transparent communication between managers and senior decision-makers, stakeholders and the public. Further, communication efforts during and just after bleaching events can raise the public's awareness of the importance of responsible behaviour in and around the coral reefs of the Maldives. Communication is, therefore, an overarching element of the Framework and of this Plan (Figure 1).

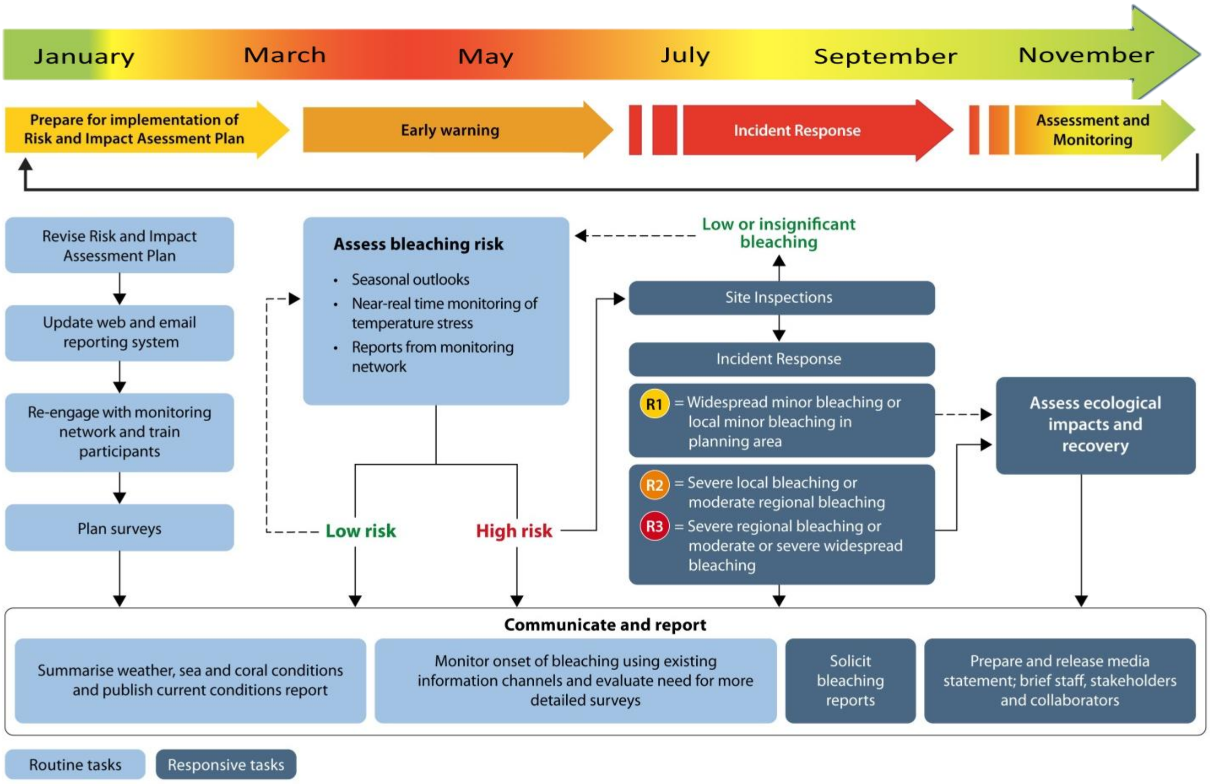

Figure 1 *Generic Coral Bleaching Response Plans schedule of routine and responsive tasks before, during, and after the coral bleaching season (see also Appendix A). Plan components follow on from each other, though responsive tasks are only undertaken if incident response is triggered. Response levels 2 and 3 activate efforts to assess and monitor impacts, which is conditionally activated under response level 1.*

The Maldives Bleaching Response Plan has been developed with reference to international best practice approaches to monitoring and responding to coral bleaching events to maximise comparability and consistency with bleaching responses in the Maldives. Key source documents include: *A Global Protocol for Assessment and Monitoring of Coral Bleaching* (Oliver et al. 2004; prepared by The World Wildlife Fund for Nature, World Fish Centre and GBRMPA), *A Reef Manager's Guide to Coral Bleaching* (Marshall and Schuttenberg 2006; an international collaborative effort led by GBRMPA, NOAA and IUCN), and the *Coral Bleaching Risk and Impact Assessment Plan* (GBRMPA). However, the Maldives Bleaching Response Plan is specifically adapted for the conditions and context of the Maldives, including considerations such as weather and available resources. The following sections of the Plan are structured around key elements of the Bleaching Response Framework (Figure 1).

2. Early warning system

Mass coral bleaching is preceded by a series of conditions that can be used to assess the probability of an event occurring. The early warning system uses: 1) climate forecasts in the months that precede the bleaching risk season (late March to late May) to provide a seasonal outlook of the likelihood bleaching will occur, 2) tools that enable near real-time monitoring of temperature stress during the bleaching risk season to target monitoring efforts, 3) a monitoring network to detect the early signs of bleaching, and 4) site inspections to ground-truth predictions or reports of bleaching and determine whether and which thresholds requiring incident response have been exceeded. All four elements are described briefly below.

Seasonal outlook

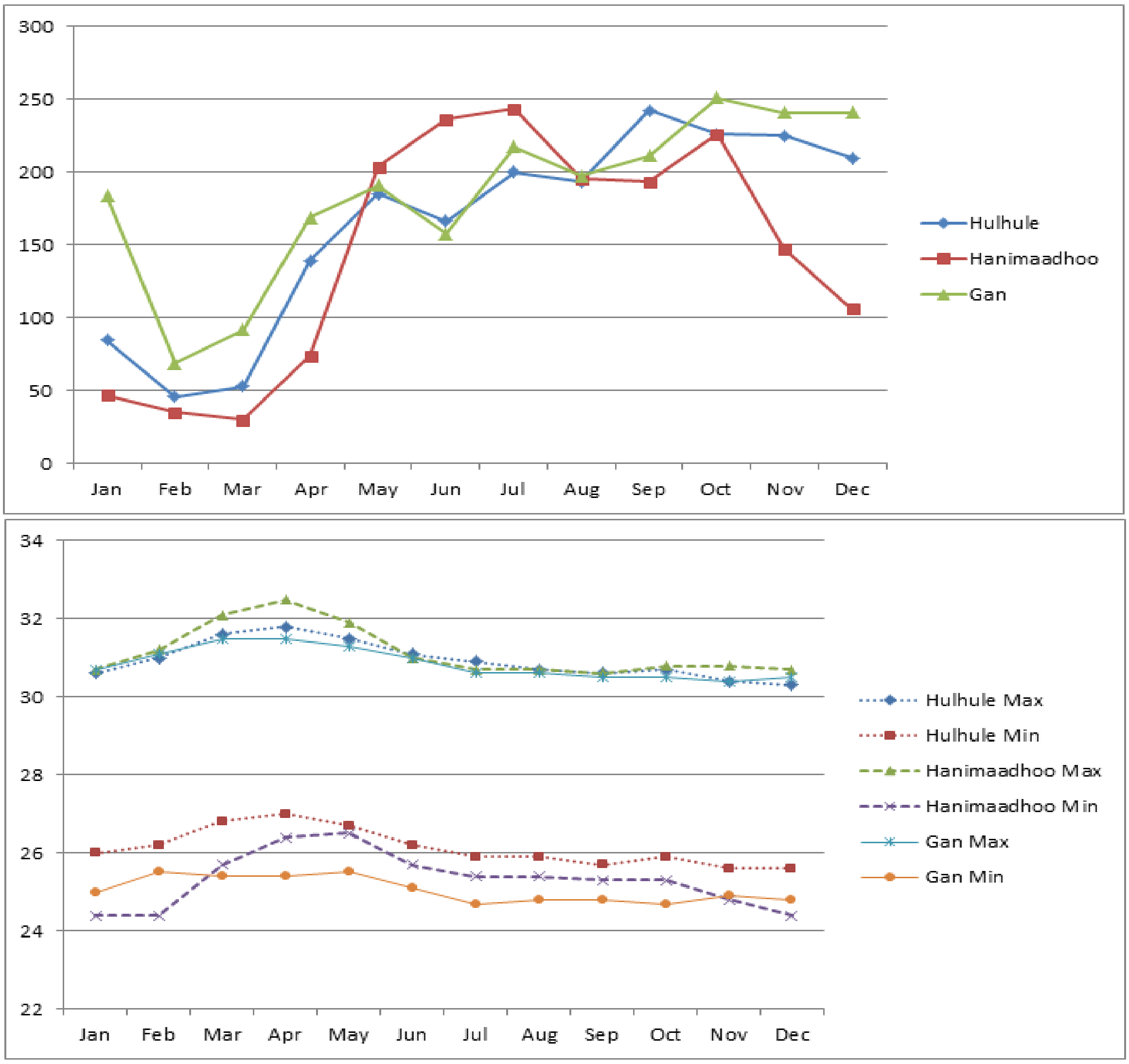

Figure 2 Average rainfall in the Maldives since 2000 (top) and average temperature in the Maldives since 2000 (bottom) (MMS 2017).

