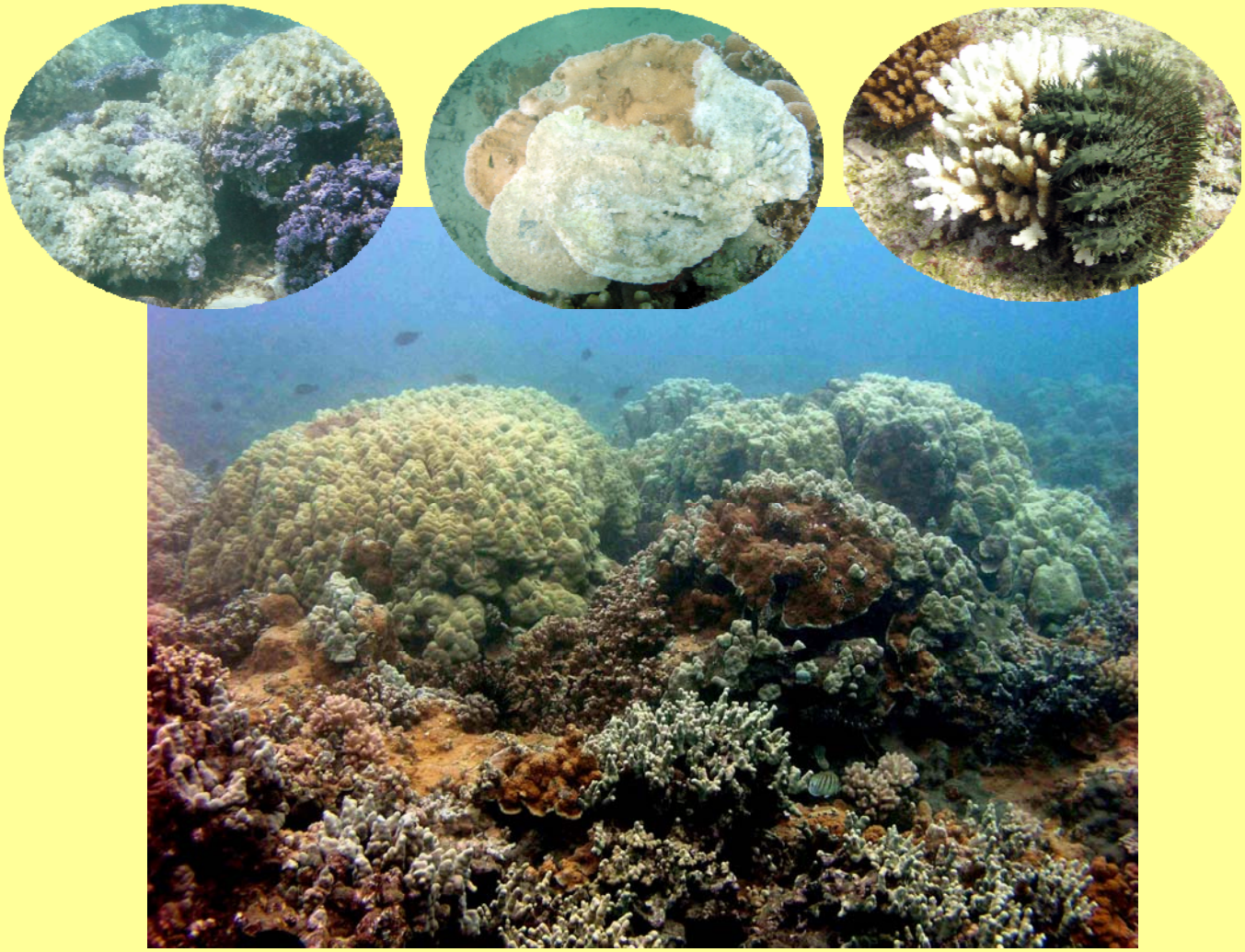
Hawaii's Rapid Response Contingency Plan

for events of coral bleaching, disease or crown-of-thorns starfish outbreaks



Dr. Greta Smith Aeby, Melanie Hutchinson and Petra MacGowan

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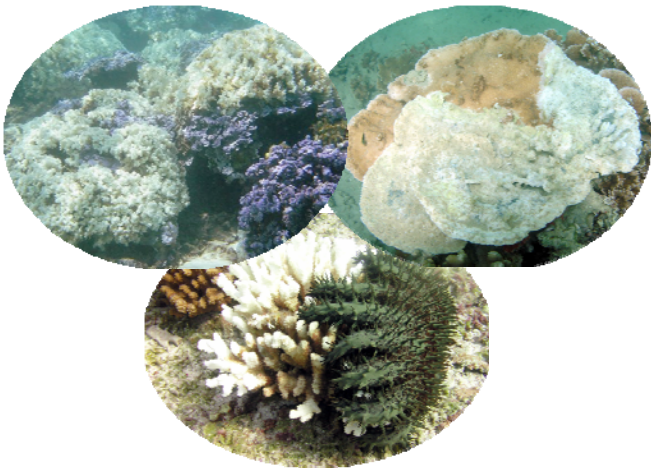
Proceedings from the development of the Rapid Response Contingency Plan workshops 2008



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ACRONYM LIST

AIS	Aquatic Invasive Species
CCMD	Climate Change and Marine Disease
CDHC	Coral Disease and Health Consortium
COTS	Crown of Thorns Starfish
CRAMP	Coral Reef Assessment and Monitoring Program
CRED	Coral Reef Ecosystems Division
DAR	Division of Aquatic Resources
DHW	Degree Heating Week
DLNR	Department of Land and Natural Resources
DOD	Department of Defense
DOH	Department of Health
EOR	Eyes of the Reef
EPA	Environmental Protection Agency
FKNMS	Florida Keys National Marine Sanctuary
FWS	Fish and Wildlife Service
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
HIMB	Hawaii Institute of Marine Biology
LAS	Local Action Strategy
MHI	Main Hawaiian Islands
MOA	Memorandum of Agreement
MOP	Marine Option Program
MWS	Montipora White Syndrome
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWHI	Northwestern Hawaiian Islands
PMNM	Papahanaumokuakea Marine National Monument
POC	Point Of Contact
QUEST	Qualitative Ecological Underwater Surveying Techniques
RAMP	Rapid Assessment and Monitoring Program
RRCP	Rapid Response Contingency Plan
SST	Sea Surface Temperature
TEK	Traditional Ecological Knowledge
TNC	The Nature Conservancy
UH	University of Hawaii
USCRTF	United States Coral Reef Task Force
USCG	United States Coast Guard
USGS	United States Geological Survey

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Introduction

Coral reefs in Hawaii provide critical services including commercial, recreational and subsistence fishing, create world-famous surfing and diving locations and are vital to Hawaii's approximately $800 million a year marine tourism industry (Friedlander et al., 2008). Despite their economic significance, reefs are experiencing high levels of anthropogenic stress from ever-increasing population pressures. Friedlander and DeMartini (2002) concluded that the human-impacted reefs of the main Hawaiian Islands (MHI) are severely over-fished after finding significant differences in the density, size, and biomass of shallow reef fish assemblages compared to the pristine reefs of the northwestern Hawaiian Islands (NWHI). They also found that the grand mean fish standing stock in the NWHI was more than 260% greater than in the MHI and that the MHI apex predators (sharks and jacks) are near extirpation. Sediments, nutrients and other pollutants from a variety of land-based activities also threaten reefs and consequently, Hawaii's reefs are starting to show significant decline (Friedlander et al., 2008). Williams et al. (2007) report that several reefs on Maui lost nearly 25% of their living coral between 1994 and 2006 primarily as a result of human influence. The most dramatic decline was at Honolua Bay, where coral cover dropped from 42% to 9% (Fig. 1) (http://hawaii.gov/dlnr/dar/pubs/MauiReefDeclines.pdf).

