



Photo by Mote Marine Laboratory

Florida Reef Tract

Coral Bleaching Response Plan



Introduction/Executive Summary

The Florida Reef Resilience Program (FRRP) is a collaborative effort among managers, scientists, conservation organizations and reef users to develop resilience-based management strategies for coping with climate change and other stresses on Florida's coral reefs. The program is designed to improve the collective understanding of coral reef resilience by exploring the biological and environmental aspects of reef health as well as understanding what people want and need from coral reefs. Ultimately, the FRRP seeks to develop strategies to improve the health of Florida's reefs and to enhance the sustainability of reef dependent commercial and recreational enterprises.

With projected increases in coral bleaching due to ocean warming, the FRRP Steering Committee, which helps guide the program, recognized the need for developing a unified plan for responding

to coral bleaching events along the Florida Reef Tract. This Bleaching Response Plan is an operational document implemented during peak bleaching temperatures throughout the summer months, but also designed for response to other reef related events throughout the year. The Plan includes four primary components:

1. Early Warning System
2. Impact Assessment
3. Communications
4. Management Actions

The Bleaching Response Plan provides a strategic approach for monitoring bleaching and other events as they occur. This Plan is intended to be used by Florida's reef managers, and implemented with the assistance of the Florida Reef Resilience Program.



Photo by Mote Marine Laboratory

Contents

Chapter 1. Introduction	2
What is Coral Bleaching?	2
Coral Bleaching Globally	2
Coral Bleaching of the Florida Reef Tract	2
Response Plan Goals and Organization	3
Chapter 2. Early Warning System	5
Introduction	5
The Florida Keys Coral Bleaching Early Warning Network (FKCBEWN)	5
Environmental Monitoring	5
Climate Monitoring	5
Remote Sensing	6
In-Situ Monitoring	6
Observer Network	7
Current Conditions Report	8
The Southeast Florida Action Network (SEAFAN)	8
Chapter 3. Impact Assessment	10
Introduction	10
Disturbance Response Monitoring (DRM)	10
Post-Bleaching Monitoring	12
CREMP/SECREMP	12
Other Large-Scale Disturbances	12
Chapter 4. Communications	14
Introduction	14
Basic Strategy	14
Phases of Communications	14
Key Messages	15
Products	15
Chapter 5. Management Actions	17
Appendix	18
Appendix I. Protocols	18
DRM Coral Bleaching In-Water Rapid Assessment Protocol	19
Site Selection	19
Benthic Survey	19
CREMP/SECREMP Stony Coral Demographic Survey (Includes SSI Data Collection)	23
Procedures	23
Stony Coral Belt Transect Survey Protocol	23
CREMP/SECREMP Camera Transects	26
Setup Procedures	26
Camera Transect Protocol	26

Chapter 1. Introduction

What is Coral Bleaching?

Corals receive up to 90% of their energy requirements from a mutually beneficial or ‘symbiotic’ relationship between corals and microscopic algae—zooxanthellae—that live within their tissues. Stressful conditions can cause this relationship to break down, resulting in dramatic decreases in the densities of zooxanthellae within the coral tissue. Because the zooxanthellae also provide much of the color in a coral’s tissue, their loss leaves the tissue transparent, revealing the bright white skeleton beneath and giving the coral the appearance of being ‘bleached’.

Many stressors may cause corals to bleach at a local scale, including storms, disease, sedimentation, cyanide fishing, herbicides, heavy metals, and changes in salinity and temperature. Coral bleaching, however, affects reefs at regional to global scales, and, therefore, cannot be explained solely by localized stressors operating at small scales. There is now broad scientific consensus that the primary cause of these regional—or widespread bleaching—events is increased sea temperatures. Temperature increases of 1-2°C above the long term average maximum are all that is required to trigger coral bleaching. Light also influences the extent of bleaching impacts, such that shaded corals are likely to be less impacted than corals exposed to normal light levels during heat stress.

Bleached corals are still living, and if stressful conditions subside soon enough, they can regain their zooxanthellae and survive the bleaching event. However, even corals that survive are likely to experience reduced growth rates, decreased reproductive capacity, and increased susceptibility to disease. If stresses are severe or persistent, bleaching can lead to the death of corals. In extreme cases, bleaching events have caused catastrophic mortality of corals.

Coral Bleaching Globally

The impacts of coral bleaching, in combination with those of local stressors, will largely determine the condition of coral reefs in the next 50 years. Already, bleaching events have caused significant deterioration to many reefs around the world. The worldwide mass bleaching event of 1997-98 alone is attributed with causing severe damage to 16% of the world’s reefs. This was not an isolated incident, with the number of regions reporting coral bleaching growing steadily. Some major reef regions have reported their most severe bleaching events since 1998, including the Great Barrier Reef and the Caribbean.

Comparing predicted sea temperature increases with existing bleaching thresholds indicates that the frequency and severity of bleaching events are likely to rise significantly. It is well known that coral reef ecosystems can adjust to higher sea temperatures; however, the rate of adjustment is expected to be significantly slower than the rate of temperature increase. This implies that, should tropical seas continue to warm as predicted, coral reef ecosystems are likely to continue to experience undesirable changes. These changes include losses to biological diversity, coral cover and wildlife habitat, as well as economic losses to the fisheries and tourism sectors.

Coral Bleaching of the Florida Reef Tract

Stretching approximately 300 nautical miles from the Dry Tortugas National Park off of the Florida Keys to the St. Lucie Inlet in Martin County, the Florida Reef Tract is the only barrier reef in the continental United States. Roughly two thirds of the Florida Reef Tract are managed within the Florida Keys National Marine Sanctuary (FKNMS) and Biscayne National Park (BNP), marine protected areas that surrounds the Florida Keys island chain. The reefs stretching north of the BNP into the southeast Florida region are managed by the Florida Department of Environmental Protection’s (DEP) Coral Reef Conservation Program (CRCP).

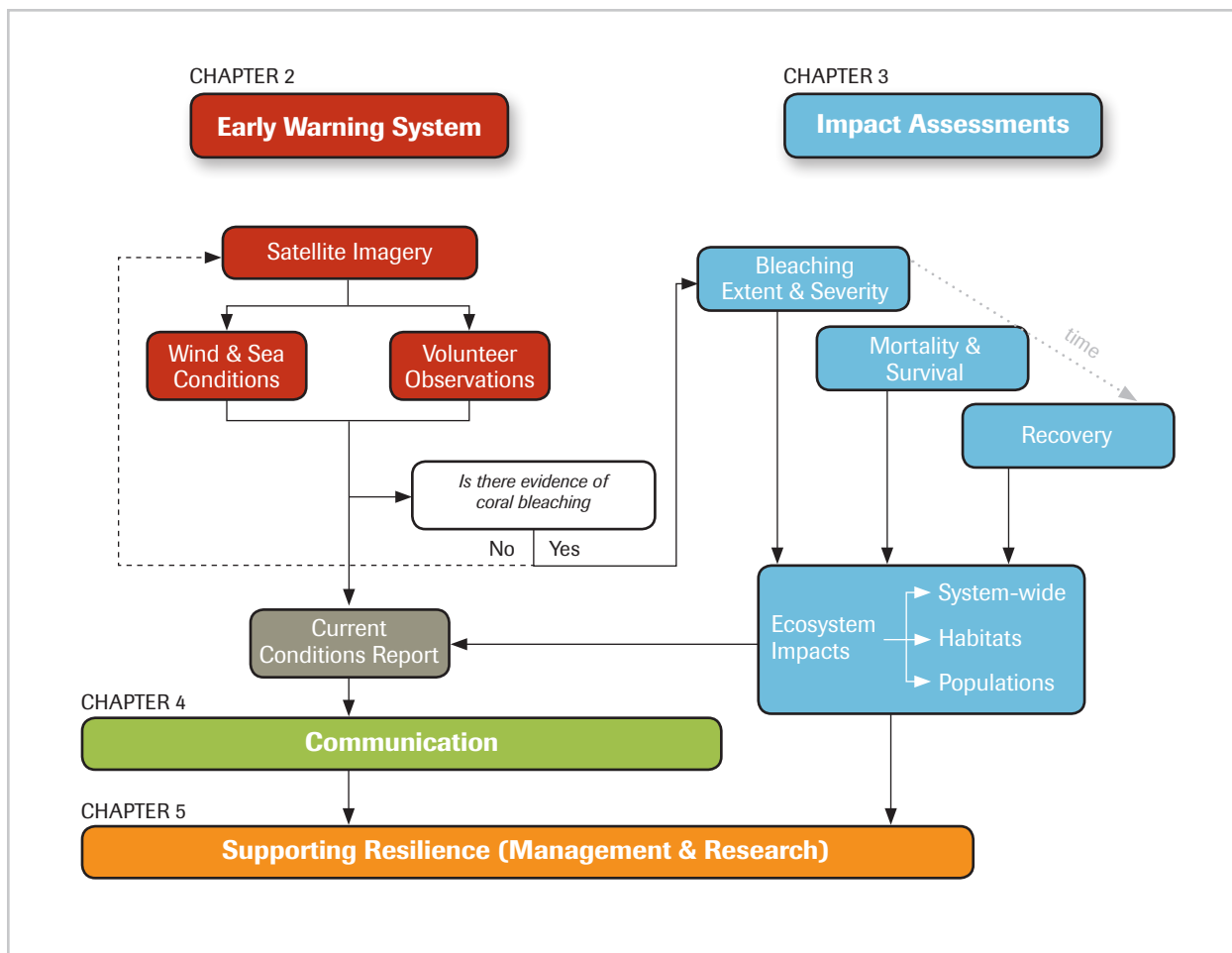


Figure 1: Florida Reef Tract strategy for predicting, assessing, and communicating coral bleaching events.