Several factors are known to cause high sea temperatures in the Maldives. Particularly stressful conditions are associated with the transition of the monsoons from the North-easterly to the South-westerly. This generally occurs in March- May and is the calmest period of the year with little wind and rain. Cooling rainfall is at its lowest in February and March (Figure 2) and temperatures at their highest in April-mid May. If this period is prolonged, and / or accompanied by el Nino, the anomalous warm temperatures can cause coral bleaching. Based on an emerging understanding of the relationship between weather and sea temperatures, current and forecast weather conditions can indicate whether conditions conducive to bleaching are likely.

Two agencies —NOAA and the Maldives Meteorological Service — use climate models that may aid in predicting bleaching likelihood in the months that precede the monsoonal transition. The probability of above average sea temperatures, and hence the likelihood of a mass bleaching event occurring, can also be ascertained from the MMS as they will issue national forecasts of local conditions and sites.

NOAA's Coral Reef Watch group produces a thermal stress outlook[1] based on sea surface temperature forecasts generated by the linear inverse model from NOAA's earth system research laboratory (Liu et al. 2008). When forecast sea surface temperature exceeds bleaching thresholds over a long enough period to cause bleaching, the outlook maps display the bleaching potential as 'watch', 'warning', 'alert level 1' and 'alert level 2' (Table 1; Figure 3)**.** The thermal stress outlook is an experimental product and is used as an indicator of potential general patterns rather than a precise predictor of thermal stress at any location — actual conditions vary due to model uncertainty, changes in climatic conditions and local variability (see Appendix B for key references and further reading).

Table 1 Thresholds, definitions and interpretations for NOAA coral bleaching warning levels

STATUS	INTERPRETATION	DEFINITION
No Stress	no thermal stress	HotSpot equals 0
Watch	low-level thermal stress	HotSpot above zero but SST below bleaching threshold
Warning	thermal stress is accumulating	SST above bleaching threshold; DHW above 0
Alert Level 1	bleaching expected	SST above bleaching threshold; DHW 4 or higher
Alert Level 2	widespread bleaching and some mortality expected	SST above bleaching threshold; DHW 8 or higher

[1]http://coralreefwatch.noaa.gov/satellite/bleachingoutlook/outlook_messages/bleachingoutlook_20101026_for_2010novfeb.html#summary

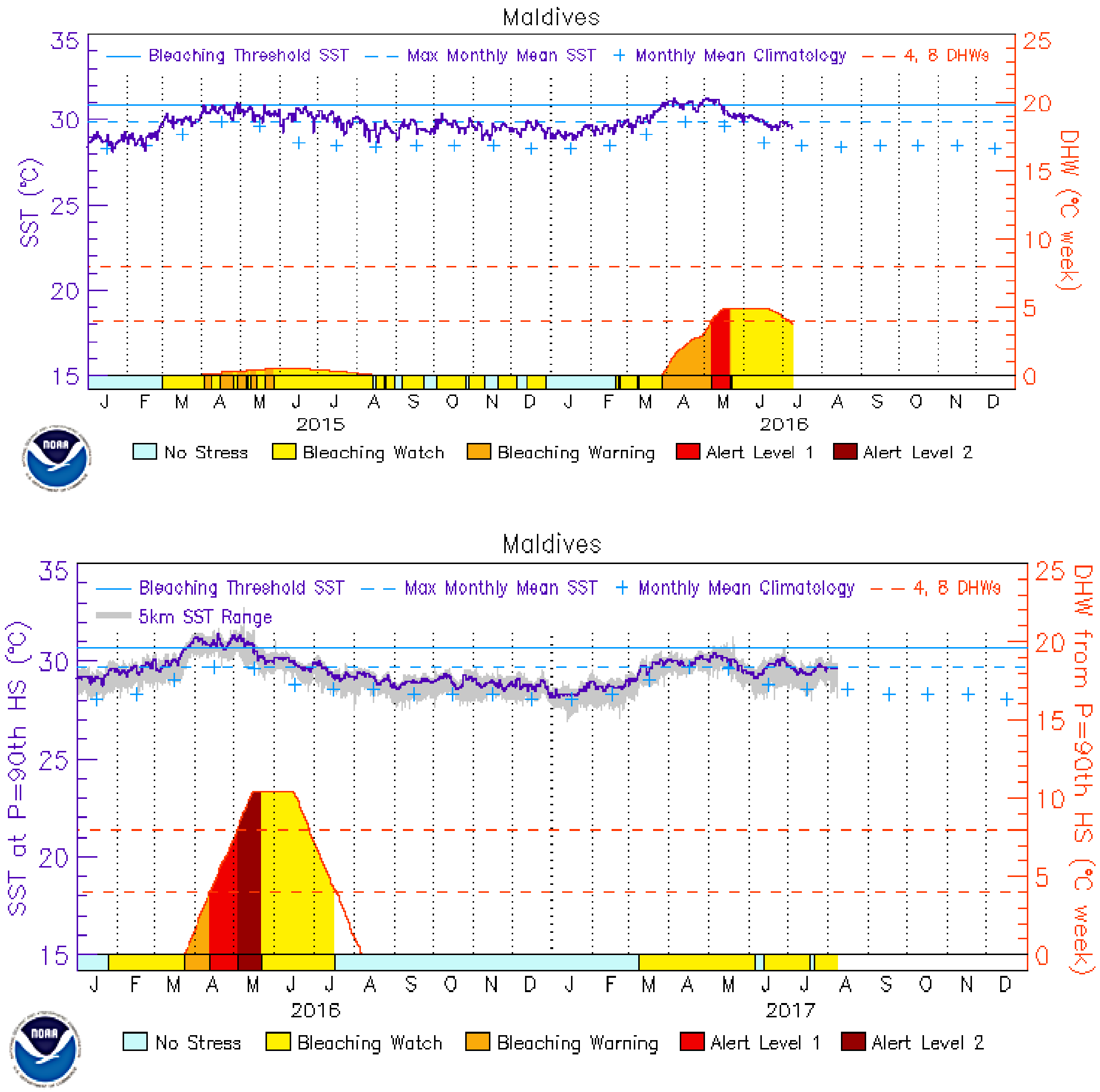

Figure 3 Sea Surface Temperature and bleaching warning for Maldives in 2015 (top) and 2016 (bottom)

Near real-time monitoring of temperature stress

While several environmental stresses contribute to bleaching stress, it is well established that spatially extensive or mass bleaching events are triggered primarily by anomalously high sea temperatures (Hoegh-Guldberg 1999). Excessive and persistent sea temperature anomalies are a good indication that conditions are approaching levels known to be stressful to corals. Sea surface temperature anomalies and other measures of temperature stress can be monitored in near real-time during the bleaching risk season via several different tools and information sources.

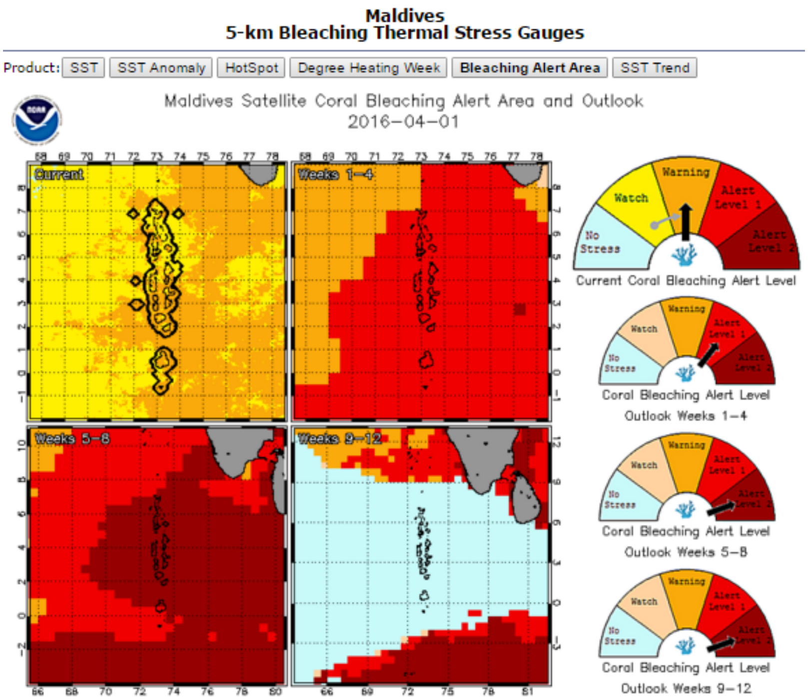

Figure 4 Bleaching Alert levels and outlook (12 week forecast) for Maldives in April 2016

NOAA's Coral Reef Watch group produces images at 5 and 50 km resolution of the Maldives region that show remotely sensed sea surface temperature anomalies [2] (referred to as 'hotspots', Figure 4) and the accumulation of heat stress, which is measured by degree heating weeks [3] (DHW) accumulated over the previous 12 weeks. A degree heating week is equal to 1 degree above the long-term maximum monthly mean, which serves as a useful bleaching threshold. Observations of minor to moderate bleaching are commonly made at sites where temperature stress exceeds 4 degree heating weeks and severe bleaching is often observed at sites that have experienced >8 degree heating weeks (see Appendix B for key references and further reading). NOAA's Coral Reef Watch group also maintains several other products that can prove useful for predictions of bleaching such as spatial maps of Sea Surface Temperature (SST), SST Anomaly, Coral Bleaching Hotspots. And Bleaching Area products[4].