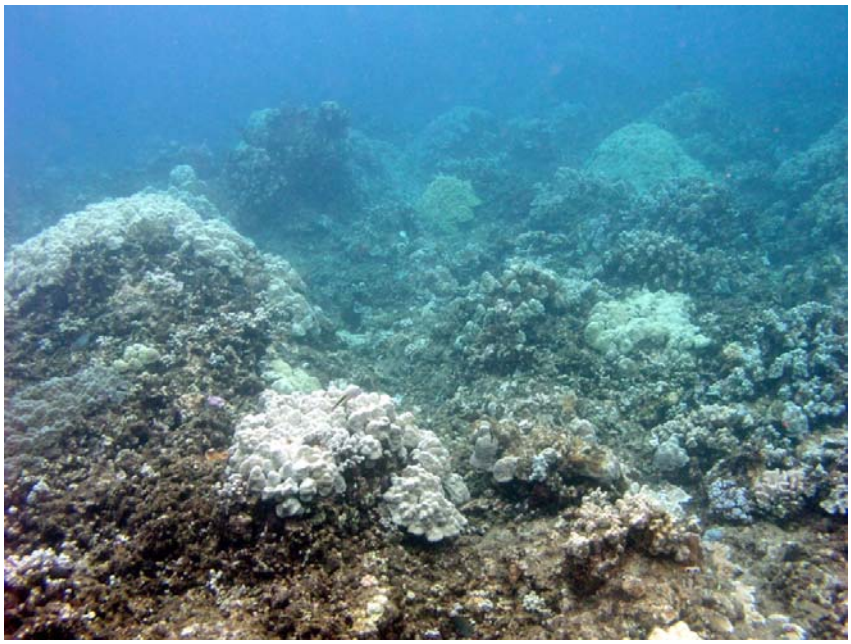


Figure 1. Honolua reef, Maui. Coral reef in decline due to human impacts.

In addition to managing local stressors, coral reef resource managers are also tasked with planning ahead to address the anticipated problems associated with global climate change, such as increases in coral bleaching, disease and the potential for crown-of-thorns starfish (COTS) outbreaks. Currently, there is no mechanism in place to properly respond to large-scale reef altering events, and so the development of Hawaii's Rapid Response Contingency Plan (RRCP) for unusual events of coral bleaching, disease and COTS outbreaks was initiated. This document represents the collaboration between the Hawaii Division of Aquatic Resources (DAR), the Hawaii Institute of Marine Biology (HIMB) and numerous other academic, management and non-governmental organizations (NGOs) that have aided in the first phase of the development of Hawaii's Rapid Response Contingency Plan.

Potential Threats to Hawaii's Reefs Associated with Global Climate Change

Coral Bleaching

Reef corals contain symbiotic, single-celled algae (zooxanthellae) that provide over 90% of a coral's energy (Muscatine, 1990). Coral bleaching is defined as either the loss of symbiotic zooxanthellae or the loss of the photosynthetic pigments from individual zooxanthellae. This results in an energy drain on the coral that can lead to reductions in growth and reproduction and possibly death (Glynn, 1984; Marshall and Baird, 2000). Although coral bleaching can occur in response to stresses such as changes in salinity, light or irradiance, mass bleaching events are usually associated with increased sea surface temperatures (SST). In 1997-98, mass bleaching occurred on reefs throughout the world due to increased sea surface temperatures associated with an El Nino event (Wilkinson et al., 1998; Wilkinson, 2000), where an estimated 16% of the world's coral reefs were lost (Wilkinson et al., 1998). Severe bleaching can result in the loss of live coral and a general decline in the integrity of coral reef ecosystems. It is predicted that the impacts of global climate change will result in more frequent and extensive bleaching episodes (Hoegh-Guldberg, 1999).

Hawaii's coral reefs were not affected in the 1998 mass-bleaching event but coral bleaching has occurred in both the main and northwestern Hawaiian Islands on other occasions. The first large-scale coral bleaching event in Hawaii occurred predominantly in Kaneohe Bay in 1996. This bleaching event was attributed to increases in SST and high irradiance during a rare cloudless period (Jokiel and Brown, 2004). In addition, a mass-bleaching event, also due to increased SST (Hoeke et al., 2006), was documented in the northwestern Hawaiian Islands (NWHI) in 2002 (Aeby et al., 2003; Kenyon et al., 2006a). The back reefs of the three northernmost atolls (Pearl and Hermes, Midway and Kure) were the most affected by bleaching. The two coral genera most susceptible to

bleaching were pocilloporids and montiporids. Another minor event was observed in 2004 in the NWHI with patterns of bleaching consistent with what was observed in 2002 (Kenyon and Brainard, 2006). Jokiel and Brown (2004) found that the sea surface temperatures in Hawaii have been steadily increasing over the past several decades and predict that if the warming trend continues, bleaching events will continue to occur in Hawaii with increasing frequency and severity.

Coral Disease

Disease can be defined as any impairment of vital body functions, systems, or organs (Stedman, 1995). The causal agent of a disease can be either biotic or abiotic. Biotic diseases are those in which the causal agent is a living organism such as bacteria, viruses or macro-parasites. Abiotic diseases result from environmental stressors, such as changes in physical conditions or exposure to toxic chemicals. There has been a worldwide increase in the reports of diseases affecting marine organisms (Harvell et al., 1999). In the Caribbean, mass mortalities among organisms in reef ecosystems have resulted in major shifts in community structure. For example, the mass mortality of sea urchins in the early 1980s throughout the Caribbean resulted in massive algal overgrowth and contributed to phase shifts from coral- to algae-dominated reefs (Hughes, 1994; Lessios, 1988). Disease has also been implicated in the dramatic decline of acroporids, one of the major frame-building corals in the Florida Keys, changing the structure and function of the coral reef ecosystem (Aronson and Precht, 2001; Patterson et al., 2002). It is unknown whether the emergence of these disease outbreaks are due to the introduction of novel pathogens, as suggested for the outbreak of sea fan disease (Smith et al., 1996; Jolles et al., 2002), or to changes in pathogenicity of existing pathogens due to deteriorating environmental conditions and/or reduced host resistance (Harvell et al., 1999; Green and Bruckner, 2000). It is predicted that the changing environmental conditions associated with global climate change will result in future increases in diseases of marine organisms (Harvell et al., 2002), lending new urgency to understanding the epizootiology of marine diseases.