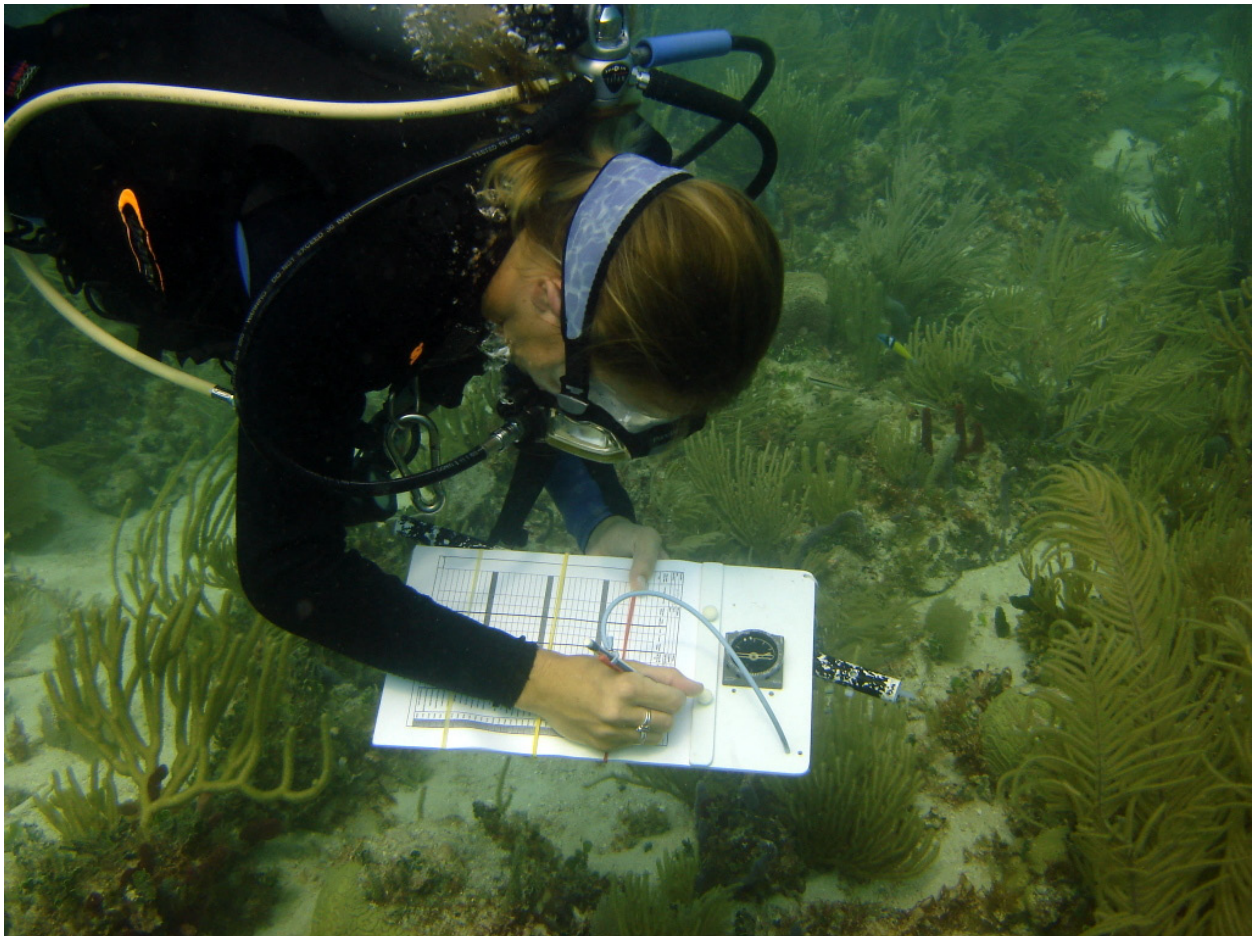
An obvious pattern of intensification of coral bleaching and other marine perturbations occurred throughout the 1980s and 1990s along the Florida Reef Tract. Coral bleaching occurred in 1983 and 1987 with little mortality observed. A coral bleaching event in 1990 was the first time that corals in nearshore waters were broadly affected, and the first time that extensive coral loss was recorded as a result of bleaching. In 1997 and 1998, the Florida Reef Tract experienced back-to-back bleaching events that were significant for their widespread geographical extent, both offshore and inshore, and their long duration. The stress from the combination of intense bleaching and Hurricane George was responsible for significant coral mortality that occurred between late summer 1998 and late spring 1999.

Response Plan Goals and Organization

The Florida Reef Tract Bleaching Response Plan outlines strategies for predicting, assessing, and communicating about coral bleaching events (Figure 1). Much of this plan details actions that are already in place in FKNMS, and which have been or are in the process of being expanded through similar efforts along the northern portion of the Florida Reef Tract in southeast Florida. These actions will strengthen reef managers' ability to develop and communicate reliable information about the likelihood and impacts of a bleaching event. These strategies do not provide a "cure" or "solution" to coral bleaching; however, they will strengthen overall coral reef management by raising awareness and advancing scientific understanding about coral reef resilience to bleaching.

Chapter 2 describes an early warning system that uses both environmental data and volunteer observations to predict the risk of mass bleaching. Chapter 3 outlines a disturbance response monitoring approach that will be implemented during and after a coral bleaching event. Chapter 4 discusses the communication strategy for coral

bleaching, before, during and after events and to build general awareness of the issue. Chapter 5 describes management actions undertaken as part of this response plan that will ultimately contribute to supporting coral reef resilience along the Florida Reef Tract.



Diver collecting coral bleaching data

Photo by Erich Bartels

Chapter 2. Early Warning System

Introduction

In coordination with Mote Marine Laboratory, the Florida Keys National Marine Sanctuary (FKNMS) has developed a program that utilizes a combination of existing environmental monitoring tools, weather reports, and trained observer reports to stay informed on the occurrence of bleaching. FDEP CRCP is in the process of developing a similar system along the northern portion of the Florida Reef Tract between Miami-Dade and Martin counties.

The Florida Keys Coral Bleaching Early Warning Network (FKCBEWN)

The Florida Keys Coral Bleaching Early Warning Network (FKCBEWN) is designed to utilize existing U.S. National Oceanic and Atmospheric Administration (NOAA) remote sensing and environmental monitoring capabilities and integrate these outputs with field observations on the occurrence or absence of coral bleaching, and basic environmental conditions at the observation site. This information can be used in three important ways: 1) NOAA researchers can further develop the accuracy of their remote sensing and in-situ monitoring capabilities for predicting bleaching, 2) early detection of mass bleaching can trigger or focus more detailed scientific studies to monitor coral bleaching impacts, such as the Florida Reef Resilience Program-Disturbance Response Monitoring, and 3) reef managers can communicate the condition of the reefs as potential bleaching events occur.

This program is a cooperative effort between Mote Marine Laboratory and FKNMS, and provides the following:

- Coordination and training of a volunteer network of observers who report on actual coral condition on a broad spatial scale, providing a standardized visual assessment of coral condition before, during, and after bleaching events

- Regular evaluation of NOAA's Coral Reef Watch "HotSpot" and "Degree Heating Weeks" maps to monitor for patterns of elevated temperatures
- Regular evaluation of water temperature data from C-Man/SeaKeys stations for each subregion (Dry Tortugas, Lower, Middle, and Upper) for regional differences throughout the Keys
- Regular evaluation of weather forecasts and meteorological data on wind speed and cloud cover
- Provide FKNMS and others with a concise summary that integrates volunteer observations on actual coral condition with available environmental information in the form of a "current conditions" report, which allows FKNMS to effectively communicate and raise awareness about mass coral bleaching events

The network is comprised of two main components: Environmental Monitoring and an Observer Network (Figure 2).

Environmental Monitoring

Previous episodes of coral bleaching have provided scientists with the knowledge of events and conditions that typically precede coral bleaching. NOAA's "Coral Reef Watch" program provides internet-based satellite imagery products that summarize sea surface temperature, which can be used to indicate if coral bleaching conditions are favorable in a particular region. On a more localized scale, NOAA's "Coral Health and Monitoring Program" provides near real-time data from a network of environmental monitoring stations.

Climate Monitoring

Although coral bleaching has been observed throughout the year in the past, mass bleaching events are generally associated with weather patterns that result in above-average water