When reefs or reef regions experience prolonged periods of excessively high temperatures, reef managers should maintain close contact with a network of observers around the Maldives to ensure regular reports of reef condition are submitted and managers are alerted to early signs of bleaching.

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[2] http://coralreefwatch.noaa.gov/satellite/current/products_hotspot.html

[3] http://coralreefwatch.noaa.gov/satellite/current/products_dhw.html

[4] https://coralreefwatch.noaa.gov/satellite/e50/index.php

Bleaching Risk Assessment Tool

The Bleaching Risk Assessment Tool (BRAT) was developed by the Marine Spatial Ecology Lab (Prof Pete Mumby) from the University of Queensland to assist with national evaluations of the impacts of future bleaching event, and to identify areas that have the highest (and lowest) risk of chronic bleaching so that marine spatial planning goals in the Maldives can be better achieved. While BRAT was not designed explicitly to inform a bleaching event response, targeting coral bleaching surveys to sites within each of the thermal regimes identified in the tool can help further refine BRAT and improve its usefulness for future predictions of bleaching risk (see text box: *An overview of the Maldives Bleaching Risk Assessment Tool (BRAT)* for further information).

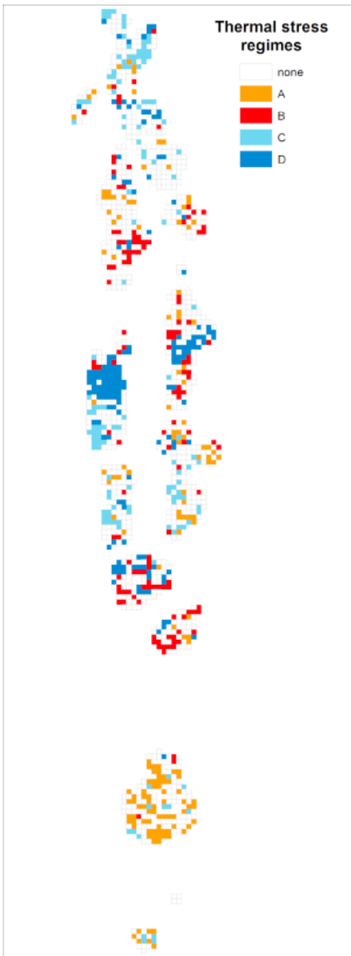
Monitoring network

Detecting the early signs of a mass bleaching event requires a wide network of observers. This is due to the size of the Maldives coral reef system and decentralized nature of its atolls. The initial onset of mass coral bleaching can range from gradual and patchy to rapid and uniform. Managers must rely on field reports provided by the National Coral Reef Monitoring Network (NCRMN) that includes resort marine biologists, marine consultants, EIA Consultants, visiting researchers, EPA and MRC officers and trained volunteers. The network should cover the entire Maldives, and include regular reef users, such as dive professionals, tourism operators (safaris), fishers, researchers, community groups, and other recreational users who may voluntarily monitor and report on conditions at reefs they visit[5] (Appendix A).

Protocols and tools developed under National Coral Reef Monitoring Framework (NCRMF) will be primarily used for recording and reporting the coral bleaching events (These tools can be accessible by visiting coraldatabase.gov.mv). Marine Research Centre in collaboration with International Union for Conservation of Nature also developed two protocols which were used to record the 2016 coral bleaching event. One protocol is Point Intercept Transect (PIT) and other is Belt Transect (BT). These were designed to have the flexibility of being modified to the observer including the coral reef knowledge and detailed taxonomy. These two protocols are included in the appendix of this document.

An overview of the Maldives Bleaching Risk Assessment Tool (BRAT)

A key aspect of BRAT is the identification of thermal stress regimes for the Maldives (Mumby et al 2011 provides further information on this approach and detailed methods). This analysis distinguishes and classifies sites (pixels) according to their history of chronic versus acute thermal stress using NOAA's Coral Reef Temperature Anomaly Database Version 4 (CoRTAD). This was used to generate four contrasting thermal stress regimes



Thermal stress regimes for the Maldives as estimated by BRAT

Corals in regime A (high chronic and low acute stress) are predicted to be the most resistant coral communities to current bleaching. They are acclimated to warmer temperatures, but experience relatively lower levels of acute stress. Corals in regime B (high chronic and high acute stress) may have some natural resistance to bleaching conditions by virtue of their acclimation to high chronic temperature, but their exposure to acute warming during bleaching events is likely to cause significant mortality. Corals in regime C (low chronic and low acute stress) are predicted to benefit from a lack of severe bleaching events but their acclimation to cooler conditions is likely to increase their vulnerability to even weak periods of rapid warming. Finally, corals in regime D (low chronic and high acute stress) are predicted to experience relatively severe mortality because they are acclimated to cooler chronic temperatures, but are exposed to high acute stress likely resulting in severe bleaching.

The resulting map of thermal regimes (Figure 3) is best used as a hypothetical map of potential bleaching risk. Uncertainty about thermal and oceanographic processes, and the composition and condition of coral communities, are all important determinants of coral bleaching outcomes. However, the BRAT can be used to target monitoring efforts during a bleaching event in the Maldives with a view to refining the tool and testing predictions of the link between thermal regime and bleaching event outcomes for corals. The researchers that produced BRAT specifically suggest that sites should "be identified within each of the four regimes, and corals will be monitored before, during and after future bleaching events to enable testing and refinement of some of the proposed hypotheses. Any measured links between coral response and thermal regime will allow for better assessments of the impacts of bleaching across the Maldives and will be valuable for spatial management goals such as reserve design".

Source: https://www.marinespatialecologylab.org/brat/

During non-bleaching months (October-March), participants should complete their reports opportunistically whenever they are visiting reefs to assist with baseline monitoring of coral reef health. During the hotter months with the shift in the Monsoons (March-May), surveys should be undertaken on a weekly or fortnightly basis. These results should be reviewed weekly during these months to identify where coral bleaching has been sighted. Information should then be collated in the National Coral Reef Monitoring Database (Figure 5). This system can display information and visual representations for all the data collected at each reef and reports are used to target site inspections in order to determine the severity and spatial extent of impacts. Reports of severe bleaching from the monitoring network are verified through site inspections conducted by the Marine Research Centre in partnership with trained staff from Environmental Protection Authority.

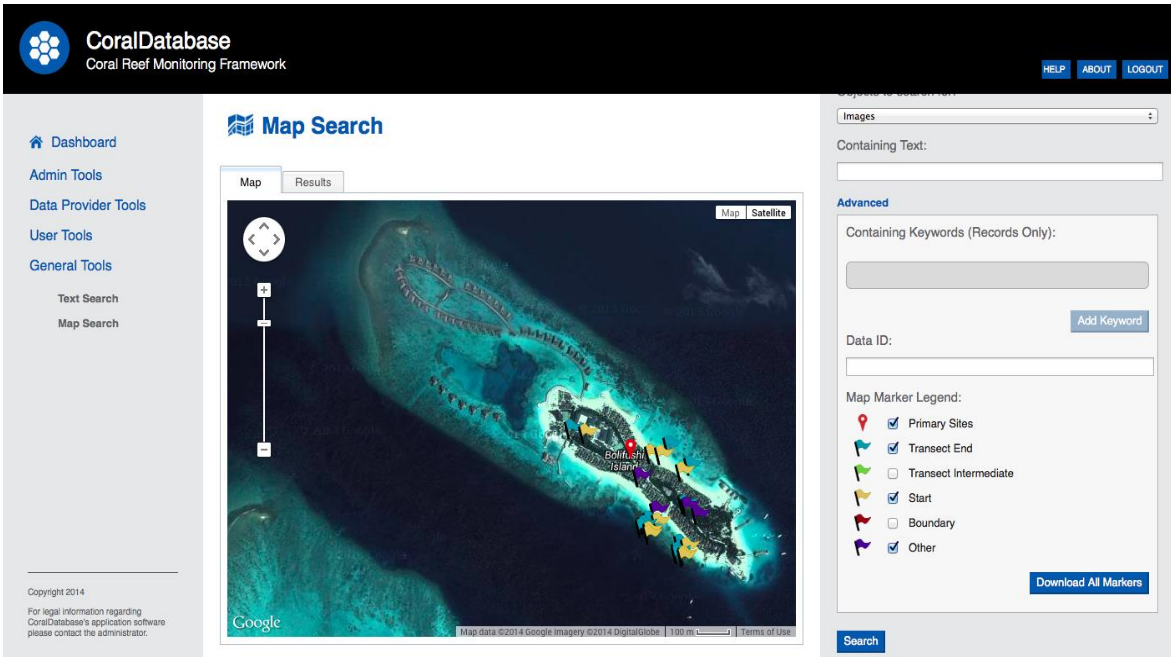


Figure 5 Sample output from the coral database (www.coraldatabase.gov.mv) of National Coral Reef Monitoring Framework, a new system developed for the Maldives that allows for rapid review and dissemination of reports from participants in the monitoring network

Site inspections

Site inspections to verify coral bleaching should involve a series of surveys at two depths using the method described in Appendix C. Site inspections are conducted on an as-needed basis at sites where:

1. Monitoring network participants have reported widespread minor bleaching, or moderate or severe bleaching over any scale (Table 2).
2. Tools enabling near real-time monitoring of conditions indicate the risk of a reef health incident occurring is high (e.g. systems indicate that temperature stress is severe enough to cause coral bleaching).
3. Other incidents are reported that could cause coral bleaching or other coral health impacts.