In Hawaii, broad-scale coral disease surveys were initiated in the NWHI in 2002 supported by the Division of Aquatic Resources (DAR) and the NWHI Coral Reef Ecosystem Reserve (now the Papahanaumokuakea Marine National Monument) (PMNM). In 2003, 73 sites were selected for long-term monitoring at nine islands/atolls across the NWHI and were surveyed to quantify and characterize coral disease. Annual monitoring for coral disease has subsequently occurred. Baseline coral disease surveys were initiated in the main Hawaiian Islands in 2004 at a limited number of islands and in 2005, long-term monitoring sites were selected and surveyed during a multi-agency cruise. From these surveys, 18 disease states have been documented from the reefs of

the Hawaiian archipelago affecting the four main coral genera *Porites, Pocillopora, Montipora, Acropora* (Aeby, 2006a; Work et al., 2008a; Work et al., 2008b; Friedlander et al., 2008). These surveys indicate that coral disease is widespread but is occurring at low levels. The exceptions are a 2003 outbreak of *Acropora* white syndrome, which is causing massive mortality of the table corals (*Acropora cytherea*) at French Frigate Shoals within the NWHI (Aeby, 2006b) (Fig. 2) and an outbreak of *Montipora* white syndrome in Kaneohe Bay, Oahu (Friedlander et al., 2008) (Fig. 3). Since coral disease is just emerging as a problem in Hawaii, managers are in a good position to be pro-active and to take action to mitigate this problem. Through management, the hope is that Hawaii can avoid the severe reef degradation associated with disease that has occurred in other areas.

Figure 2. *Acropora* white syndrome

Figure 3. *Montipora* white syndrome

Crown-of-Thorns Starfish Outbreaks

The crown-of-thorns starfish (*Acanthaster planci* Linnaeus) (Figure 4) is a selective corallivore that at high densities has caused widespread destruction on numerous reefs throughout the Indo-Pacific (e.g., Chesher, 1969; Done, 1985; Walbran et al., 1989; Endean et al., 1989). Crown-of-thorns (COTS) are usually present at very low densities and have little effect on the abundance of reef corals (Glynn, 1973, Zann et al., 1990). However, when COTS population outbreaks occur, the resulting damage to coral communities can be extensive. In 1962, on the northern Great Barrier Reef (GBR), outbreak populations of COTS killed 80% of reef-building corals across the entire reef (Pearson and Endean 1969). COTS continue to be a primary concern for conservation of the GBR, with COTS outbreaks reported to have caused greater declines in coral cover than any other threat to the GBR (www.aims.gov.au/docs/research/biodiversity-ecology/threats/cots.html). It is still unclear what drives these population surges but they have been linked to enhanced larval survival due to elevated nutrients from terrestrial runoff (Birkeland, 1982; Brodie et al., 2005). Furthermore, it is likely that *A. planci*

Figure 4. Crown-of-thorns feeding on a montiporid coral

outbreaks are due to a combination of factors and the cause(s) and these may vary among locations (Pratchett, 2005). In Hawaii, a series of outbreaks occurred off the south coast of Molokai in the 1970s with more than 20,000 *A. planci* reported in the initial infestation (Branham et al., 1971). More recently, a localized COTS outbreak was documented off the coast of Oahu with towed-diver surveys reporting more than 1,000 animals (Kenyon and Aeby, in press) (Fig. 5). Even though, COTS have not previously been a major problem for reefs in Hawaii, continual increases in human populations combined with climate change may significantly increase COTS outbreaks. Hence, the decision was made to include COTS outbreaks in the development of the RRCP.

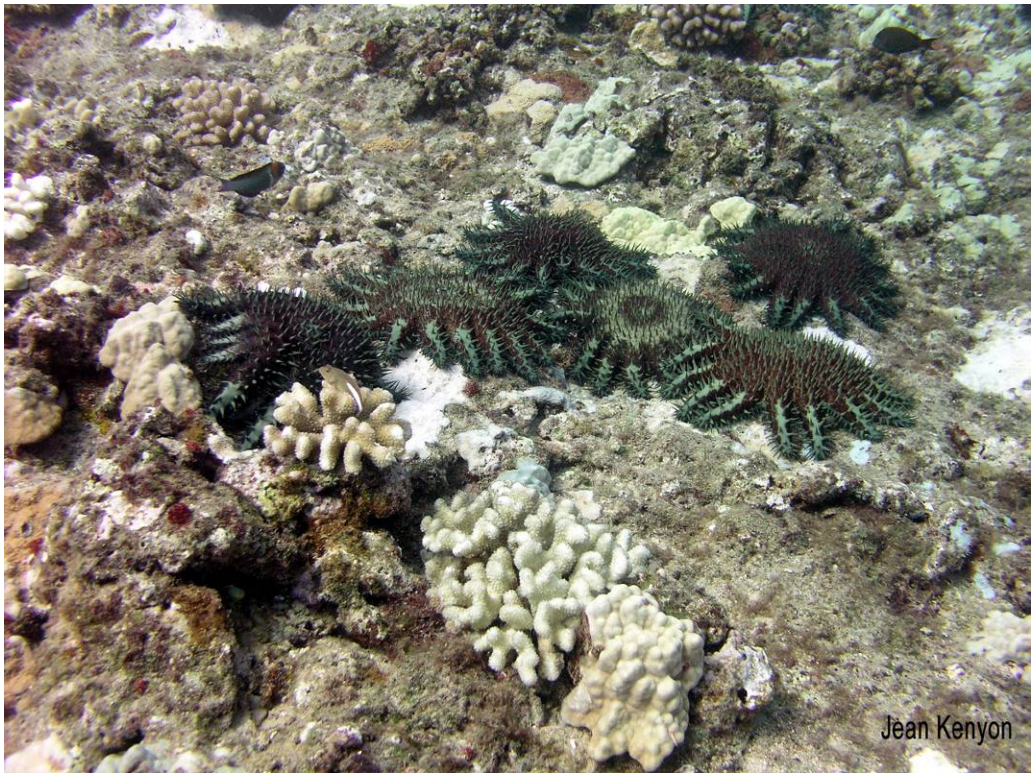


Figure 5. Photo showing high COTS density and outbreak conditions.

Hawaii’s Rapid Response Contingency Plan

PROJECT DEVELOPMENT

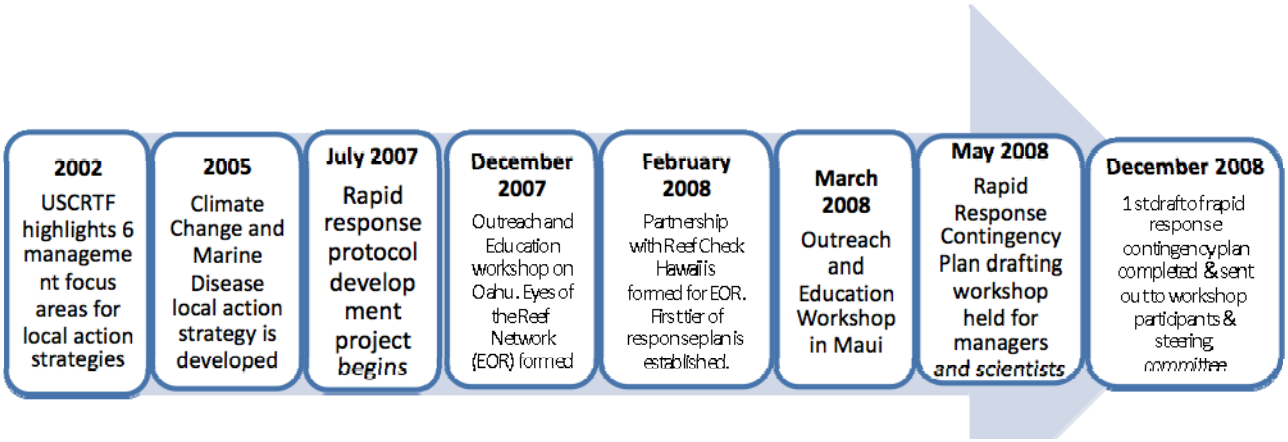


Figure 6. Timeline of events in the Rapid Response Contingency Plan and protocol development process.