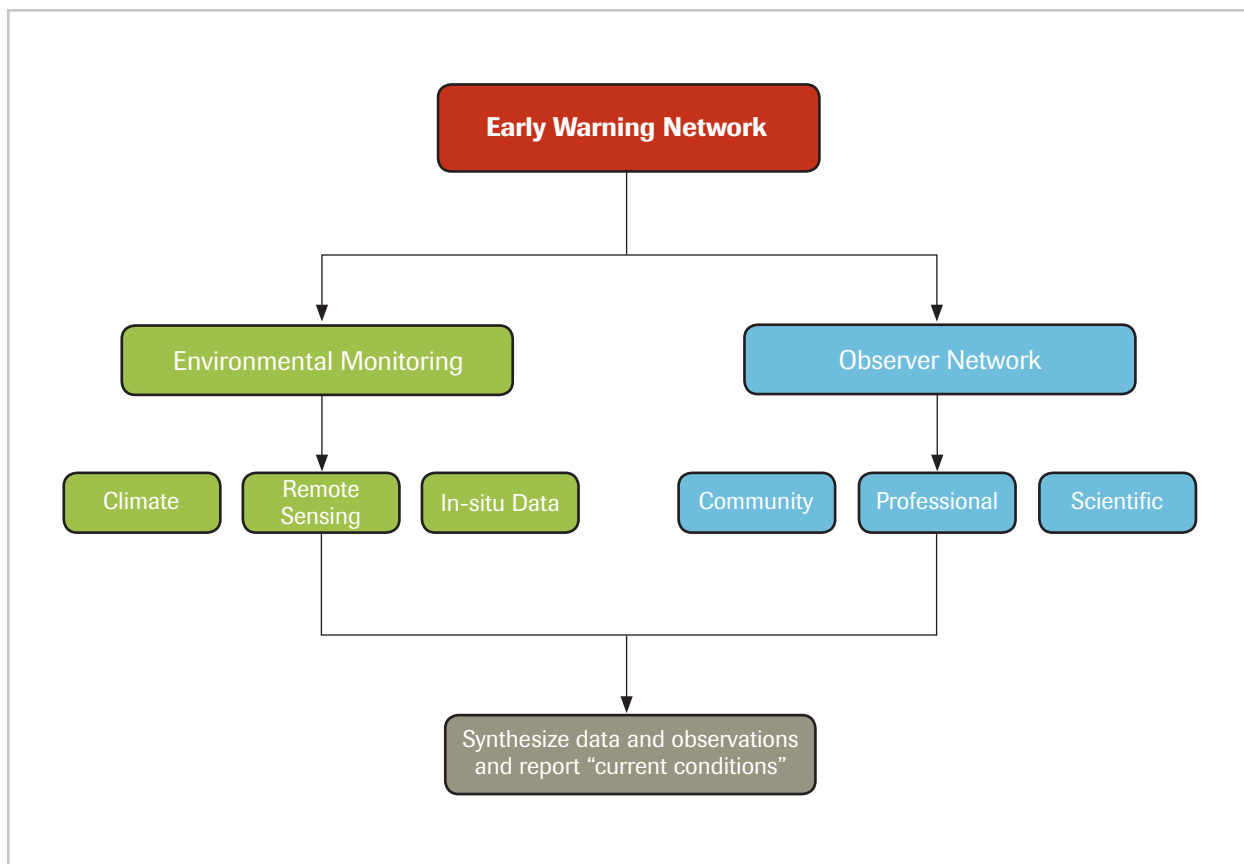


Figure 2: Components of the Florida Keys Coral Bleaching Early Warning Network.

temperatures, such as doldrums in mid to late summer. Seasonal climate predictions can be examined at the start of the summer, and short-term regional forecasts can be obtained to monitor local weather patterns and potentials for warming conditions. Short-term forecasts can be evaluated routinely to monitor for periods of light winds and decreased cloud cover, which are known to result in increased coral stress during times of elevated sea temperature.

Remote Sensing

Sea temperature analysis for the region is monitored on NOAA's Coral Reef Watch website (<http://coralreefwatch.noaa.gov>) throughout the bleaching season. Readily available on the web and updated bi-weekly, the Coral Reef Watch program produces several products (50km square resolution) that summarize sea temperature anomalies:

- “Hot-spot” charts: bi-weekly analysis that indicates regions where the sea-surface temperature (SST) is 1°C greater than the maximum expected summer time temperature.
- Degree Heating Weeks (DHW): bi-weekly analysis that indicates the accumulation of elevated temperature based on the previous 12 weeks.

Additionally, sea surface temperature satellite imagery (1.4 km resolution) is evaluated regularly from NOAA's CoastWatch website (<http://coastwatch.noaa.gov>) to monitor for regional differences and more specific areas of concern.

In-Situ Monitoring

The Florida Reef System has variation in coral reef types, habitats, flow patterns, localized eddies and local environmental conditions from influences such as the Florida Current, SW

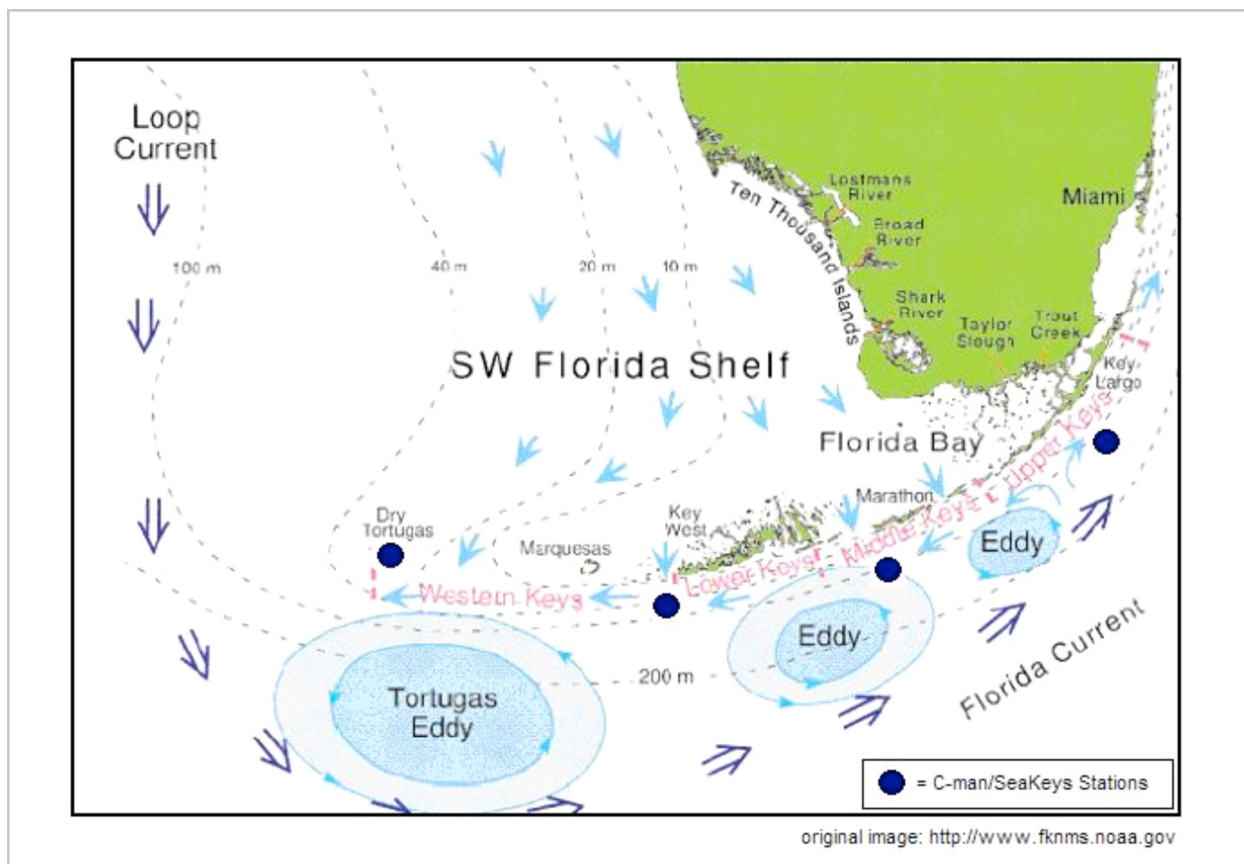


Figure 3: Map depicting typical current patterns throughout the FKNMS and locations of NOAA in-situ instrumentation that will be routinely monitored.

Florida Shelf, and Florida Bay (Figure 3). Because of these geographical differences, there is a need to provide greater spatial resolution of temperature analysis in order to monitor conditions within each sub-region. Near real-time measurements from several locations throughout the Keys are monitored routinely. These platforms can provide not only temperature data, but other variables that might influence coral bleaching such as wind, current, tide, and irradiance data.

Observer Network

Although remote sensing and *in-situ* data collection can provide an indication of when conditions are ideal for the onset of coral bleaching, the actual onset can be a gradual process, and effects can vary over large areas. In order to accurately assess the initial effects of bleaching events, and to assess coral condition during and after bleaching events, a large network of observers is needed to provide

regular reports of actual coral conditions.

The BleachWatch observer network utilizes residents and visitors, marine professionals, and scientists to provide information on the condition of reefs before, during, and after bleaching events. BleachWatch participants fall into three categories:

- *Community* — resident and visiting recreational divers and snorkelers
- *Professional* — educational groups, marine life collectors, commercial divers, and the dive tourism industry
- *Scientific* — Federal, State, local and private or academic researchers conducting fieldwork

Periodic calls for observations encourage the Observer Network to stay engaged throughout the summer and can elicit additional surveys during periods of particularly warm temperatures.

Conditions	Frequency of Update
Environmental conditions suggest low risk of mass coral bleaching	Monthly
Climate or sea temperatures are elevated above normal	Every two weeks
Sea temperature stress has accumulated to levels associated with a moderate risk of bleaching	Every two weeks
Sea temperature stress has accumulated to levels associated with a high risk of bleaching and/or reports of mild bleaching are reported by volunteers	Twice per week
Mass coral bleaching is being widely reported by volunteers	Twice per week

Table 1: Timetable for providing synthesis of Environmental Monitoring data and “BleachWatch” observations to FKNMS/NOAA during coral bleaching season (May – September).

Current Conditions Report

Information from remote sensing and in-situ data analysis is combined with volunteer observations from the field to provide a comprehensive overview of current conditions throughout the FKNMS. This Current Conditions report is sent to FKNMS and NOAA staff for review and use for the overall communications plan. Reports include a summary of relevant weather information, NOAA “hotspot” and DHW analysis, and updated in-situ data analysis, as well as a summary of BleachWatch observer reports for each region. The current conditions and the potential risk for coral bleaching dictate the frequency in which these reports are generated (Table 1).

The Southeast Florida Action Network (SEAFAN)

Coordinated by the Florida Department of Environmental Protection’s Coral Reef Conservation Program (FDEP CRCP), the Southeast Florida Action Network (SEAFAN) is a reporting and response system designed to capture the occurrence of episodic events, such as coral bleaching, along with a variety of other marine incidents that may be impacting the coral reef ecosystem. SEAFAN was established based on the Marine Ecosystem Event Response and Assessment (MEERA) program in the Florida Keys and provides for early detection and follow-

up assessment, as necessary, of marine incidents occurring along the northern portion of the Florida Reef Tract.