If site inspections confirm moderate to severe localised impacts (relating to any incident) or widespread minor impacts (relating to bleaching, disease outbreaks, and/or cyclones), the incident response component of the Coral Bleaching Framework (Figure 1) is activated.

Table 2 *Levels of bleaching severity and extent of bleaching. Below, reference to morphologies relates to data collected using the Bleaching Protocol in Appendix C. Hence, both types of monitoring protocols result in data that can be used to determine the severity of bleaching impacts. Examples given within 'minor impacts' of morphologies and taxa that have high, low, and very low sensitivity to bleaching (see also Appendix C) work for both the 'moderate impacts' and 'severe impacts' sections. The matrix in Figure 6 of bleaching severity and spatial extent determines the response level triggered in the incident response.*

Severity	Description
High bleaching risk	Degree heating days index >50 at multiple sites Heating rate index >2 at multiple sites Major dredging or construction of coastal catchment imminent Major storm passed over reef
Minor impacts	Severe bleaching of many (10–50 per cent) colonies of coral taxa (*Acropora* and *Pocillopora*), or morphologies (branching, bushy, tabular/plate) usually known to be highly sensitive to bleaching) Severe bleaching of some (<10 per cent) colonies of taxa (e.g. *Montipora* and Faviids) or morphologies with low sensitivity to bleaching (encrusting and mushroom) Paling of colonies of taxa (*Porites*) or morphologies (massives) with very low sensitivity to bleaching Severe bleaching of colonies of taxa or morphologies with low or very low sensitivity to bleaching but confined to reef flat
Moderate impacts	Bleaching extends deeper than reef flat and: Severe bleaching of most (>50 per cent) colonies of taxa or morphologies usually highly sensitive to bleaching Severe bleaching of many (10–50 per cent) colonies of taxa or morphologies with low sensitivity to bleaching below reef crest Severe bleaching of some (<10 per cent) colonies of taxa or morphologies with very low sensitivity to bleaching Some mortality of colonies of taxa or morphologies usually highly sensitive to bleaching but confined to reef flat

Severe impacts	Bleaching extends deeper than upper reef slope and: Mortality of many (>50 per cent) colonies of taxa or morphologies usually highly sensitive to bleaching Severe bleaching of most (>50 per cent) colonies of taxa or morphologies with low sensitivity to bleaching Severe bleaching of many (10–50 per cent) colonies of taxa or morphologies with very low sensitivity to bleaching

Extent	Description
Local	Impacts present in less than 10 sites within one atoll
Regional	Impacts present in more than 10 sites but confined to one atoll
Widespread	Impacts present in more than 10 sites in each of multiple atolls

In summary, the early warning system works as a chain of events prior to and during the transition of the Monsoons, when bleaching risk is greatest. Forecasting tools heighten alert levels prior to the bleaching risk season and tools that enable monitoring of temperature stress in near real-time target the efforts of the monitoring network. If site inspections confirm moderate to severe localised impacts or widespread minor bleaching (Table 1) then incident response is activated, though use of the tools and monitoring network within the early warning system continues until the high-risk season has passed.

3. Incident response

The incident response framework used by Maldives Bleaching Response Task Force is based on the approach used in the Great Barrier Reef, derived from the Australasian Inter-service Incident Management System[6]. This provides the framework to coordinate the governance, planning, operations, logistics, financial and inter-agency liaison arrangements required to adequately respond to a reef health incident.

Information gathered from the early warning system and site inspections helps to understand the severity and spatial extent of impacts. Once the spatial extent and severity of the impact have been classified based on the standardized criteria for each incident, the matrix in Figure 6 can be used to inform a detailed situation analysis.

The situation analysis is assessed by the Inter-Agency Task Force on Coral Bleaching which is made up of MRC, EPA, and the Coast Guard , and includes the senior management group, the coral reef program coordinator and the scientific, communications and liaison, and stakeholder advisory groups. This Task Force will make a final decision on the required level of response (Figure 7). There are three potential response levels — 1, 2 and 3. Each increase in response level (from 1 to 3) correlates to a corresponding increase in the severity and spatial extent of the impacts as well as an increase in the management investment and resources required to effectively respond. The activation and conditional activation of the incident response framework varies according to each response level but the framework used for each of the three response levels is standardized for all reef health incidents. **Activation by the Task Force of a response level would be reviewed and endorsed by the Minister of Fisheries and Agriculture.**

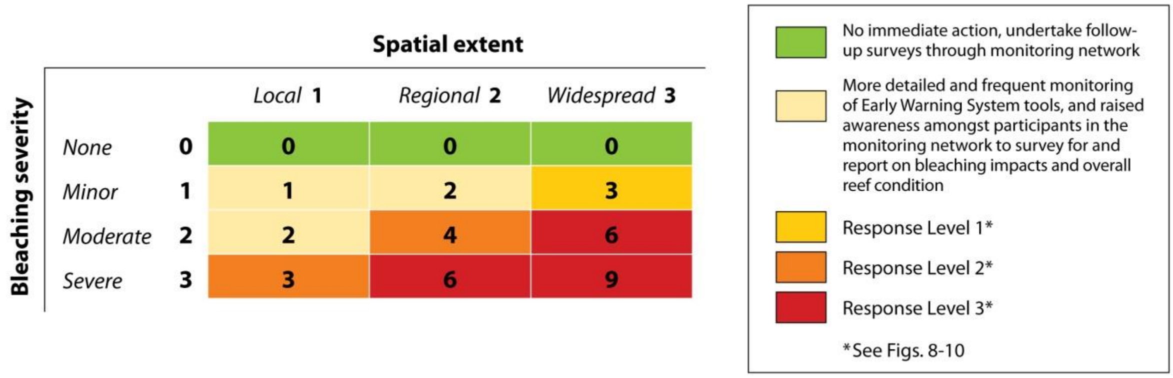


Figure 6 ***Matrix combining measures of bleaching severity and spatial extent (from Table 1) to inform the situation analysis (Figure 7), which results in the final decision as to which response level has been triggered (if any). Specific criteria for the levels of bleaching severity are described in detail in Table 1.***