In 2002, the United States Coral Reef Task Force (USCRTF) identified six management focus areas based on prioritization of nationwide threats to coral reef ecosystems due to human activities. Identified threats were coral reef fisheries, land-based pollution, lack of public awareness, recreational use, coral bleaching, and reef organism disease. The USCRTF requested that each United States jurisdiction develop three-year plans or local action strategies (LAS) for each of the priority threats. In Hawaii, there are five LAS that address the priority threats listed above, one of which is the Climate Change and Marine Disease local action strategy (CCMD LAS). This LAS was formed to address the threats of coral bleaching and marine organism disease.

A steering committee comprised of local scientists, resource managers, NGO and community members was formed to direct the creation of the CCMD LAS. The steering committee formulated five objectives as priority focal areas for the CCMD LAS. The objectives are: 1) *To support research that provides a scientific basis for managing impacts to reef ecosystems from climate change and disease*, 2) *To increase public awareness and engage stakeholders in monitoring and reporting bleaching and disease,* 3) *To develop a rapid response contingency plan for events of bleaching and disease,* 4) *To develop proactive and mitigative long-term management strategies to increase resistance and resilience of reef ecosystems to impacts from climate change and marine disease,* 5) *To develop a program to monitor the impacts from climate change and marine disease on the reefs of the Hawaiian archipelago* (Appendix A). Every year the steering committee meets to review these objectives and decide on projects to satisfy the requirements of the LAS and fulfill its objectives. The development of a rapid response contingency plan was chosen by the steering committee as a priority project to address both Objectives 2 and 3.

Hawaii's Rapid Response Contingency Plan

This document outlines the Rapid Response Contingency Plan (RRCP) for events of coral bleaching, disease or COTS outbreaks in Hawaii and details its development. In the early stages of the development of the RRCP, the need to engage the public for assistance in the early detection and reporting of coral bleaching, disease or COTS outbreaks was identified. Since Hawaii spans such a vast area with extensive coral reef habitat, scientific and management monitoring efforts cannot adequately cover this broad range. Early detection is also necessary to mitigate the damage that these sorts of events can have on the reefs. Therefore, it is essential to have a large network of coral reef users who are trained in the identification of coral bleaching, disease or COTS outbreaks statewide. To this end, two workshops were held with local outreach and community monitoring providers to increase awareness about the project, and to solicit support and guidance for a monitoring and reporting network of reef users. From these workshops the development of the rapid response contingency plan and response network for coral bleaching, disease and COTS events in Hawaii was initiated.

The system that developed from the outreach workshops took on a tiered structure. Three tiers were identified beginning with the first response, a public report or primary observation. A major component of the first tier was named the Eyes of the Reef (EOR) Network. The second tier is the secondary assessment whereby trained personnel conduct an in water survey to confirm or negate a response. A third level response would involve management action, to conduct monitoring activities or initiate response protocols. Figure 7 shows a simple overview of the tiered Rapid Response Contingency Plan structure.

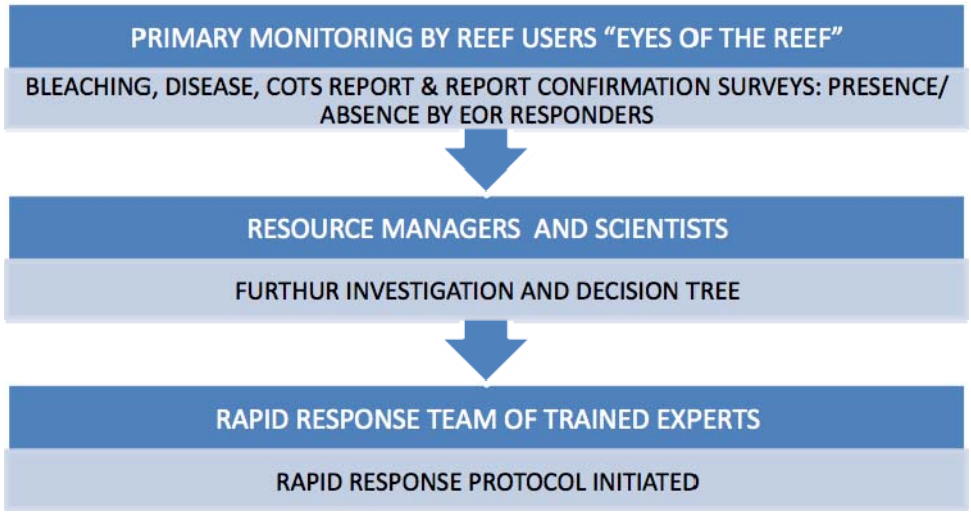


Figure 7. Tiered structure of the RRCP**.**

A major gap that was identified during these workshops was the capacity to receive and house reports. However, after the workshop convened, representatives from Reef Check

Hawaii volunteered the use of their website and phone line to place reports of coral bleaching, COTS or disease observations. A significant outcome from this workshop was the development of a partnership between Reef Check Hawaii, DAR and the Hawaii Institute of Marine Biology to form the Eyes of the Reef volunteer monitoring network.

A third planning workshop was held for scientists and managers to design the RRCP for Hawaii. The workshop convened regional resource managers, academics and scientists to draft the response protocols for coral bleaching, disease and COTS outbreaks. Personnel from Papahanaumokuakea Marine National Monument (PMNM), Coral Reef Ecosystem Division (CRED) of NOAA, Division of Aquatic Resources (DAR), The Nature Conservancy (TNC), Bishop Museum, Oceanic Institute, National Park Service (NPS), University of Hawaii (UH) and the Hawaii Institute of Marine Biology (HIMB) were present at this meeting. The participants were arranged into three groups according to their areas of specialization and expertise and consisted of coral bleaching and COTS, coral disease, and resource management. The workshop objectives for the participants are outlined below and each focus group had a set of questions to address that was particular to that group. The results and recommendations of their meetings are summarized and found in Appendix B.

Workshop Objectives:

1. Discuss the development of the rapid response contingency plan and introduce other plans already in place.
2. Have managers, scientists and other participants develop protocols for bleaching, disease and COTS outbreaks in Hawaii.
3. Review and agree on draft coral bleaching, disease and COTS outbreak protocols

Figure 8. Workshop Participants L-R Back Row; Kem Lowry, Alan Friedlander, Larry Basch, Steve Coles, Melanie Hutchinson, Fenny Cox, Kimo Carvalho, Randy Kosaki, Bernardo Vargas-Angel, Michael Stat, Barrett Wolfe, Kevin Lino, Kyle Koyanagi, Amanda Meyer, Eric Conklin, Steve Cotton, Brent Henning. Front Row L-R; Greta Aeby, Chris Runyon, Jean Kenyon, Stephanie Schopmeyer, Elizabeth Keenan, Cori Kane, Pam Weiant.