Anyone who spends time on the water in southeast Florida, such as local divers, fishermen, and recreational boaters, can become part of the SEAFAN observer network and submit reports by calling a hotline phone number or filling out an online form. Beyond coral bleaching, SEAFAN allows reef users to report marine debris, vessel groundings and anchor damage, biological disturbances such as algal blooms, fish kills, and invasive species, and any other unusual incidents that may have a negative impact on coral reefs. FDEP-CRCP tracks and synthesizes all reports, then coordinates with regional partners to initiate site assessments and any response that may be necessary. Through the SEAFAN program, FDEP-CRCP will issue periodic reports that summarize the observations received, as well as any data collected and analyzed. These will be distributed via email and available on the SEAFAN website.

As the program continues to develop, FDEP CRCP staff will work closely with Mote Marine Laboratory to include volunteer training modeled after the BleachWatch program, environmental monitoring, and the development of current conditions reports for the southeast Florida region.

Chapter 3. Impact Assessment

Introduction

The goals of the impact assessment are to determine the extent, severity, and impacts of individual disturbance events, such as coral bleaching, to support communication and management efforts during these events. The impact assessment also aims to collect information that will help identify trends in coral bleaching patterns, and support understanding of management for long-term ecosystem resilience. In order to meet these goals, the monitoring is structured to answer management questions about the impacts of coral bleaching events across varying temporal and spatial scales (Figure 4).

Disturbance Response Monitoring (DRM)

The Disturbance Response Monitoring (DRM) program was developed and first implemented in 2005 to monitor shallow coral reefs from Martin County to the Dry Tortugas. The DRM consists of a probabilistic sampling design and a stony coral condition monitoring protocol (see Appendix I) implemented across 59 discrete reef zones

(Figure 5) during the annual period of peak thermal stress. Since 2005, The Nature Conservancy has coordinated survey teams from federal, state, and local government agencies, non-profit organizations, and universities to complete ~200 surveys across the Florida Reef Tract within a six to eight week period of peak heat stress each year. Information is gathered on the coral population's size frequency, size structure, bleaching prevalence, and coral condition, including disease and percent mortality.

The Florida Reef Resilience Program (FRRP) Steering Committee guides the direction and oversight of the DRM and is made up of reef managers, scientists, and reef user groups. The FRRP Steering Committee has determined that even in mild bleaching years, monitoring should take place to ensure preparedness and to provide "background" condition data. The following are the annual chain of events that occur as part of the DRM coral bleaching surveys. The timeline of these events can be modified for other

Questions Driving the Impact Assessment	System-wide	Habitats/ Reef Classifications	Populations/ Subpopulations
Bleaching Extent & Severity	What is the extent & severity of this coral bleaching event?	Which reefs/habitat types are the most/least affected by this event?	Which species & populations have been most susceptible/ resistant to this event?
Mortality/Survival	How has this coral bleaching event affected the condition of the coral reef ecosystem soon after the event?	Which reefs/habitat types have experienced the greatest mortality/ best survival soon after the event?	Which species & populations have experienced the greatest mortality/best survival soon after the event?
Recovery	How has the coral reef ecosystem recovered from this mass bleaching event after 0.5, 1, and 2 years and longer?	Which reefs/habitat types have most/least recovered from this mass bleaching event after 0.5, 1, and 2 years and longer?	Which species & populations have most/ least recovered from this mass bleaching event after 0.5, 1, and 2 years and longer?

Figure 4: Questions driving the Impact Assessment.

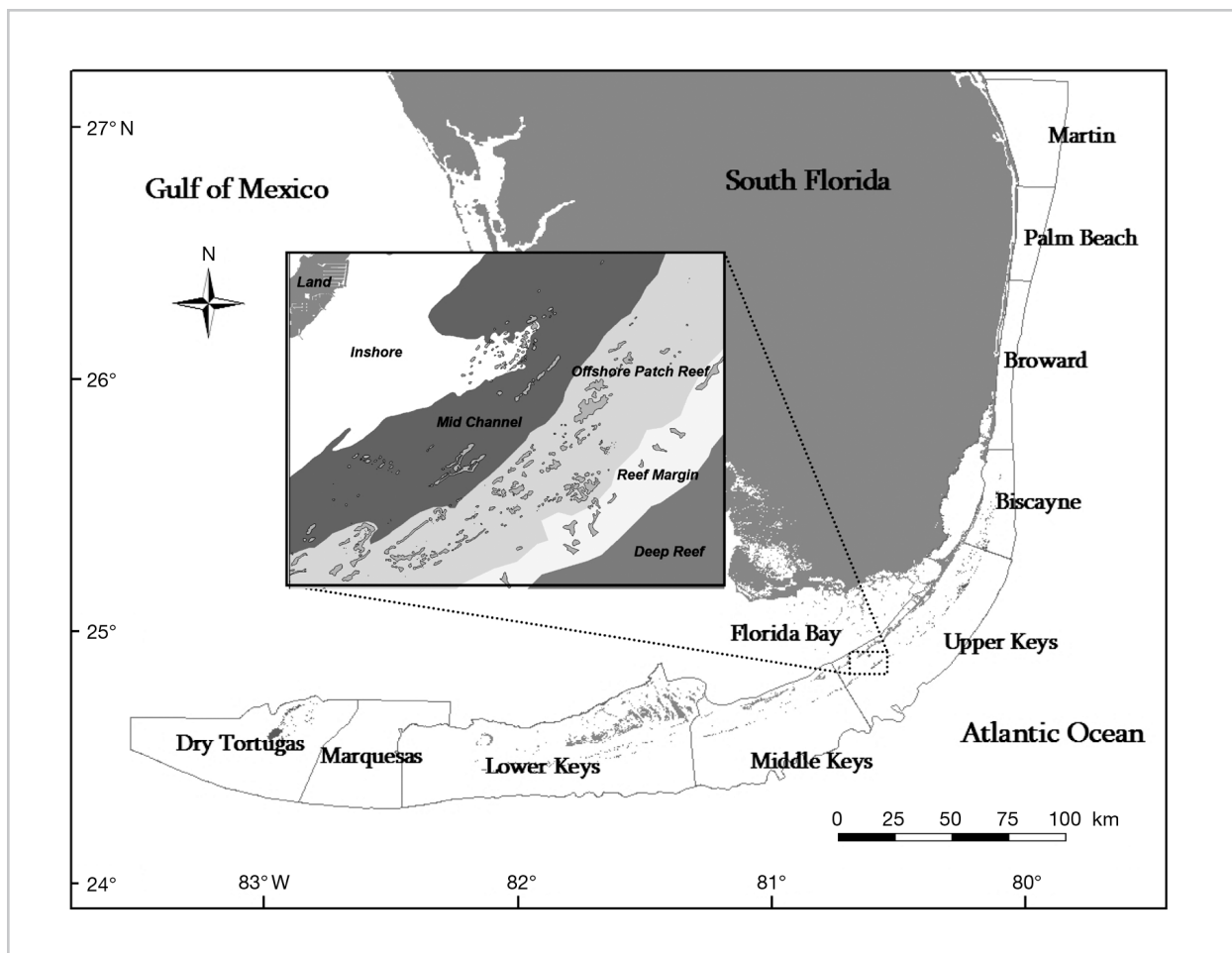


Figure 5: Map of the FRRP sub-regions. Map inset shows cross-shelf zones.

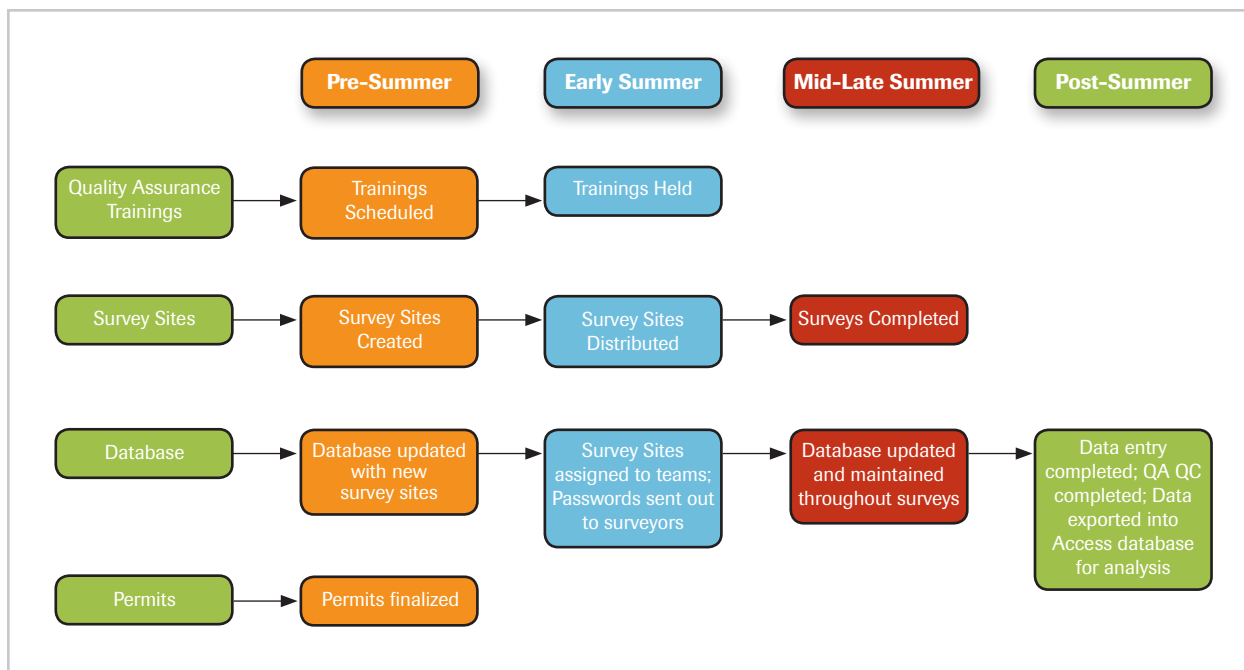


Figure 6: DRM annual chain of events. These events can be modified for other disturbances that are not planned each year.

disturbances, including severe bleaching events that occur earlier than the annual DRM surveys.