[6] Australasian Fire Authority Council website, 2004, www.afac.com.au

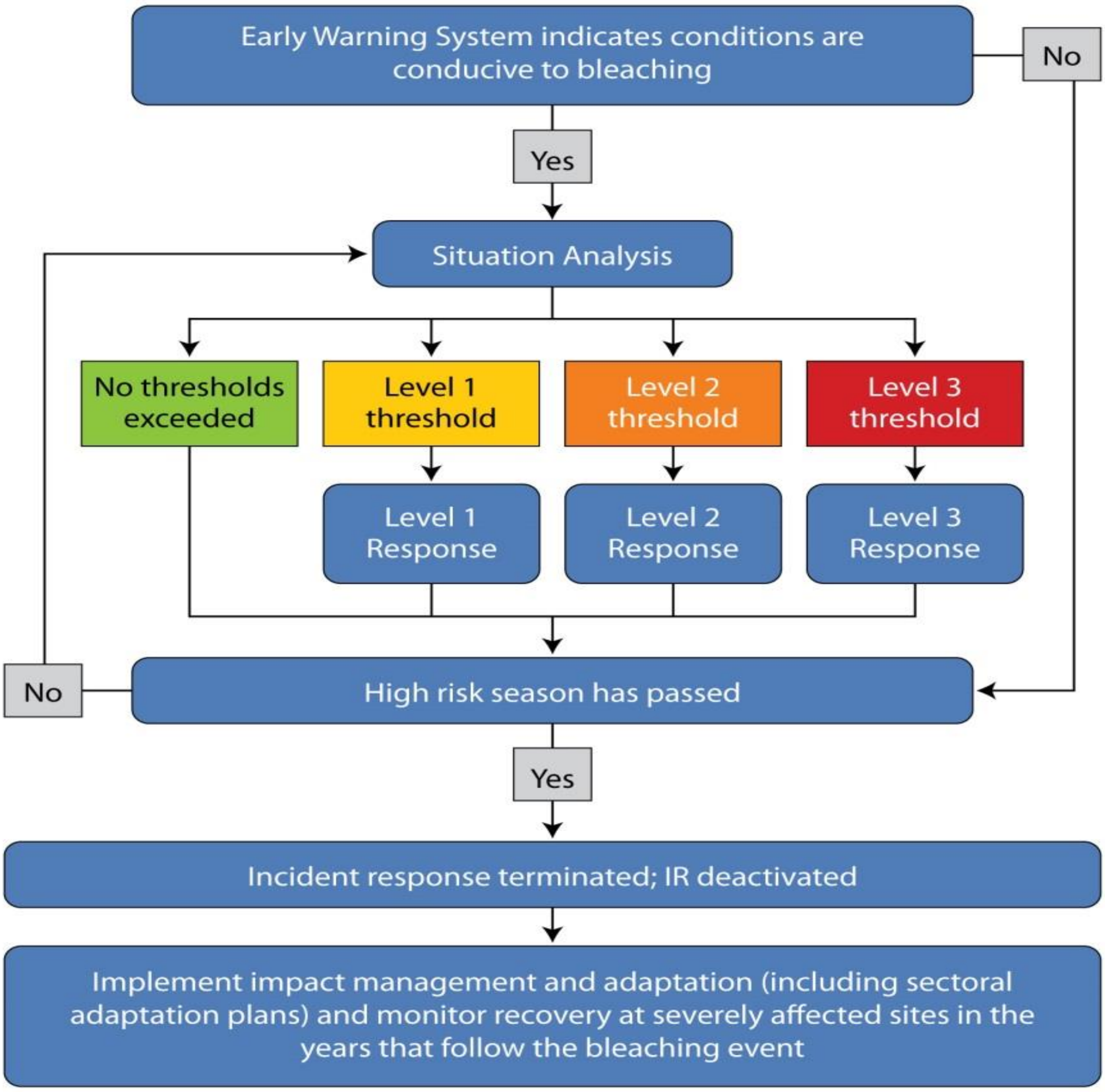


Figure 7 Incident response chain of events during a bleaching event. The situation analysis is informed by the matrix seen in Figure 6 and is revisited if the high risk season has not passed.

Once the appropriate response level has been determined, the corresponding planning and resource provisions of the incident response are activated. Communications, liaison, and reporting tasks are activated for all response levels. For response level 1, which may lead to response levels 2 or 3 if impacts become more severe or extensive through time, the logistics for extensive underwater surveys are only conditionally activated, and budgeting, contracting, staff procurement, and impact mitigation/recovery surveys are not activated. Conditional activation is based upon the type of incident and the outcome of the situation analysis. For response level 2, vessel support and underwater surveys are activated, as are budgeting and administration. Contracting, staff procurement, and impact mitigation/recovery surveys are all conditionally activated. For response level 3, the entire incident response framework is activated. In all instances, decisions about the appropriate monitoring response and methods should be driven by the information priorities of the Task Force.

4. Assessment and monitoring

To accurately characterize the extent and severity of bleaching, bleaching-induced mortality and the associated longer-term ecological implications three temporal surveys are undertaken: baseline, event and survival/mortality. While the spatial scale and total size of the reef area makes it infeasible for a monitoring program to track conditions on all reef areas in the Maldives, previous surveys in the general vicinity of a reef can be used as proxies for baseline conditions. By surveying sites that are also surveyed as part of the MRC long-term monitoring program (Figure 8), managers can use historical data in combination with surveys done during and after (6 and 12 months) to assess the ecological implications. When recovery surveys (post-bleaching) are undertaken, surveys for disease should be conducted concurrently because bleaching can greatly increase the susceptibility of corals to diseases (GBRMPA 2010). In this sense, it is important to coordinate surveys to assess impacts and recovery in the year that follows the bleaching with longer-term ecological *monitoring* surveys as part of MRC long-term monitoring program. By combining and coordinating monitoring and assessment efforts, the Task force will be better able to efficiently obtain a reliable picture of reef health and the effects of coral bleaching. This approach will also underpin efforts to measure and understand reef resilience, which enables testing of the effectiveness of various strategies aimed at supporting the natural resilience of reefs.

> Severe bleaching can cause extensive coral mortality, and also lead to shifts in coral community structure, altered habitat composition, and ecosystem flow-on effects.

Figure 3: Long term monitoring sites from the MEMP and NCRM (yellow) monitoring programs, and the MCS/Biosphere sites (red)

The implications of severe bleaching on reef ecology include but are not limited to coral mortality, shifts in coral community structure, altered habitat composition, and ecosystem flow-on effects. Severe bleaching also has implications for industries that depend on the reef as well as associated human communities since bleaching can reduce the social or economic value of reef sites important to tourism operators, fishers, or recreational users. Monitoring of the social and economic impacts of bleaching events should also be undertaken.

When the situation analysis (Figure 6) determines thresholds for response levels 2 or 3 have been reached, managers implement a two-tiered approach to assessment. Intensive in-water surveys at routine sites (surveyed during each event) and targeted sites (those most affected by bleaching) are conducted, in combination with aerial surveys that give broad reef coverage (Oliver et al. 2004). These surveys are conditionally activated for response level 1 (Figure 7) and may be undertaken depending on the outcome of the situation analysis.

The photo transects, while requiring a more lengthy analysis, provide a long-term record, more detailed information and increased data resolution, which is useful for understanding the patterns and specificity of bleaching events. In addition, the photos taken or each transect could be an independent statistical sample, ensuring the data can be used to help answer a variety of research questions. The data from bleaching and recovery surveys are loaded into the same database as the reports collected by participants in the NCRMF (Figure 5). The visual representation of the data facilitated by that system can aid in communicating the need for various management actions.

While there have been recent developments in the use of satellites to measure spatially extensive bleaching events (Elvidge et al. 2004), this approach is still experimental and is best considered a complement to in-water and aerial surveys where available.

4.1. Aerial surveys if needed in case of widespread bleaching

If coral bleaching is believed to be extensive or rated as a mass bleaching event as agreed by the Task Force based on evidence from government and private data streams, sea plane operators may be engaged to obtain aerial information on the extent on bleaching. This was done during the 2016 bleaching episode and reasonable response was received from the seaplane operators in the Maldives. To increase effectiveness of this survey, a simple protocol may be formulated and communicated with them. However, dedicated aerial surveys may be conducted with appropriate equipment and using methods employed similar in remote sensing work. For this to happen during a nationwide coral bleaching event, Department of Civil Aviation (DCA) will be consulted and involved as the main stakeholder to facilitate the aerial surveys with the domestic airlines including the sea plane operators.

4.2 In situ-temperature loggers

During 2016 mass bleaching event, number of temperature loggers were deployed across the Maldives specially the areas which are permanently monitored by MRC and other stakeholders. This loggers will be maintained (retrieved and replaced) to understand temperature variability across the Maldives.

5. Communications strategy

Responding to coral bleaching events strategically and effectively involves a combination of routine and responsive tasks implemented through an early warning system and, if a bleaching event occurs, assessment and monitoring via the incident response (see Figure 1). All routine and responsive tasks rely on effective communication, particularly since bleaching events attract significant interest from the public, media and senior decision-makers (see Table 3). The Bleaching Response Plan ensures timely and credible information on the status of coral in the Maldives and should be available during and in the months and years that follow bleaching events. As a consequence, the Task Force will be able to prevent misleading or incorrect information from proliferating through various media sources. This ensures that factually accurate assessments of reef condition are readily accessible by reef stakeholders, media and the general public during an incident. **All public communications made the Task Force shall be reviewed and endorsed by the Minister of Fisheries and Agriculture.**

Table 3: The frequency and timing of tasks associated with collating current bleaching information and effectively communicating during the bleaching season.

Frequency	Timing/trigger	Task	Responsible Institution
Weekly	Sunday	Check NOAA hotspot and degree heating week maps on web	MRC
		Check sea temperature graphs from experimental virtual bleaching stations from NOAA	MRC
		Review weekly weather summary and temperature graphs from the weather stations of Maldives Meteorological Service and	MRC
		Review reports from the monitoring network	MRC
		Prepare briefing for internal meetings	MRC
Weekly/ fortnightly	Constant	Monitor extent of bleaching using existing information and evaluate for trends (i.e., change in bleaching extent)	MRC
		Advise Task Force senior management and the Minister of Fisheries and Minister of Environment if worsening of conditions	MRC
		Announce web update and send brief report to senior management	MRC
Event-based	High bleaching risk*	Actively solicit confirmatory bleaching reports from reliable sources, including: participants in the monitoring network, day-to-day management field officers, MRC and other researchers	MRC
		Alert relevant project coordinators and	MRC/ EPA

		managers	
		Brief relevant staff	MRC/ EPA
	Response level 1, 2, or 3 (see Figures 8–10) triggered.	Brief Director Generals of MRC, EPA, and the Ministers	MRC/ EPA
		Prepare media position, draft statement and consult with institutional media coordinators and DG´s	MRC/ EPA
		Brief all MRC and EPA staff, stakeholders and collaborators	MRC/ EPA
		Release media statement	MRC/ EPA/ MNDF
		Actively promote and solicit submissions to online bleaching reports to provide broad spatial coverage	MRC/ EPA/ MNDF

* See also Table 1.