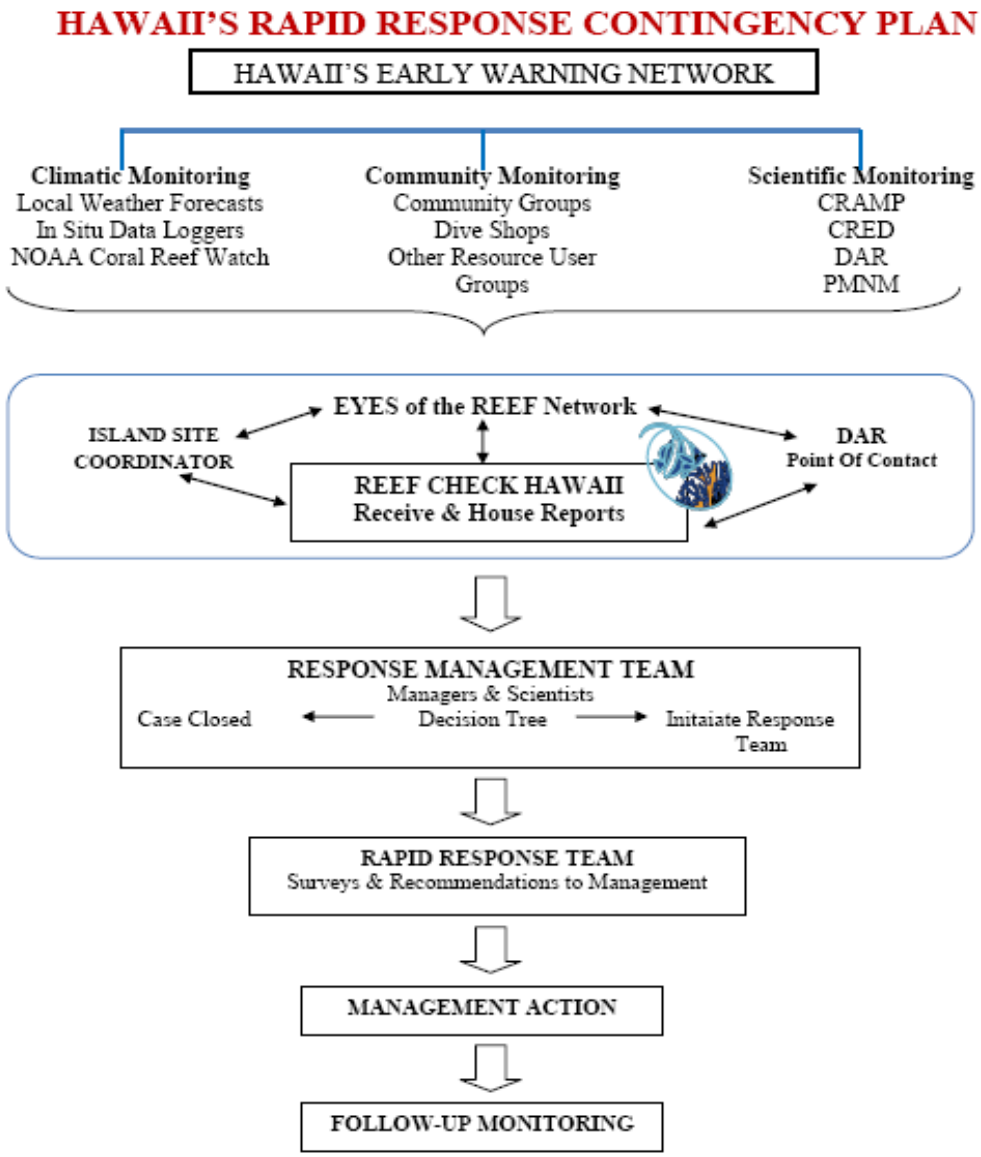
Hawaii’s Rapid Response Contingency Plan

Overview of Hawaii's Rapid Response Contingency Plan

Introduction

Hawaii's Rapid Response Contingency Plan (RRCP) for unusual events of coral bleaching, disease, and COTS outbreaks was developed to give managers the capacity to respond to events in a timely and efficient manner. The establishment of protocols to investigate these events provides the opportunity to methodically collect a range of data to assist in determining the significance, epizootiology and causal linkages, and to evaluate the findings, develop predictive models and present options for future research and mitigation to resource managers. Figure 9 below gives a conceptual model of the overall framework of the RRCP. The initial phase of a response begins with an observation by a diver, scientist or other reef user of an unusually high level of bleaching, disease or COTS on one of Hawaii's reefs. A report would be made to the **Eyes of the Reef (EOR) Network,** which is housed within Reef Check Hawaii. The EOR network will have a volunteer Site Coordinator on each of the main Hawaiian Islands who will be responsible for educating local reef users about the program and will be trained and tasked with making an initial evaluation of any reports from their island. The **Island Site Coordinator** in consultation with local DAR biologists and appropriate scientists with expertise in coral bleaching, disease or COTS will evaluate the report and decide on next steps. Their recommendations will be given to the **DAR Point of Contact (POC)** for the RRCP who will contact the appropriate member(s) of the **Response Management Team**. The working Response Management Team would review the case to determine if a rapid response should be initiated. If a response is warranted, the **Rapid Response Team** would be contacted and an incident action plan formulated. A Rapid Response Team Coordinator should be appointed to facilitate permits, site access, logistics, data management, etc and should be the POC for the appropriate regulatory agency (e.g., DAR). A Lead Field Investigator should be appointed and responsible for ensuring surveys are conducted appropriately and samples are collected and processed properly. The Rapid Response Team would be tasked with collecting all relevant biological information, sample collection and reporting their findings immediately to the Response Management Team. The Response Management Team, in collaboration with the Rapid Response Team, would then make decisions on management actions, follow-up monitoring and be responsible for communicating findings to decision-makers, stakeholders and media**.**

Figure 9. Conceptual model of Hawaii's RRCP



Components of the Contingency Plan

Hawaii's Early Warning Network and Eyes of the Reef

Resource limitations in conjunction with the widespread and numerous reef areas create a challenge for reef managers wishing to detect the onset of coral bleaching, disease or COTS events. Hawaii's early warning network was developed to address that problem and is composed of climatic, community and scientific monitoring efforts. The strong relationship between temperature and the onset of mass bleaching allow managers to estimate the risk of coral bleaching based upon forecast and observed climatic conditions and sea temperatures. Climatic monitoring allows a manager to be the source of timely and credible information about bleaching risk for decision makers, stakeholders and the media. Coral disease and COTS outbreaks will depend more heavily on community and

scientific monitoring to assist managers in keeping an eye on the reef. Reports from these three components would feed into the EOR network.

Climate monitoring

Climatic monitoring includes tracking local and regional weather patterns, as well as sea surface temperatures (SST). SST is measured on the local scale using in situ temperature loggers and at the regional scale through satellite imagery. Coral Reef Watch (NOAA) has developed three tools that analyze satellite imagery to assess the likelihood of mass coral bleaching events: Hot Spot maps, Degree Heating Week (DHW) maps and Tropical Ocean Coral Bleaching Indices (http://coralreefwatch.noaa.gov/satellite/). These products help to provide managers with an effective early warning system for bleaching events.

Community Monitoring

Community monitoring is one of the critical components of the RRCP as there are numerous coral reefs spread across many islands within Hawaii. Reef users can play a critical role in helping managers monitor the reefs. The support of the community will also be necessary if management actions, following an event, require a modification of human activities. The primary component of the community-monitoring network is the **Eyes of the Reef (EOR) volunteer monitoring network** (www.reefcheckhawaii.org/eyesofthereef) that is sponsored through Reef Check Hawaii and represents collaboration between DAR, HIMB and Reef Check Hawaii. The Eyes of the Reef Network is discussed in detail in section three.