Following a bleaching season, both DRM and BleachWatch data are used to determine whether a post-bleaching response is required.

Combining measures of bleaching severity and spatial extent (Table 2) informs the situation analysis (Figure 8), which determines which Response Level of post-bleaching monitoring should be triggered (Figure 7).

Severity	Description
High bleaching risk (BleachWatch Only)	Sea temperature stress has accumulated to levels associated with a high risk of bleaching and/or reports of mild bleaching are reported by volunteers (BleachWatch only)
Mild bleaching	Bleaching prevalence of surveyed colonies is mild (0-20%) (DRM); mild bleaching is reported by volunteers (BleachWatch)
Moderate bleaching	Bleaching prevalence of surveyed colonies is moderate (21-50%) (DRM); moderate bleaching is reported by volunteers (BleachWatch)
Severe bleaching	Bleaching prevalence of surveyed colonies is severe (> 50%) (DRM); severe bleaching is reported by volunteers (BleachWatch)

Extent	Description
Local	Severe bleaching occurring in 2 or more zones within 1 sub-region
Regional	Severe bleaching occurring within 2 or more zones in 2 sub-regions
Widespread	Severe bleaching occurring in 2 or more zones in >2 sub-regions

Table 2: Levels of bleaching severity and extent based on BleachWatch and DRM data. Note: This table should also be used if ONLY BleachWatch data is available.

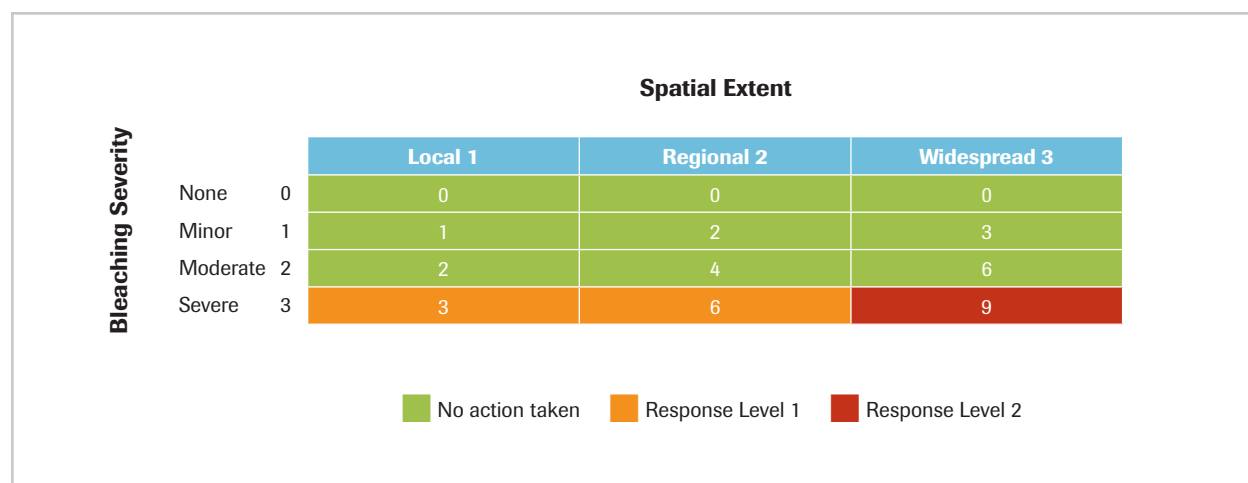


Figure 7. Matrix combining measures of bleaching severity and spatial extent (from Table 2) to inform the situation analysis and level of post-bleaching response (Figure 8).

Post-Bleaching Monitoring

Post-bleaching monitoring is completed after a severe or mass bleaching event. This is defined based on 1) BleachWatch annual predictions and data, and 2) DRM annual data. For DRM, a severe bleaching event is defined as more than one sub-region with >50% bleaching prevalence of surveyed coral colonies. This is reliant on rapid reporting based on annual DRM data collection. BleachWatch also predicts and then documents severe bleaching, if severe bleaching is predicted and documented then it is considered a severe bleaching event. If DRM defines the disturbance as severe, post-bleaching monitoring will occur 3-4 months following the event.

CREMP/SECREMP

Post-bleaching monitoring includes both random survey sites (DRM described above) as well as fixed survey sites (CREMP/SECREMP). The Coral Reef Evaluation and Monitoring Project (CREMP) monitors the status and trends of selected coral reefs, patch reefs, and hardbottom areas in the Florida Keys National Marine Sanctuary (FKNMS). CREMP was initiated in 1995 as part of the Water Quality Protection Program (WQPP) which mandated a comprehensive monitoring program be established for corals, seagrasses and water quality in the FKNMS. CREMP assessments have been conducted annually at 34 fixed sites since 1996 and data collected provide information on the temporal changes in spatial cover and diversity of stony corals and associated marine flora and fauna. CREMP is one of the longest tenured monitoring programs in the State of Florida and has been instrumental in documenting how a variety of perturbations have resulted in both widespread and localized changes to benthic

community composition in the FKNMS. In 2003, CREMP was further expanded to include 17 sites offshore southeast Florida in Miami-Dade, Broward, and Palm Beach counties. This CREMP expansion, named the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP), will assist in filling gaps in coverage of knowledge and monitoring of coral reef ecosystems statewide. Some changes identified in the benthic community composition are due to direct disturbances that have occurred since CREMP was initiated, but many are likely the result of centuries' old anthropogenic modifications to the South Florida environment well before the designation of the Sanctuary in 1990 or the inception of CREMP in 1995 and SECREMP in 2003.

There are two response levels for post-bleaching monitoring. The type of response initiated is dependent on the spatial extent of the severe bleaching event (Figure 8), resources, and effort available.

Other Large-Scale Disturbances

Other large-scale disturbances (e.g. cold-water events; toxin spills; algae blooms; etc.) that may severely affect the health of corals along the Florida Reef System should be documented. For non-bleaching disturbances, documenting the spatial extent and severity of coral stress responses (e.g. bleaching) and/or mortality may be completed. The FRRP Steering Committee along with local management agencies will determine the need to document a disturbance, and what level of response will be initiated. Programs such as MEERA and SEAFAN will serve as the early warning system for informing these decisions.

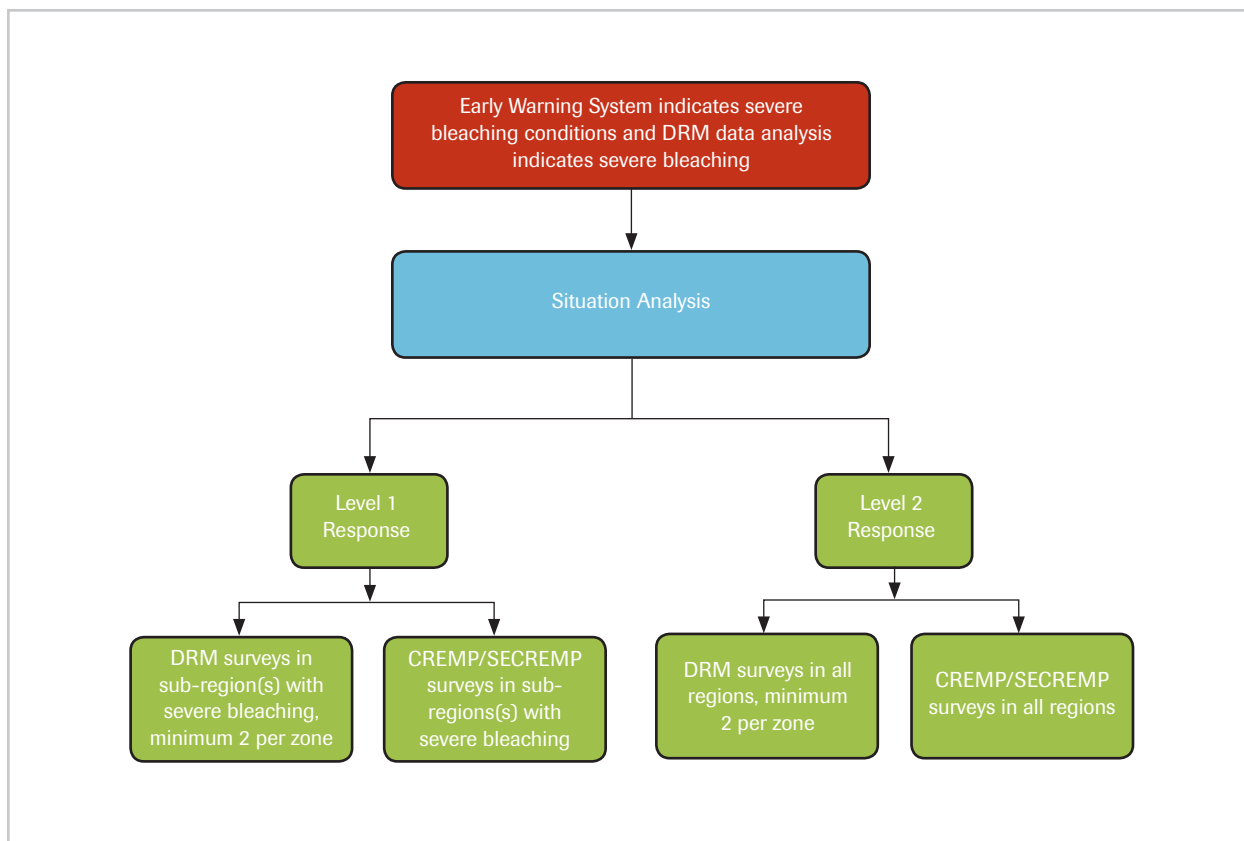


Figure 8: Post-Bleaching response chain of events based on the spatial extent of a severe bleaching event.