In addition to the task and reporting schedule outlined in Table 3 (see also Appendix A), a briefing schedule for MRC and EPA senior management, the Minister, and stakeholders is outlined in Table 4. This schedule ensures these groups are aware when delivery of reports can be expected.

Table 4: Targeted briefing schedule to communicate onset of bleaching season (predetermined dates) and bleaching risk and occurrence throughout the bleaching season (date determined by reaching a trigger). Asterisks denote triggers that will result in determining a media position and the release of a media statement (see also Table 3).

Approximate date	Trigger[1]	Briefings			
		Senior management	Minister	Stakeholders	Message
1 March	Annually	^	^	^	Bleaching risk season approaching; bleaching risk period; plan being implemented
20 March	Annually	^			Temperature trends for March; plans for April
	High bleaching risk*	^	^		Temperatures unusually high; coral bleaching event probable
	Response level 1 (see Figure 8)*	^	^	^	High temperatures recorded; widespread minor bleaching observed; and the areas most affected
	Response levels 2	^	^	^	Very high temperatures recorded; moderate or

	and 3 (see Figures 9 and 10) *				severe bleaching observed at regional scale or widespread; areas worst affected and mortality likely
15 April[3]	Annually	^			Temperature trends for first half of bleaching season; summary of any observed coral bleaching
31 May	No bleaching	^	^	^	Bleaching season over; bleaching risk period over; no significant bleaching observed
	Response levels 1, 2 and 3 (see Figures 8-10)*	^	^	^	High water temperatures recorded; bleaching observed; preliminary assessment of extent and severity; detailed surveys underway (if response level 2 or 3 triggered)
30 June	Moderate, major or severe impact (see Table 1)	^	^	^	Summary of full extent and severity of bleaching; implications for affected regions, communities and Maldives

Importance of management actions

Bleaching events are expected to increase in frequency and severity as a result of climate change, making recovery processes increasingly important for reefs to persist as coral-dominated systems. Significantly, many human activities impose stresses on coral reefs that compound the risks imposed by coral bleaching and can work to lengthen recovery timeframes (Marshall & Schuttenberg 2006; Hooidonk et al 2017). For example, chronic stress due to poor water quality associated dredging and coastal development can affect the recovery potential of reef communities as reproduction and larval recruitment in corals are particularly sensitive to environmental conditions. Through reducing compounding stressors, management actions help reefs cope with or recover from coral bleaching events, which works to build the resilience of reefs to future climate-related disturbances.

Through collaborations with researchers, the Task Force can rapidly advance the understanding of factors that increase the resilience of reefs, as measured by the capacity to resist, tolerate and cope with, and recover from climate-related disturbances. In particular, researchers are poised to increase our understanding of spatial variability in the likelihood that a site will be impacted by climate-related disturbances like bleaching, disease outbreaks, floods and cyclones due to geographic location, community composition and thermal history. Increased knowledge of the spatial variability in factors that confer resilience to reefs will improve the capacity of the Maldives to explicitly include resilience to climate change in coral reef management plans. Furthermore, knowledge of spatial variability in resilience factors enables assessments of the effectiveness of strategies implemented to support resilience.

In addition to measures to build ecosystem resilience, the plan can help build social and economic resilience to coral bleaching events. Resource users who are well-informed of risks and are included in decision-making processes about strategies to address resource issues can be expected to be much more resilient to resource impacts (Marshall and Marshall 2007; Rasheed et al 2016). Similarly, community-based social marketing can encourage stewardship behaviours, (e.g. not anchoring on corals or disposing of fishing tackle on the reef). Such communications efforts may be undertaken following reef health incidents like bleaching in the future.

Therefore, during bleaching events it is important to reduce all extra stress on coral reefs in order to give them a higher chance of survival.

Environmental managers of coral reefs, resorts, and custodians of coral reefs, can act to improve the chance of corals surviving by taking certain actions on island reefs.

1. ***Cease sand pumping and dredging of sand during and directly after the bleaching event in areas close to corals*.** Sediment in the water stresses corals by smothering them, and if corals are smothered whilst they are bleached then the chance of mortality is higher. If any sand pumping takes place, a sediment screen should be used to avoid sediment smothering the corals but ideally no sand pumping should take place during and after bleaching to minimise risk of developers or .
2. ***No anchoring or trampling of corals during and after bleaching events.*** Physical damage of corals will reduce their capacity to recover; so strict rules should be enforced with no anchoring on the coral reefs and with tourists being extra careful when they snorkel. Sections of reef that are most affected by bleaching could also be closed off to snorkelers. Green Fins guidelines for environmentally-friendly snorkeling can be implemented. See this link http://greenfins.net/best-snorkelling-practices.
3. ***Monitor the bleaching event in order to understand the severity and the recovery.*** A monitoring methodology has been developed by MRC and IUCN for measuring the effects of coral bleaching on coral reefs. Resort marine biologists or dive instructors could spend some time every month monitoring the bleaching event and sharing this information with the scientific community in order to develop the best management options that would reduce reef impact and enhance recovery at resort reefs. MRC is happy to provide training to resort marine biologists on the monitoring methodology. Monitoring should take place before, during and after the bleaching event. Resort managers can contact MRC to receive the monitoring methodology and to enquire about training.
4. ***Circulate best practice to resort staff in advance.*** Resort staff and others who can assist with monitoring coral bleaching should be aware of the bleaching event and that extra care should be taken during bleaching events to ensure best environmental practices in daily operations. MRC can support Resort Senior Managers in providing best practice to their staff.
5. ***Maintain good water quality*.** Water quality is a key factor for coral survival, and is especially important in the aftermath of coral bleaching events. Resorts and other operators of infrastructure should take care not to dump any pollutants onto the reef, including sewage and chemicals used for laundry and cleaning boats. Emptying bilge water of vessels should be undertaken manually in the open ocean where possible and not in lagoons. Environmentally friendly options for cleaning agents exist under Green Fins environmental guidelines and can be accessed on this link http://greenfins.net/downloads.
6. ***Raise awareness of general public and tourism service providers*.** Tourists may be interested in learning why the corals are bleaching. Information about coral bleaching should be shared with your guests so that they understand the phenomenon and take extra care whilst snorkelling on the reefs. MRC can provide support with this. Maldives National University (MNU) will play key role as partner institution for education and awareness of the coral bleaching events to general public too via state broadcasters and private mass media groups.
7. ***Develop a Marine Managed Area and Resort House Reef Management Plan*.** In the long run, a holistic assessment of resort house reefs and reducing potential local

stressors of operations is the best strategy for a healthy and vibrant coral reef that can recover from bleaching events, that is pleasing to guests, and that ensures the long term viability of the beaches. To ensure a healthy coral reef, it is important to understand the operations at resorts that may be causing stress to the reef and to mitigate these through environmental best practices and the development of a resort house reef management plan.

6. Conclusion

As bleaching events become more frequent and severe regionally and globally, impacts on the reef ecosystem and on reef users will become increasingly acute and apparent in the Maldives. This Bleaching Response Plan outlines the strategic approach that should be employed to understand and respond to climate-induced coral bleaching events. Specifically, the plan provides practical tools for monitoring, assessing and reducing bleaching risk and impacts. The three-component structure described here is based on a model proven successful in responding to bleaching events on the Great Barrier Reef and has been adopted by reef managers in Florida and Hawaii.

This Bleaching Response Plan outlines the strategic approach that should be employed to understand and respond to climate-induced coral bleaching events. Specifically, the plan provides practical tools for monitoring, assessing and reducing bleaching risk and impacts.

The long term risks from coral bleaching are exacerbated by other stresses, such as pollution, sedimentation, unsustainable tourism practices, vessel incidents and coral disease. Future development of an overarching Reef Incident Response Framework will assist managers in EPA and MRC to evaluate and respond to cumulative and simultaneous impacts. In the meantime, it is vital that government agencies cooperate to share information and identify activities that could exacerbate the impacts of a bleaching event, and curtail or moderate those activities during the time of peak stress and recovery.

The capacity to predict and respond to cumulative and simultaneous impacts will be further developed in the coming years as the capacity to monitor conditions that cause the range of reef health incidents increases. As with the other risk and impact assessment plans this Bleaching Response Plan helps lay the foundations for an informed and adaptive approach to building the Reef's resilience under a changing climate.

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Appendix A — Schedule of Maldives Bleaching Response Plan routine and responsive tasks for before, during and after the coral bleaching season.