Scientific Monitoring

A number of independent coral reef monitoring programs exist in Hawaii, which examine different components of the Hawaiian coral reef ecosystem. The different monitoring programs present a wealth of information on the basic community structure of Hawaii's reefs which is currently being integrated into a comprehensive geospatial database and will be housed on the server at HIMB. It will be available to management agencies and reef scientists (http://www.hawaii.edu/himb/ccmdgis/index.htm) in 2009. This data provides a baseline on the health of coral reefs around Hawaii. This will be useful for comparative purposes to evaluate whether or not reported bleaching, disease or COTS events are higher than the established baseline levels. Periodic surveys by monitoring programs can also assist managers in monitoring reefs for coral bleaching, disease and COTS outbreaks. Representatives from the different monitoring programs have been involved in the development of this RRCP and will play a prominent role in response activities. The main coral reef monitoring programs in Hawaii are described below.

The NWHI were designated a National Monument in 2006 (Papahanaumokuakea Marine National Monument (PMNM)) and are now managed by three Co-Trustees: the State of Hawaii, the US Dept. of Interior through the Fish and Wildlife Service and the Dept. of Commerce through NOAA. Annual surveys throughout the PMNM have been undertaken since 2000 and in 2003, 73 long-term monitoring sites were established which are re-surveyed in alternating years by either NOAA's Coral Reef Ecosystem Division or PMNM. The Coral Reef Assessment Monitoring Program (CRAMP) has been ongoing since 1999 and monitors changes in benthic and fish communities at 30 sites around the main Hawaiian Islands (http://cramp.wcc.hawaii.edu/). The Division of Aquatic Resources (DAR) currently has coral reef monitoring programs on Oahu, the Big Island, Lanai and Maui (http://hawaii.gov/dlnr/dar/coral/coral_monitoring.html). They have 26 sites across west Hawaii, 2 sites on Lanai and 23 sites on Maui. Ten monitoring sites are planned for Oahu. They monitor benthic (including coral disease) and fish communities. The main Hawaiian Islands Rapid Assessment and Monitoring Program (MHI-RAMP) was initiated in 2005 through CRED to survey sites across the main Hawaiian Islands in areas not monitored by other programs. They collect data on the fish, algae, non-coral invertebrate and coral communities including coral disease assessment.

Response Management Team

The Response Management Team will be composed of resource managers and scientists involved in coral reef research or management in Hawaii. They will be responsible for evaluating reports and deciding if a rapid response is required. Criteria defining what will trigger a response needs to be more clearly defined for each type of event (bleaching, disease, COTS) but an outbreak is commonly defined as an unexpected increase in occurrence in a time or place where it does not normally occur or at a frequency greater than previously observed (Woodley et al., 2008). Outbreaks are usually transitory and short-lived especially for disease outbreaks. They should be treated with a matter of urgency to collect as much information as possible while it is available. The Response Management Team will also be involved in post-response decisions on management actions, follow-up monitoring and communication of the event to media, stakeholders and decision-makers.

Rapid Response Team

The Rapid Response Team will be responsible for documenting the spatial extent of the event, coral species affected, magnitude and severity of the event and for a COTS outbreak, the number of animals. In some cases, especially disease outbreaks, samples may also be required for follow-up laboratory analyses. Investigative teams may be

composed of individuals from local, state and federal agencies, academic institutions, non-government organizations, and trained volunteers. A list of response team members and their contact information will be developed and updated on a regular basis. The Rapid Response Team will be familiar with the investigative techniques and standardized protocols established for the RRCP. A workshop is planned for 2009 to train scientists and test protocols. The Rapid Response Team must function within the legal structure of the jurisdiction overseeing the area affected by the outbreak, which may be federal, state, regional and/or local authorities. Issues such as permitting, safety, dive reciprocity, etc. will need to be addressed.

Management Actions

The ultimate goal of the RRCP is to develop the framework that will give managers the capacity to minimize damage from events and maximize recovery of the reef following the event. Management strategies will vary depending on the type of event (bleaching, disease or COTS) and could be mitigative or supportive in nature. Managing local stressors such as recreation, water quality and fishing would be considered a supportive strategy and would be a good first step in aiding recovery and mitigating damage of any stressed reefs. Other mitigative strategies might include removal of animals (COTS) from the reef, or through the successful manipulation of disease determinants. To that end, management strategies for disease outbreaks must understand the three basic determinants of disease: the host, the agent and the environment. Implementation of Management Actions will be determined in a case by case basis, and factors such as extent of the event, socio-economic value of the reef, presence of rare or endangered species or other factors will be taken into consideration.

Follow-up Monitoring

Monitoring through time is a critical component of responding to a stress event, allowing managers to understand the long-term impact to reefs from events and evaluate the effectiveness of any Management Actions taken. Understanding how a reef responds to a specific stressor will help in the development of predictive models to better guide future control and management efforts.

Hawaii’s Rapid Response Contingency Plan

EYES OF THE REEF Volunteer Monitoring Network

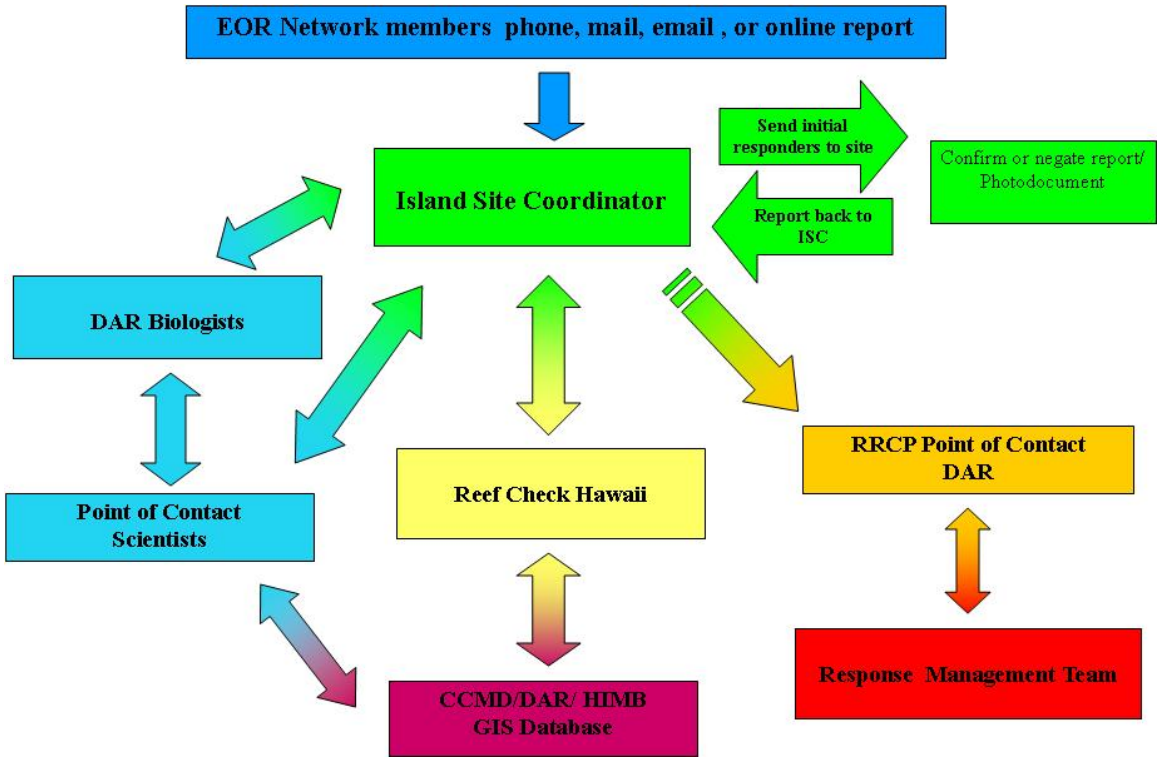
Figure 10. Eyes of the Reef network banner