Chapter 4. Communications

Introduction

The goals of communications are to increase awareness of coral bleaching and participation in volunteer programs. These goals are described in more detail below:

Goal 1: Increase awareness about the causes and results of coral bleaching and significance to reef health.

- Objectives:
- a) Develop talking points and educational products.
 - b) Highlight coral bleaching research and programs on websites and social media.
 - c) Have an educational presence at festivals and events.
 - d) Build relationships with local media.

Goal 2: Increase participation among the diving and fishing community in volunteer observer programs like BleachWatch.

- Objectives:
- a) Identify and contact leaders in local dive and fishing communities.
 - b) Hold a minimum of five public trainings annually throughout South Florida.
 - c) Foster relationships with volunteers through additional email updates.

Basic Strategy

Accurate and effective communication about coral bleaching will require open communication and cooperation among communications, education and outreach staff, scientists, managers, and the public.

Prior to the summer season, communication efforts will focus on creating awareness of the causes and implications of coral bleaching and of the concept of managing for resilience locally, regionally and nationally among the audiences identified in the figure on the next page.

During the summer season, Mote Marine Laboratory will prepare a current conditions report based on information obtained from bleaching monitoring volunteers, the Marine Ecosystem Event Response and Assessment (MEERA) program, DRM, and other sources. The information in the current conditions report should be the basis for other communications.

The Current Conditions report will itself be used as a communication tool and can be posted on web sites and sent to volunteers, an email list of interested parties and the media. In the case of a severe bleaching event, communications may be expanded to the regional and national media. As significant new information becomes available, additional press releases will be drafted and disseminated. The impact of communications tools will be increased by sharing information widely with partners, colleagues and stakeholders and encouraging them to pass it along via their websites, newsletters, and other communications vehicles. Once a severe coral bleaching event ends, communications should focus on closing the loop and ensuring that all audiences receive information about the result of assessments.

Phases of Communications

Communication about coral bleaching is divided into four phases:

- 1) Creating awareness among the general public, the local community, decision makers and partners about coral bleaching before high risk conditions occur or a mass bleaching is underway;
- 2) Alerting the volunteer base, the local community, decision makers and partners about the presence of high risk conditions and the need for additional observations;
- 3) Updating the volunteer base, the local community, the general public, decision makers and partners about the status of bleaching once a mass bleaching event is underway;

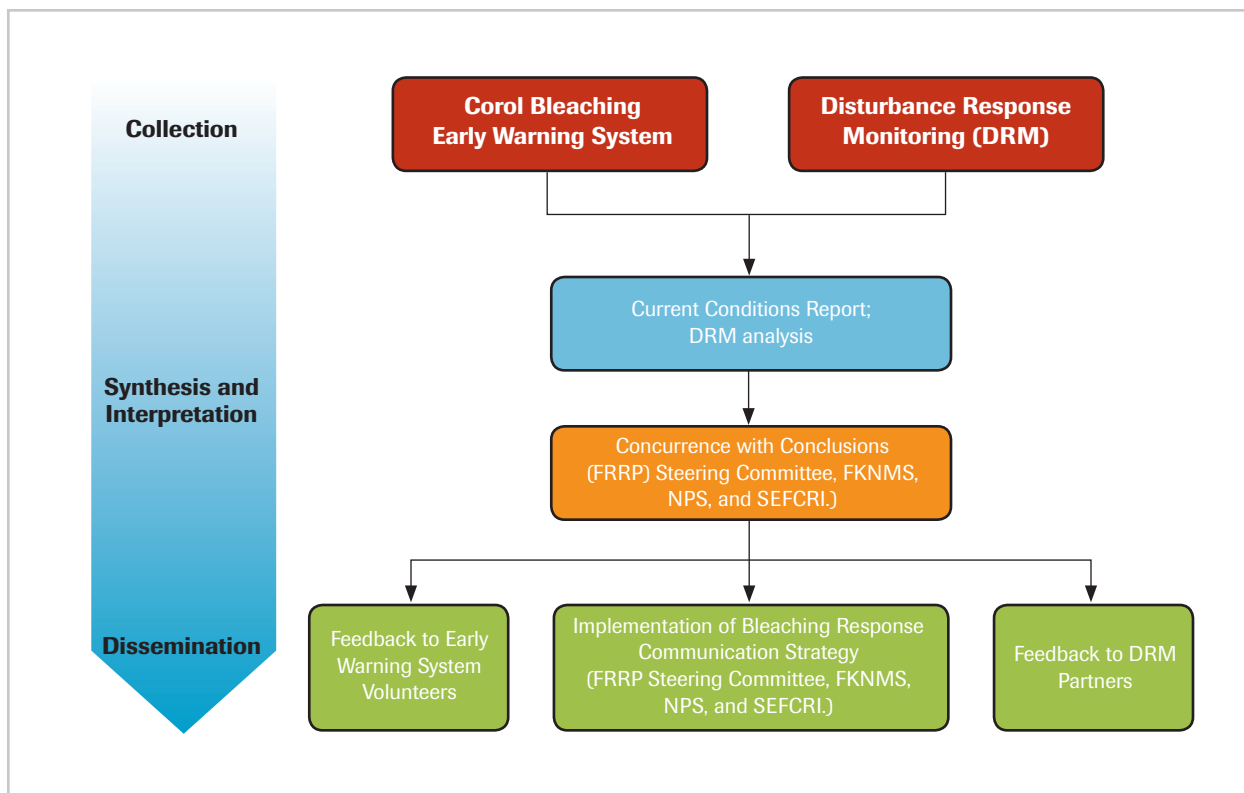


Figure 9: Information flow during a severe bleaching event.

- 4) Following up to inform the volunteer base, local community, general public, decision makers and partners about post bleaching assessment and management efforts and whether corals have recovered or died.

The four phases are better described in the table on the next page.

Key Messages

Coral bleaching is a stress response in which coral animals lose the symbiotic algae which resides in their stomachs/tissues, helps them eat, and gives them color. Bleaching can occur due to exposure from: pollution, thermal stress, etc.

A bleached coral isn't automatically a dead coral. Sort of like it's in the hospital's ICU. If the stress subsides, corals may regain their algae and can bounce back. Corals that bounce back and endure stress better are referred to as "resilient."

Reef managers use different tools, including satellite imagery of sea surface temperatures, to predict if and when corals might bleach, but the most valuable information comes from first hand volunteer observations by the public.

Volunteer observations are used to inform reef managers of where and when bleaching is occurring along the Florida Reef Tract, and can be the trigger mechanism for a major reef survey effort including DRM and CREMP/SECREMP surveys.

Scientists survey reefs during peak bleaching temperatures, and then revisit the sites to compare if the corals were able to bounce back or perished. This information helps scientists and managers determine the resilient qualities of certain coral species and locations.

Products

- FAQs
- ID tip sheets
- Web links
- Fact sheets
- Photo CD
- PowerPoints

Phase	Month	Trigger	Briefings	Message
1	June/July	Annually	General public, Bleachwatch volunteers, reef managers, FRRP partners	Summer approaching; bleaching risk period; Response Plan may be implemented
2	Aug-Oct	Annually	General public, Bleachwatch volunteers, reef managers, FRRP partners	BleachWatch and FRRP DRM surveys taking place
3	Late October	Annually	General public, Bleachwatch volunteers, reef managers, FRRP partners	Results of DRM survey analysis, Current Conditions Report
3	Late October	Severe bleaching	General public, Bleachwatch volunteers, reef managers, FRRP partners; Local, regional and national media	Summary of full extent and severity of bleaching; implications for affected sub-regions
4	Dec-Jan	Severe bleaching	General public, Bleachwatch volunteers, reef managers, FRRP partners	DRM and CREMP post-bleaching surveys taking place
4	February	Severe bleaching	General public, Bleachwatch volunteers, reef managers, FRRP partners	Summary of post-bleaching DRM and CREMP analysis

Table 3: Phases of communications

Chapter 5. Management Actions

The impact of a coral bleaching event depends on the spatial extent, bleaching severity, and mortality that occur as a result of the event. Many human activities, during and after these events, may add additional stress to the corals that could be avoided. The following are management actions that could be implemented during a severe event:

- 1) Review of existing permits- limit permitted activities that may occur in severe bleaching areas.
- 2) Limit manipulation/collection of corals during severe bleaching events.
- 3) Implement temporary closures of reef areas during disturbance events (e.g. White Banks closure, coral disease event).



Bleached brain coral, *Diploria labyrinthiformis*

Photo by Meaghan Johnson

Appendix

Appendix I. Protocols

DRM Coral Bleaching In-Water Rapid Assessment Protocol

Site Selection

All sites will be predetermined by The Nature Conservancy and GPS coordinates will be assigned to each dive team in advance. The FRRP approach is a probabilistic survey design using randomized 2-stage stratification appropriate for population census and prevalence. The primary sampling unit is a 'site' defined as a 200m x 200m cell and the secondary sampling unit is a 'transect' defined as 1x10 m belt transect. At a minimum the survey design calls for 2 sites per reef 'strata' and two replicate transect per site. More sites are allocated to higher variability strata such as patch reefs. The strata have been developed and refined each survey year since 2005, the past two years and are based on subregional divisions, cross shelf divisions, habitat type, and bathymetry. This stratification framework continues to be revisited each year and is being iteratively improved to more accurately describe how reef community types are organized.

Each survey site will have a primary and secondary set of GPS coordinates (first attempt to locate coral habitat at the primary coordinates- search an area of 100 m radius around the GPS point. If any suitable (non-soft bottom) habitat is found, drop a float and anchor the boat. If no suitable area is found within the 200x200 m cell, then go to the secondary location (within the same zone) and repeat the procedure. If the secondary site is either too far away or also unsuitable, go to an area known to have hardbottom/reef with THE SAME FRRP ZONE and survey that location- (If the site is not within 200 m of the primary or secondary coordinate, when you log into www.FRRP.org to record the data, it will assign a site number which denotes a strategic location instead of a randomly selected site).