TIMING/ TRIGGER	TASK	EXPECTED OUTCOME	TICK WHEN COMPLETED
Pre-bleaching risk season preparations and training			
January	Seasonal outlook meeting	• Assessment of coral bleaching risk for the approaching season • Preparations for coordinated response in the event of coral bleaching	
February – July	Communications processes initiated (see Table 3)	Communications updated regularly on the status of coral bleaching	
February	Incident response planning meeting	Preparations for activation of the incident response	
February	MRC EPA internal staff training in the Bleaching Survey monitoring protocol	Training of staff in coral bleaching assessment and reporting	
February	Bleaching Protocol training	Training of monitoring network in coral bleaching assessment and reporting	
March	Refresher training first aid, CPR and oxygen provider training; updates of diver medicals	Field staff suitably qualified and prepared in case response initiated	
April	Review of seasonal outlook, meeting convened if high likelihood of coral bleaching	Meeting convened to refine coordinated response if there is a risk of coral bleaching	
April	Brief senior management, Minister and stakeholders	Senior management, Minister and stakeholders aware of approaching season bleaching risk	
April	Revise Maldives Bleaching	Revised plan Maldives Bleaching Response Plan	

	Response Plan	published by April	
April	In-water rescue refresher training	Staff proficient in in-water rescue and safety	
April-May	Permanent Monitoring Sites	Support for ongoing resilience and monitoring of pre 1998 sites	
April-May	Citizen Science Monitoring Network activated	Additional participants for the monitoring network recruited	

Commencement of early warning system			
April	Commence web-based updates for seasonal outlook and coral bleaching risk — current conditions reports	Communication of reef stressors to community through web on a monthly basis	
March	Planning for bleaching season and any government or national holidays	• Assignment of duties over any holidays • Senior management notified of arrangements • Ministers advised if coral bleaching risk moderate–high	
March – June	Assess bleaching risk weekly	• Check NOAA hotspots on web • Review weekly weather summary reports • Review reports from the monitoring network and update spatial layers • Review MMS temperature graphs • Prepare briefings for internal meetings, round table • Advise senior management of changes	
June	Assess temperature trends and bleaching for season	• Senior management update on conditions • Contact made with monitoring network participants in areas of interest	

Event reported – incident response initiation			
Bleaching reported	Situation analysis conducted	Incident response situation analysis	
Bleaching reported	Situation analysis reviewed	Level of incident response agreed (this includes nil response)	
Incident response activated	Appointment of incident controller	Incident coordinator appointed to establish a response team	
Incident response active	Notification of incident to relevant agencies	Heightened awareness of the incident amongst relevant agencies	
Incident response active	Action plan developed	• Action plan identifies roles and responsibilities for coral bleaching response • Action plan implemented and all sub plans including communications plan activated	
Incident response active	Deploy operational teams	• Operational teams to manage incident deployed • Incident managed effectively • Emergency fast track permits authorised	
High risk season passed	Incident response terminated, Incident response deactivated	Incident debrief convened	

Incident response terminated and long-term management implemented			
Post event	Progress implementation of long-term impact management actions and adaptation plans	• Sectoral impact management plans implemented • Management actions (e.g. emergency Special Management Areas (SMAs)) implemented	
Post event July	Preliminary report on the incident produced	Summary report of responses initiated for internal use	
Post event July-September	Formal incident report produced	Summary report of the extent and severity of the impact	
Post event	Incident response revision and update	Review incident response implementation and incorporate feedback	
Post event	Brief senior management, Ministers and stakeholders	Senior management, Ministers and stakeholders aware of bleaching risk season impacts and reef recovery	
September–January	End of season updates	• End of season reports posted onto the Web, including nil reports • End of season summary emailed to participants of the monitoring network	
Post event ongoing	Impact recovery monitoring	Monitoring of recovery from severe coral bleaching impacts	

Appendix B — Early warning system tools, key references and further reading

Tools that form the early warning system within the Bleaching Response Plan have been developed by a number of agencies and research institutions. Each of these institutions has scientists who have published peer-reviewed publications on their work in the area of predicting bleaching. The key references and further reading providing technical details (websites) on the products are listed below, and are divided into the same sub-sections seen in the early warning system section of the plan.

Seasonal outlooks of bleaching risk

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NOAA Coral Reef Watch website:
http://coralreefwatch.noaa.gov/satellite/methodology/methodology.html

Bureau of Meteorology POAMA web page:
http://poama.bom.gov.au/experimental/poama15/sp_gbr.htm

Near real-time monitoring of temperature stress

Berkelmans R (2002) Time-integrated thermal bleaching thresholds of reefs and their variation on the Great Barrier Reef. Marine Ecology Progress Series 229:73-82

CSIRO ReefTemp web page:
http://www.cmar.csiro.au/remotesensing/*ReefTemp*/web/*ReefTemp*_techinfo.htm

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Appendix C — Maldives Coral Bleaching Monitoring Protocol

Overall Objective

The aim is to monitor bleaching events by surveying coral at different depths. The data should be collected by using the Coral Bleaching protocol. Depending on your time you want to invest and your knowledge of coral taxonomy you can choose from 2 options.

Option A – Belt transect

This option is recommended for observers with good knowledge of coral genera existing in Maldives. This option is quite time consuming and therefore requires enough time to conduct the surveys. The estimated time to do one transect (10m) depends on the coral cover present at the site.

Objective

Survey coral bleaching in each reef habitat: on the reef flat (~1 m), reef crest (~5 m), reef slope (~10 m) and vertical slope (~10 m). If you can only do 1 habitat then survey corals on the reef crest **(~5 m).**

Suggested equipment

Protocol forms, pencils, Perspex or other u/w slate or clipboard, rubber bands, 50 m transect tape, species ID guides, snorkeling or SCUBA gear and associated safety equipment, sunscreen and/or protective clothing, a safety plan and these instructions.

Frequency

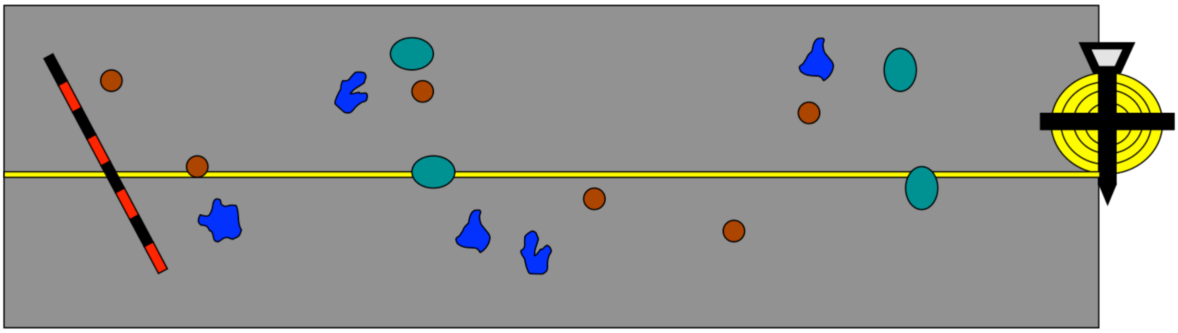
Twice-yearly. In case of a bleaching event, repeat at least once a month, if possible every 1-2 weeks.

Notes

A minimum of three transects should be completed at each of the three depths at the established permanent marker locations. If you have set up a second (and third) site with three transects at each of the three depths, then you should complete these surveys during the same week.

Instructions

Lay a transect tape parallel to the beach and survey **all** the corals present in three consecutive 10 by 1 m transects. Leave a gap of ~3m between each transect. Always survey a minimum of **three consecutive** transects for statistical comparisons.



For each transect, survey all the coral colonies, identify them by genus and record the extent of bleaching per colony using these six categories (from Gleason 1993):

1) No bleaching

2) 1-10% of the colony is bleached

3) 11-50% of the colony is bleached

4) 51-99% of the colony is bleached

5) 100% bleached

6) Dead

At each reef where you lay your three transects, please complete the required fields, entering the reef- and dive site name that is commonly used in the area, the time, atoll, latitude and longitude, water temperature, depth, visibility, and reef habitat.

It is also important to record whether there are additional stressors visible or in the vicinity such as sedimentation, macro algae, cyanobacteria, near a sewage treatment plant, other or not applicable.

Write in the start time of the survey, the site ID, the direction of the transect in compass degrees, and your 'Observer ID' on the protocol datasheet. Write the survey method as one of these: Scuba or Snorkel.

Data sheet (option a - belt transect)

Site: Observer:

Date: Depth:

Transect	Genera	Bleaching Severity					
		1	2	3	4	5	6
1	Acropora						
	Favia						
	Favites						
	Goniastrea						
	Leptoseris						
	Montipora						
	Pavona						
	Pocillopora						
	Porites						
	Psammocora						
2	Acropora						
	Favia						
	Favites						
	Goniastrea						
	Leptoseris						
	Montipora						
	Pavona						
	Pocillopora						
	Porites						
	Psammocora						
3	Acropora						
	Favia						
	Favites						
	Goniastrea						
	Leptoseris						
	Montipora						
	Pavona						
	Pocillopora						
	Porites						
	Psammocora						

Option B – Line intercept transect

This option is recommended for observers with limited time and basic knowledge about benthic organisms in Maldives. Knowledge in coral taxonomy is not required to collect data by using this option of. The estimated time to do one transect (50m) is about 15-20 minutes regardless of the coral cover present at the site.