An essential component of the first tier (Early Warning Network) of the Rapid Response Contingency Plan is the engagement of the community in the Eyes of the Reef (EOR) volunteer monitoring network. Hawaii's reefs span an enormous geographical area making it difficult for managers to detect the early onset of coral bleaching, disease or COTS events. Reef users will be essential in helping managers monitor the reefs, providing the critical mass of 'eyes on our reefs' needed to detect and hence respond to events in an expedient manner.

The development of the first tier of the RRCP began with two outreach and education workshops. From those workshops, a partnership between Reef Check Hawaii, DAR and HIMB was formed and the development of the Eyes of Reef Network was initiated. Reef Check Hawaii now has the capacity to receive and house reports on coral bleaching, disease and COTS outbreaks. The EOR reporting network has recently been expanded to include reports of aquatic invasive species, enhancing linkages between the Climate Change and Marine Disease and Aquatic Invasive Species Local Action Strategies.

The EOR network will have a Site Coordinator on each of the main Hawaiian Islands. This person will receive reports of alleged coral bleaching, disease or COTS events and invasive species via the Reef Check reporting line. They will be responsible for following up on all reports, and in consultation with DAR and local scientists, deciding whether or not a report requires a site visit by an initial responder. EOR site coordinators will also be tasked with reporting the outcome of each report investigation to the GIS Database housed at HIMB for recordkeeping. If a rapid response is recommended based upon the initial site visit, then all information will be given to DAR's RRCP Point of Contact (POC) who will contact appropriate Response Management Team members. This flow of information is diagrammed in Figure 11.

Figure 11. This diagram shows the communication flow through the EOR network.

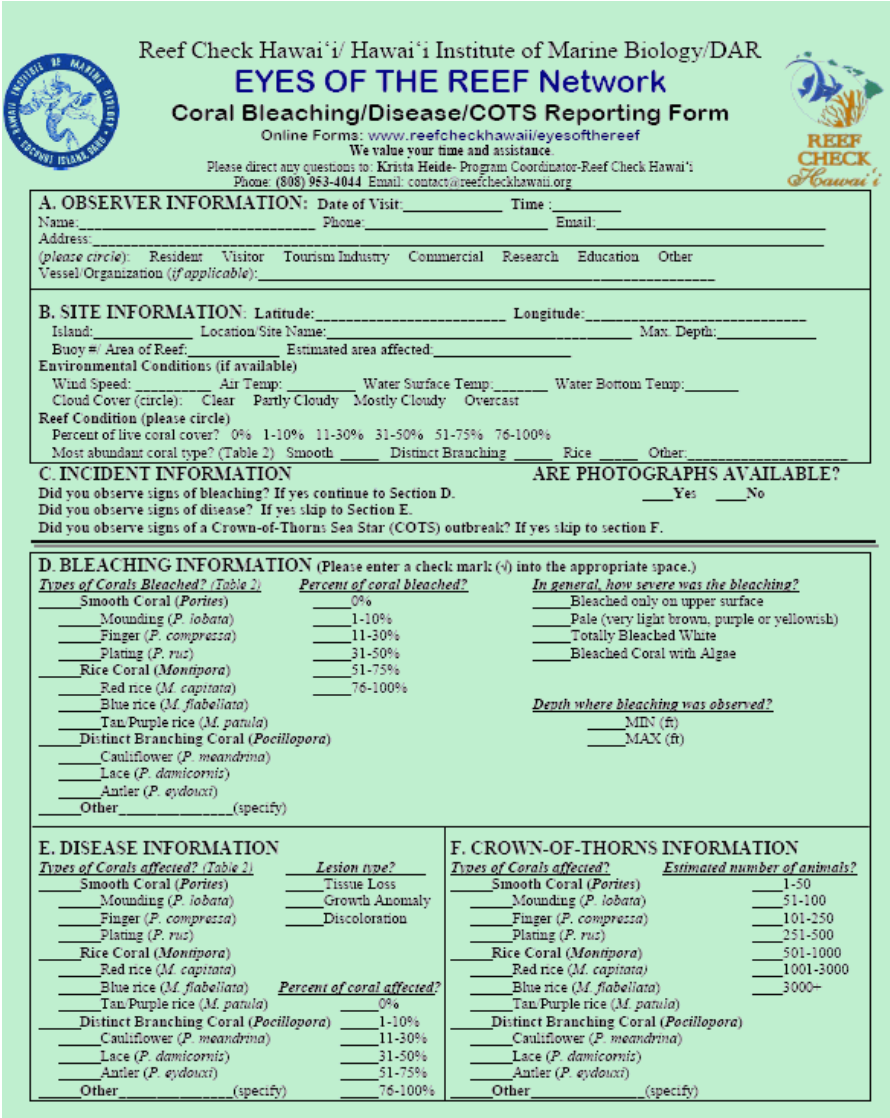


The EOR is also very involved in outreach and education to train community groups, managers, NGOs and others in identification of coral bleaching, disease or COTS outbreaks and aquatic invasive species. Groups targeted to join the EOR network include commercial SCUBA dive shops, skin diver groups, water sport clubs, Malama community groups, NGOs, and schools.

Currently, EOR Island Site Coordinators have been identified for the Big Island, Maui and Kauai. These coordinators along with persons from the CCMD and AIS LAS(s), Reef Check Hawaii and DAR are helping to develop training and outreach materials for the program. These volunteer information packets will include information on the EOR program, coral bleaching, disease, COTS and aquatic invasive species, report forms and waterproof identification cards (Appendix C). Informational posters are also being printed for display at participating organizations. These educational materials will inform the public of the Eyes of the Reef network and direct them where to find more information.

EOR network members will be classified as either level one (novice) or level two (advanced) depending on the amount of training they have received. Two training

modules are under development and will be complete with a PowerPoint presentation prepared for novice community groups, and an advanced presentation for audiences with more experience identifying aquatic organisms. Report forms have been developed for both novice and advanced reporters (Fig. 12). These forms can be filled out online or downloaded from the Eyes of the Reef webpage on the Reef Check Hawaii website: http://www.reefcheckhawaii.org/eyesofthereef.html. Reports can also be called in (808-953-4044).