Once at the proper site, it is critical that the exact location of the actual survey (transect locations) be recorded using a GPS. Drop a float at the site based on the numbers and then try and anchor or attach to a mooring ball as close as possible. We

are also encouraging teams to use a small weighted float to make transect locations less biased- lower or throw two weighted line when you are near the suitable reef survey are. Before doing this, you should adjust the length of the buoy line to be similar to the water depth. Swim down to the weight end of the line and start your transect from that location by laying out the line. When you are done with the benthic survey (2 transects per site), you should record the GPS location of the buoy.

Benthic Survey

1. At each site, record the following information on your UW datasheet before each dive. (We strongly suggest that each team member fills in every category.)
 - Name of recorder (use four letter codes- first two initials of first name, first two initials of last name. Example: John Smith= JOSM)
 - Date as day with two digits/abbreviation of month/year with two digits;
 - Latitude; As determined by dGPS.
 - Longitude; As determined by dGPS.
 - FRRP site code ID number
 - Reef Zone/Habitat (e.g. reef crest, reef front, spur and groove, etc.) (note- if the reef zone/habitat surveyed appears different than predicted, please describe the actual reef zone/habitat following the survey)
2. In Time Start, record the time at which you start the first transect.

Haphazardly lay the 10 m transect line just above the reef surface. Make sure the line is taut.

Note: Be sure to avoid and don't cross the other transect that is being set by a second surveyor. Lines should be at least 5 m apart so data from the each transect are not autocorrelated, which can happen if you are too close and features of one transect impact the other (big corals for example). Stay away from the edges of the reef. Also try to avoid areas with

abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble. Swim without looking down at the bottom as you unreel the line.

Each transect can be surveyed in two “passes” of the transect line as follows:

First Pass

Parameter	Method
None	Lay out and straighten line.
Additional request	Record presence/absence of any acroporid corals (outside of belt)

Second Pass

Parameter	Method
Stony Coral Density	ID species all corals $\geq$ 4 cm within the 10x 1 m belt transect
For scleractinian corals record the following	
Coral Size	Max. length and height to nearest cm
Coral Partial Mortality	% “recently dead” and “old dead” of the total surface area per colony
Tissue isolates	Number of isolated tissue fragments on colony.
Coral Bleaching	Score any visible bleaching on the colony- use codes ((P-PB,BL) per colony
Coral Disease	Identify any coral disease on the colony- use disease codes (BB=black band)
Comments	Make a note of any overgrowths, predation, or other sources of recent mortality
For hydrocorals (e.g. fire corals) only record the following	
Coral Bleaching	Score bleaching by code (P-PB,BL) per colony within the belt transect

First pass:

3. Swim a belt transect along the 10 m line. Tie the first end of the transect line off to a dead piece of coral, fire coral, gorgonian, or other feature that is not living coral. Once at the end of the transect (past the 10m mark), pull tightly and securing the line. Note the depth at the start and the end of the transect line (0 m and 10 m).

Second pass:

4. As you swim from one end of the transect line to the other, assess the cover, size and condition of each stony coral that is 4 cm in length or greater and for which any live or dead part of its skeleton is within 1 m of the transect line. Lay down the 1 m measuring pole perpendicular to the transect for scale. Try to work the same side of a transect line.

- a. Identify stony corals to species and record using four letter species codes.
- b. For all scleractinian corals measure the x, z dimensions of the colony with the 0.5 m measuring bar (or tape): i.e. the maximum diameter (x) of the outward-facing colony surface (perpendicular to the axis of growth) as seen from above in planar view, and the maximum height (z) (parallel to the axis of growth) as seen from the side of the colony. Record these measurements to the nearest cm.

Note: Colony boundaries can be difficult to recognize when parts of the coral have died and are overgrown by other organisms—particularly other colonies of the same species. Look for connected live tissues, connected skeletal deposits above a common base, and at the size and color of separated polyps.

Colonies derived from new recruits:

- 1) *Live tissue, generally concentric with clear edge boundaries. Often have a raised “lip” at edges approximately 1-2 mm above underlying substrate/old dead coral.*
- 2) *Upward growth, branching evident.*
- 3) *Underlying substrate is very old dead.*

Colonies derived from resheeting:

- 1) *Live, often with preferred growth in one direction, edges on at least one side often “merge” with underlying substrate/dead coral.*
 - 2) *Live tissue rarely displays upwards growth (branching) except at tips.*
- c. Estimate the partial mortality (old and recent) of the whole colony surface. Try to round your percentage to the nearest 5% unless it is very small or very large, in which case try to round to the nearest whole number (e.g. 1%, 97%).

“Old dead” is defined as any non-living parts of the coral in which the corallite structures are either gone or covered over by organisms that are not easily removed (certain algae and invertebrates). If it is entirely “old dead”, indicate this on your data sheet as 100% “old death”, as long as you can identify it to either to the species (e.g. *Acropora palmata* by gross morphology; *Montastraea cavernosa* by polyp size and shape) or to the genus (e.g. *Diploria* by size of meandering ridges and valleys).

Note: In some cases, a coral may be partially or completely overgrown by one of the species of brown, zooxanthellate clionid sponges. If you look closely you will observe the in/ex- current holes of the sponge and sponge tissue instead of live coral polyps. If you can see the coral skeleton beneath the sponge, and are able to identify it to genus or even species, include the affected area in your estimate of “old death” and note “Cliona overgrowth” in the corresponding Comments box.

“Recently dead” is defined as any non-living parts of the coral in which the corallite structures are either white and still intact or slightly eroded but identifiable to species. Recently dead skeletons may be covered by sediment or a thin layer of turf algae.

Note: How to assess corals that are detached from the substratum:

- i. If it has recently fallen, the length, height and % mortality should be measured as if it were still upright; write “fallen” in comments box.*
 - ii. A detached but wedged coral should be marked as “wedged” in the comments section (as it is likely to remain in this position for an extended period). If it has been fallen for long enough to have reoriented to grow upward in its new position, the “new” maximum length and maximum width should be measured, and the new outward-facing surface used for calculating % mortality.*
- e. Scan over the surviving portions of the ENTIRE coral colony for any DISEASES and/or BLEACHED tissues present.
 - f. Characterize any DISEASES by the following color categories:
 - BB = Black band
 - WB = White band (*Acropora* only)
 - WS = White patches/white pox/patchy necrosis (*Acropora* only)
 - WP = White plague
 - YB = Yellow-band/yellow-blotch
 - RB = Red band
 - UK = Unknown

For more information about coral diseases see the disease cards (Bruckner & Bruckner 1998) or one of the following web sites:

<http://www.unep-wcmc.org/marine/coraldis/cd/index.htm>

http://www.coral.noaa.gov/coral_disease/

Characterize any BLEACHED tissues as approximate severity of discoloration:

blank = No bleaching

P = Pale (discoloration of coral tissue)

PB = Partly Bleached (patches of fully bleached or white tissue)

BL = Bleached (tissue is totally white, no zooxanthallae visible)

Many severely bleached corals are translucent, but you can still see the polyp tissues above the skeleton. Bleached tissues should not be included with the “recently dead” estimates.

Note: It is important to be able to differentiate between tissues that are alive but look white because they are bleached and white, recently dead skeletons.

- g. For Milleporid species (*Millepora alcicornis* and *Millepora complanata*) that are 4 cm or greater within the belt transect, you only need to record the presence of each colony and the degree of bleaching.
9. You should complete two transects per site. After surveying, either transcribe slates to paper and then enter data to spreadsheet, or enter data into spreadsheet and print out a copy. Enter your data into ww.frrp.org, according to the prompts in the website. Please check your data to verify its accuracy then close the site.

CREMP/SECREMP Stony Coral Demographic Survey

(includes SSI data collection)

Procedures

- One diver will complete one entire Stony Coral Belt Transect survey independently at each station within a given site.
- Each surveyor will swim to the offshore stake of the 300 transect of a sampling station and confirm the stake coding (number of holes drilled into stake) at the offshore stake of the station to verify their station location and complete data info.
- A surveyor will run a transect tape to the inshore stake of that station and lay chain beneath the transect tape. The surveyor affixes a brass clip to a chain link above the 10m mark for additional reference. The surveyor must ensure the distance is 10m from the stake, not necessarily the 10m mark on the tape. This is to account for transect tapes wrapped around the stake or tapes in which the ends have broken off. Surveyors will complete 1 x 10m belt transect survey starting at the offshore stake, working inshore, using the chain as a guide. Each surveyor will use a 0.5m PVC measuring stick to denote the belt transect boundaries (0.5m to either side of the chain, such that the chain lie at the center of the sampling unit).
- When it is necessary to split the completion of a transect between two divers, each diver will be responsible for 5m² of the transect. Divers will predetermine which section of the transect to complete (e.g. 0–5m, 5–10m) and affix a brass clip to the chain at the 5m mark in addition to the 10m mark.
- Record collector name, site name, station number, and date at beginning of survey. If the transect was split between two surveyors record which portion of the transect was completed; 0–5m or 5–10m.