Objective

Survey coral at different depths. At 1m (or top reef), 5m and 10m. If you can survey only one depth, then choose **5 m**.

Suggested equipment

Protocol forms, pencils, Perspex or other u/w slate or clipboard, rubber bands to fix the form, 100 m transect tape (2x 50m), snorkeling or SCUBA gear and associated safety equipment, sunscreen and/or protective clothing, a safety plan and these instructions.

Instructions

Lay a 50m transect tape and identify every 50cm what intercepts with the transect tape according to the given categories:

BC All fully or partially bleached, living hard corals

NBC All not bleached, living hard corals

RKC Recently killed coral (disease, predation)

OT Anything other than living hard corals

When surveying, never count the benthic at 0m on the transect tape. Instead start at 0.5m, and till 50m to complete one transect. Leave a 5m gap between each transect. At each site and depth, 3 transects (3x50m) should be completed. For each reef, where you lay the transect tape, please fill in the required fields on the data form. Enter the reef name that is commonly used in the area, the time, atoll, water temperature, depth and visibility. Note down the latitude, longitude of the starting point and the direction (in compass degrees) to which the end transect tape is pointing. It is also important to record whether there are additional stressors visible such as sedimentation or crown of thorn starfish. You can take a video of the transect line but make sure that the transect tape and whole coral colonies are visible (do not go to close!).

Frequency

Twice-yearly. In case of a bleaching event, survey at least once a month, if possible every 1-2 weeks.

Notes/Suggestions

Draw a line on the transect tape every 0.5m with permanent marker, on both sides. This makes it quicker underwater to see the location where you are assessing (and thus saves a LOT of time underwater). Also, if people are filming it'll make it easier for whoever is interpreting the video where to survey especially if the tape has rotated.

Data sheet (option b – line intercept)

Coral Bleaching - Option B - Line intercept

m	T1	T2	T3	m	T1	T2	T3
0.5				10.5			
1				11			
1.5				11.5			
2				12			
2.5				12.5			
3				13			
3.5				13.5			
4				14			
4.5				14.5			
5				15			
5.5				15.5			
6				16			
6.5				16.5			
7				17			
7.5				17.5			
8				18			
8.5				18.5			
9				19			
9.5				19.5			
10				20			

Observer Name:
Atoll:
Reef Name:
Start point Latitude:
Start point Longitude:
Transect direction:
Transect depth:
Start time:
Date:
Water Temperature:

Codes:
BC Bleached hard coral
NBC Not bleached hard coral
RKC Recently killed coral
OT Other

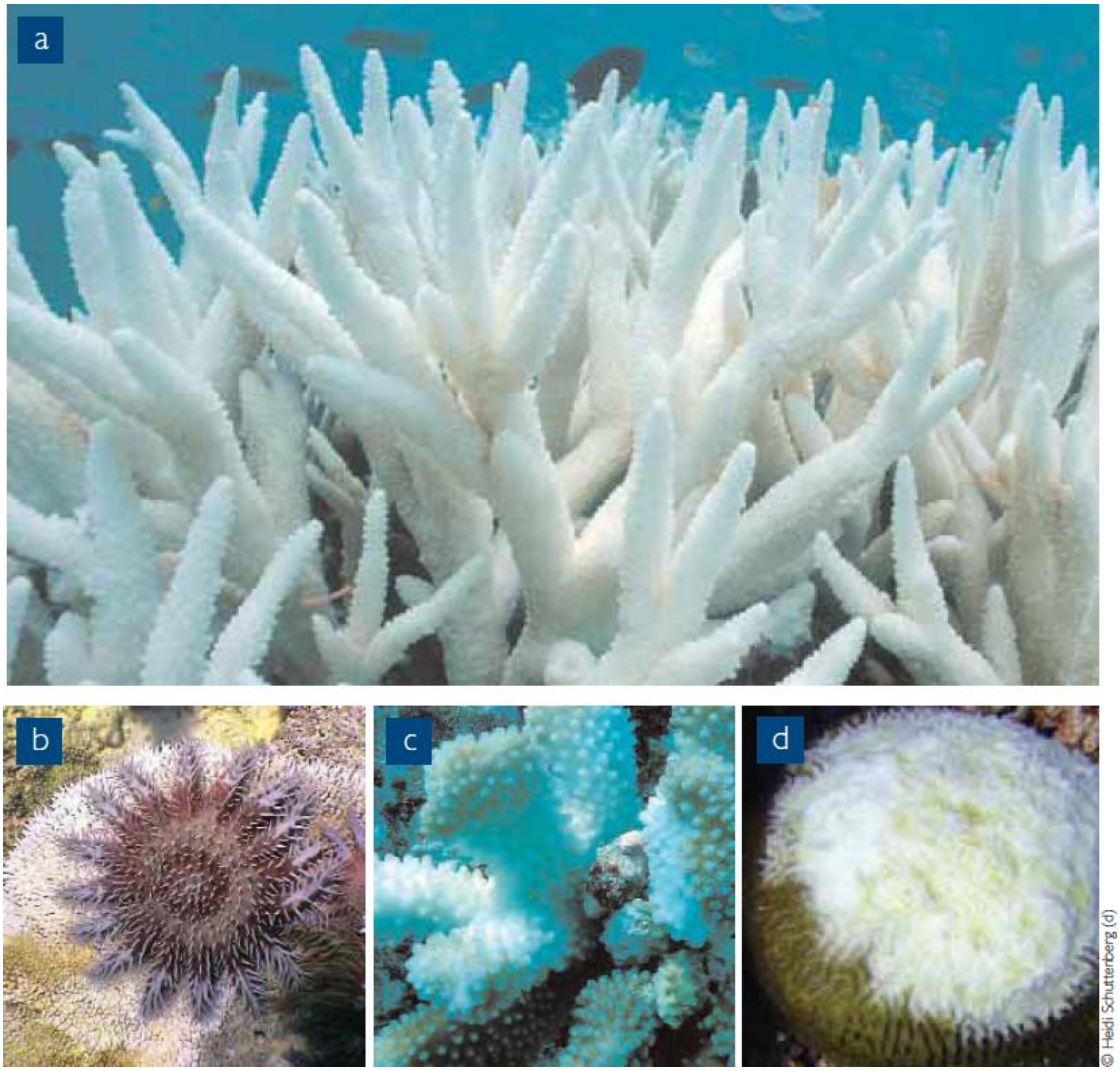
T1 Transect 1
T2 Transect 2
T3 Transect 3

m	T1	T2	T3	m	T1	T2	T3	m	T1	T2	T3
21				30.5				40.5			
21				31				41			
22				31.5				41.5			
22				32				42			
23				32.5				42.5			
23				33				43			
24				33.5				43.5			
24				34				44			
25				34.5				44.5			
25				35				45			
26				35.5				45.5			
26				36				46			
27				36.5				46.5			
27				37				47			
28				37.5				47.5			
28				38				48			
29				38.5				48.5			
29				39				49			
30				39.5				49.5			
30				40				50			

COMMENTS:

Appendix D — How to identify bleaching

Mass coral bleaching is visually very distinctive, but determining whether bleaching or some other stress is affecting individual corals can sometimes be difficult. See the photos below: (a) Bleaching is usually distinguished by the way it affects entire colonies or large sections of colonies similarly. Sometimes coral tissue and polyps can still be seen remaining on the skeletons as the coral is still alive. The effects of coral predators, such as (b) crown-of-thorns starfish and (c) Drupella snails can often be recognized by patches of bare skeleton adjoining patches of live, healthy tissue. (d) Coral diseases can also be sometimes mistaken for the early stages of mass coral bleaching. Disease takes many forms, but the effects of disease are often characterized by a strong line separating live and dead parts of a coral, or by rapid erosion of the surface structure of the coral, as shown here (Marshall & Schuttenberg 2006: “A Reef Manager’s Guide to Coral Bleaching”).



White tips

Branching and plating corals (for example Acropora species) appear to have white tips although the rest of the colony seems to be intense in color. In this case, it is part of the growing process of a healthy coral.

A healthy, branching coral (*Acropora sp.)* displaying white tips.

A branching coral (*Acropora sp.)* displaying white tips as part of a natural growing process. These corals are not bleached.

For more information, see the links below

Facts about coral bleaching:

http://oceanservice.noaa.gov/facts/coral_bleach.html

Snails feeding on coral polyps:

http://www.reefresilience.org/coral-reefs/stressors/predator-outbreaks/drupella/

Crown of thorn starfish:

http://www.reefresilience.org/coral-reefs/stressors/predator-outbreaks/crown-of-thorns-starfish/

Coral disease:

http://www.reefresilience.org/coral-reefs/stressors/coral-disease/