Stony Coral Belt Transect Survey Protocol

- **General Guidelines:** All corals ≥ 4 cm in diameter within the 1m belt transect boundary will be identified to species, using a four letter species code, measured to the nearest cm using the ruler affixed to the 0.5m PVC pipe, and assessed for condition by completing the Stony Coral Belt Transect Datasheet.
- Any coral < 4 cm and identifiable to species will be circled on the species list on the data sheet and marked as present only. A precise measurement to determine if the maximum diameter is ≥ 4 cm is made using an aluminum measuring tool.
- When present, the hydrocoral *Millepora alcicornis* is only denoted by circling its species code in the upper right column. *Millepora alcicornis* colonies are not measured. *Millepora complanata* colonies are recorded and measured.
- **Belt Transect Boundaries:** All colonies ≥ 4 cm with a portion of living tissue inside the 10 x 1m belt transect should be recorded and measured. Colonies in which only the dead portion of skeleton is present within the 10 x 1m belt and contain no living tissue inside of the 10 x 1m belt are NOT enumerated.
- Colonies that are ≥ 4 cm in maximum diameter but the area of living tissue is < 4 cm are recorded and measured.
- If a colony contains tissue isolates (defined in **1.1.2.14**) all isolates are counted regardless of whether they occur inside or outside of the belt transect.
- Broken or fragmented colonies that are loose along the substrate are NOT enumerated. Colonies that are loose but are 'entangled' in the substrate such that they cannot be picked up are recorded and measured.

- **Maximum Diameter and Height**

Measurements: The surveyor measures and records the maximum colony diameter and maximum height for each autonomous colony to the nearest cm using the 0.5m PVC ruler.

- Maximum diameter is defined as the outward-facing surface of the colony (perpendicular to the axis of growth). The maximum diameter measurement includes both living tissue and dead areas of the colony. The surveyor should apply a conservative approach to measuring the maximum diameter of a colony. If previous mortality cannot be *conclusively determined* (in other words, there is NO doubt in your observation) around the perimeter of the colony, the maximum diameter measurement should only measure the area of living tissue.
- Maximum height is parallel to the axis of growth, perpendicular to growth bands, as viewed from the side of the colony.
- **Mortality:** For each colony the surveyor will estimate the percentage of “old” and “recent” mortality to the nearest percentage.
- Old mortality is defined by the absence of any corallite structure and often overgrown by algae or invertebrates. Whole colonies that are 100% “old” dead are NOT recorded in the survey.
- Recent mortality is defined by algae-free, intact or slightly eroded calyx structure in the absence of any living tissue.
- **Isolates:** Tissue isolates are fragmented, disconnected portions of living tissue on the same colony. Distinguishing between tissue isolates and autonomous coral colonies can be difficult for some species when the perimeter of the isolates have been overgrown by algae or other encrusting organisms (e.g. *Siderastrea siderea*). The surveyor should apply a conservative approach when classifying isolates as part of the same colony. If it cannot be *conclusively determined* (in other words, there is NO doubt in your observation) that the isolate in question is part of the same colony, then the coral should be treated as a separate

autonomous colony and measured and recorded separately.

- For each colony with ≥ 2 tissue isolates, the total number of isolates is recorded, regardless of isolate size.
- For colonies with many isolates, the number of isolates should be counted quickly in an attempt to gain an accurate estimate rather than intensively counting every isolate.
- Isolates are not enumerated for the following species: *Acropora cervicornis*, *Eusimilia fastigiata*, *Porites porites*, and *Madracis* spp.
- **Disease and Condition:** The presence of any disease, syndrome, paling, bleaching, or adverse conditions (e.g. presence of *Cliona* spp. or *Clonid delitrix*, damselfish, or predation) will be recorded for each species. Each disease or condition present will be denoted individually using the condition codes listed in the lower right column of the datasheet.
- For each condition, the percentage of the colony affected is estimated in parentheses. Multiple conditions on a single colony are listed and estimated separately.
- The estimate (percentage) for disease includes the active portion disease and the recent mortality inflicted that can be conclusively assigned to the disease lesion, and is calculated as a proportion of the live and/or recently dead part of the colony only. This estimate does not include old, dead areas of the colony.
- The estimate for *Cliona* spp. includes the area occupied by the colony (evidenced by tissue presence and/or oscula), and is calculated as a proportion of the entire coral colony, including live and dead areas.
- Bleaching is determined as either bleached (defined as tissue is totally white with no zooxanthellae visible) or paling (defined as discoloration of coral tissue, but still containing some zooxanthellae cells).
- **Diadema:** The total number of *Diadema antillarum* encountered along the 10 x 1m

belt transect are tallied in the box in the lower right hand corner of the datasheet. Whether an individual urchin is counted or not is dependent upon the location of the test. Urchins with any portion of their test inside the belt transect are counted. Urchins are NOT counted if only their spines are inside the belt transect.

- Note location of specimens needing confirmation or consultation for identification.

Several difficult-to-identify forms are lumped into a single species complex. The following is a list of the complexes with all associated forms:

- *Agaricia agaricites* complex may include:

- *agaricites* (linne, 1758)
- *carinata* (wells, 1973)
- *danai* (milne edwards and haime, 1860)
- *purpurea* (lesueur, 1821)

- *Porites porites* complex may include:

- *porites* (pallas, 1766)
- *clavaria* (lamarck, 1816)
- *furcata* (lamarck, 1816)
- *divaricata* (lesueur, 1821)

- *Montastraea annularis* complex may include:

- *annularis* (ellis and solander, 1786)
- *faveolata* (ellis and solander, 1786)
- *franki* (gregory, 1895)

- On deck, rinse data sheets and review entries prior to submittal to FWRI designee.
- Each surveyor is responsible for entering their datasheet into the FWRI database. Enter data using designed .csv template

CREMP/SECREMP Camera Transects

Setup Procedures

- Prior to beginning field work, charge all camera batteries and format the memory cards (at the beginning of each field trip).
- Once on the boat, prepare the clapperboard with the correct date, site name, and photographer. Ensure that all necessary station and transect pieces are attached to the back of the clapperboard.
- Remove, clean, and re-grease the o-ring at the beginning of each field trip and at least every few days. Replace the o-ring on the housing and check it carefully for nicks, fibers, sand, etc., removing any debris before closing the housing to ensure a tight seal. Do this even when not re-greasing the o-ring.
- If there is room inside the housing, insert a desiccant before closing.
- Once the housing is latched shut, turn on the camera and ensure that the batteries are fully charged and the image size is set to M2. If shooting a site shallower than 30ft, set the camera to underwater (Func. Set → Rec. Mode). If the site is deeper than 30ft (or if the water is especially dirty/green), set the camera to program mode and custom white balance.

* Note: the Canon housing does not allow access to white balance settings. When possible, use the Ikelite housing at deeper sites.

- Attach the scale bar to the bottom of the housing, so that the bar is perpendicular to the housing and the bend at the bottom of the bar points toward the top of the camera (see diagram). Tighten the bolt until the scale bar does not swivel at all.
- Do not jump into the water with the camera. Have someone hand you the camera or set the camera on the dive platform.



Camera Transect Protocol

- Locate the offshore stake of the first station to be photographed and turn on the camera. If using custom white balance, set the white balance by going to Func Set → White Balance → Custom. Turn the clapperboard over, so the white side is up, and set it on the substrate. With the scale bar on the substrate behind the clapperboard, the camera zoomed all the way out, and the center of the viewfinder set on the back of the clapperboard, press the “Disp.” button.

* Note: when setting the custom white balance, it is critical to do so in the same conditions in which the rest of the transect will be shot (e.g., same distance from lens, depth, lighting). If there is a considerable change in depth from one side of the station to the other, swim to the middle of the transect to set the white balance.

- Take a picture of the clapperboard, ensuring that the correct station and transect pieces are in place on the clapper. If zooming in for the clapper image, make sure the camera is zoomed all the way out again before beginning the transect.
- Once the 300 chain has been laid and the transect tape has been removed, place the bottom of the scale bar on the substrate behind the offshore stake (facing the station) so that the front of the camera is approximately parallel to the substrate. Ensure that the stake is clearly visible in the viewfinder (preferably toward the bottom of the frame). Press the shutter release button lightly until the box in the center of the viewfinder turns green (indicating the camera is focused) and then fully depress the shutter button to capture the image.

* Note: anytime an object or organism (e.g., stake, octocoral, sponge) in the middle of the frame is closer to the camera lens than the substrate, the camera will tend to focus on that instead of the substrate. It might be necessary to pull an octocoral to the side or tilt the camera to one side (without lifting or moving the scale bar) in order to focus on the substrate. Press and hold the shutter release button halfway down and move the camera back into position before taking the picture.

- Take note of what is at the top of the viewfinder. This will be the beginning of the next image to be captured. Once the image has been captured, move the scale bar along the chain until what was at the top of the viewfinder is now at the bottom. Use the chain or other prominent benthic features or organisms as markers.
 - * Note: when using the Ikelite housing, set the bottom of the scale bar just to the left of the chain. When using the Canon housing, set the scale bar just right of the center of the chain.
 - * Note: avoid setting the scale bar down on live coral tissue. In cases where there is a colony directly beneath the chain, be careful to hold the camera so that the bottom of the scale bar floats just above the surface of the colony.
 - * Note: the flash should not fire, even on auto. If it does, turn off the flash and reshoot the image. Also reshoot any images you think might be blurry. If possible, delete the image that was reshot, and if not, make a note in the camera log whenever there are images that need to be deleted.
- Repeat this process until reaching the end of the transect, ensuring that the inshore stake is clearly visible in the last image of the transect.
- Turn off the camera between stations to prolong battery life, paying close attention to the battery meter if shooting multiple sites in one day.
- Repeat steps 1.4.2.1 through 1.4.2.6 until all stations are completed for that site. Return to the boat and immediately place the housing in a fresh water bath and let it soak for at least 10 minutes. If there is plenty of battery life remaining, do not open the housing between sites (just update the clapperboard). If the battery does need to be replaced, dry the outside of the housing thoroughly before opening it.
- When field work is completed for the day and the camera housing has been soaked and dried, place the housing (with the camera inside) in the appropriate Pelican case.
- Recharge any batteries that were used, fill out the camera log, and upload all pictures from the day into corresponding site and station folders on the 250 GB portable hard drive. Do not delete images from the memory card.



Photo by Jiangang Luo



Financial assistance provided by the Coral Reef Conservation Act, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Association. Grant NO. NA09NOS4190173