Reef Check Hawai'i/ Hawai'i Institute of Marine Biology/DAR

EYES OF THE REEF Network

Coral Bleaching/Disease/COTS Reporting Form

Online Forms: www.reefcheckhawaii/eyesofthereef
We value your time and assistance.
Please direct any questions to: Krista Heide- Program Coordinator-Reef Check Hawai'i
Phone: (808) 953-4044 Email: contact@reefcheckhawaii.org

A. OBSERVER INFORMATION: Date of Visit:_____ Time :_____
Name:_____ Phone:_____ Email:_____
Address:_____
(*please circle*): Resident Visitor Tourism Industry Commercial Research Education Other
Vessel/Organization (*if applicable*):_____

B. SITE INFORMATION: Latitude:_____ Longitude:_____
Island:_____ Location/Site Name:_____ Max. Depth:_____
Buoy #/ Area of Reef:_____ Estimated area affected:_____
Environmental Conditions (if available)
Wind Speed: _____ Air Temp: _____ Water Surface Temp:_____ Water Bottom Temp:_____
Cloud Cover (circle): Clear Partly Cloudy Mostly Cloudy Overcast
Reef Condition (please circle)
Percent of live coral cover? 0% 1-10% 11-30% 31-50% 51-75% 76-100%
Most abundant coral type? (Table 2) Smooth _____ Distinct Branching _____ Rice _____ Other:_____

C. INCIDENT INFORMATION — **ARE PHOTOGRAPHS AVAILABLE?** ___Yes ___No
Did you observe signs of bleaching? If yes continue to Section D.
Did you observe signs of disease? If yes skip to Section E.
Did you observe signs of a Crown-of-Thorns Sea Star (COTS) outbreak? If yes skip to section F.

D. BLEACHING INFORMATION (Please enter a check mark (√) into the appropriate space.)

Types of Corals Bleached? (Table 2)	*Percent of coral bleached?*	*In general, how severe was the bleaching?*
_____Smooth Coral (*Porites*)	_____0%	_____Bleached only on upper surface
_____Mounding (*P. lobata*)	_____1-10%	_____Pale (very light brown, purple or yellowish)
_____Finger (*P. compressa*)	_____11-30%	_____Totally Bleached White
_____Plating (*P. rus*)	_____31-50%	_____Bleached Coral with Algae
_____Rice Coral (*Montipora*)	_____51-75%	
_____Red rice (*M. capitata*)	_____76-100%	
_____Blue rice (*M. flabellata*)		*Depth where bleaching was observed?*
_____Tan/Purple rice (*M. patula*)		_____MIN (ft)
_____Distinct Branching Coral (*Pocillopora*)		_____MAX (ft)
_____Cauliflower (*P. meandrina*)		
_____Lace (*P. damicornis*)		
_____Antler (*P. eydouxi*)		
_____Other_____(specify)		

E. DISEASE INFORMATION

Types of Corals affected? (Table 2)	*Lesion type?*	
_____Smooth Coral (*Porites*)	_____Tissue Loss	
_____Mounding (*P. lobata*)	_____Growth Anomaly	
_____Finger (*P. compressa*)	_____Discoloration	
_____Plating (*P. rus*)		
_____Rice Coral (*Montipora*)		
_____Red rice (*M. capitata*)		
_____Blue rice (*M. flabellata*)	*Percent of coral affected?*	
_____Tan/Purple rice (*M. patula*)	_____0%	
_____Distinct Branching Coral (*Pocillopora*)	_____1-10%	
_____Cauliflower (*P. meandrina*)	_____11-30%	
_____Lace (*P. damicornis*)	_____31-50%	
_____Antler (*P. eydouxi*)	_____51-75%	
_____Other_____(specify)	_____76-100%	

F. CROWN-OF-THORNS INFORMATION

Types of Corals affected?	*Estimated number of animals?*
_____Smooth Coral (*Porites*)	____1-50
_____Mounding (*P. lobata*)	____51-100
_____Finger (*P. compressa*)	____101-250
_____Plating (*P. rus*)	____251-500
_____Rice Coral (*Montipora*)	____501-1000
_____Red rice (*M. capitata*)	____1001-3000
_____Blue rice (*M. flabellata*)	____3000+
_____Tan/Purple rice (*M. patula*)	
_____Distinct Branching Coral (*Pocillopora*)	
_____Cauliflower (*P. meandrina*)	
_____Lace (*P. damicornis*)	
_____Antler (*P. eydouxi*)	
_____Other_____(specify)	

Figure 12. Advanced EOR report form

Outreach and education efforts to date include presentations on the new EOR program that have been given to local community groups as well as at Maui's Ocean Awareness Training, the Hawaii Conservation Conference, the Responding to Climate Change Workshop for Coral Reef Managers held at HIMB, and at a workshop held during the Coral Reef Task Force meeting on the Big Island. Brochures have been created (Fig. 13) and distributed to stakeholders during these different events and have been given to various educational tour groups visiting the Hawaii Institute of Marine Biology.

As a result of these coordinated efforts, several organizations have incorporated coral bleaching, disease and COTS protocols into their monitoring regimes. Reef Check

Hawaii has added a disease component to their diver training modules and the UH scientific diver training courses and the QUEST program through UH Hilo now include a segment on coral disease identification training. Divers with the DAR Maui herbivore project are now also trained to identify coral bleaching and disease.

The Eyes of the Reef network is expanding and at this time represents a cohesive and broad outreach and education program. The significance of this effort on the overall RRCP is invaluable. This network is the first tier and is the foundation upon which the entire RRCP is built. It is very important that this network continues to grow and provide education and outreach to the community, our eyes of the reefs.

Figure 13. Eyes of the Reef informational brochure.

RESPONSE ASSESSMENT & MONITORING TOOLS

Introduction

Local academic, governmental and non-governmental scientists, with extensive backgrounds and experience in different aspects of coral reef ecology, were assembled at a workshop and tasked with developing protocols for responding to reef events. This section provides a summary of the major workshop outputs and a toolkit for assessment and monitoring of bleaching, disease or COTS events including a detailed section outlining disease investigative techniques.

Recommended Response Team Members

The next step in the development of a rapid response protocol is to establish and train a team of responders. Since a response will be a cross-agency multi-stakeholder effort, it is essential that cooperating agencies identify which personnel will be on the rapid response team. The consensus of workshop participants was that DAR is the primary resource trustee and therefore should be responsible for coordinating the response with a standing crew of academics, scientists and managers from DAR, NOAA, HIMB, United States Geological Survey (USGS), UH, Marine Option Program (MOP) and Qualitatitive Underwater Surveying Techniques (QUEST) program graduates. The response team will be trained in the investigative techniques and standardized protocols established for the RRCP and a workshop is planned for 2009 to provide this training.

Equipment Needs

Each response will require the use of a variety of field and lab equipment. Depending upon the location and nature of the event and the resource trustee of that area, there will be certain equipment needs that will not be met by the management agency. Therefore, a list of equipment needs and available resources should be developed for response team members. Field kits for data collection need to be assembled and made available for each island. For disease investigations, potential labs will need to be identified (both primary and secondary labs) for microbiological, molecular and histological assessment and agreements forged between the labs and funding agency. Boat availability will need to be determined by region and agreements forged for potential use.

The NWHI will have some unique needs due to the isolation and logistical difficulties associated with access. To address these issues, a list of resources that are available by

atoll should be assembled and someone trained in disease, bleaching and COTS outbreak assessment will need to follow-up on reports. PMNM is currently developing response protocols for their region.

Regulatory Authority

The response team must function within the legal structure of the jurisdiction overseeing the area affected by the outbreak. This may be federal, state, regional and/or local authorities. In Hawaii, management agencies mandated to protect coral reefs include the Hawaii Division of Aquatic Resources (the State waters boundaries are from emergent land out 3 nm), National Park Service (Kaloko-Honokohau National Historical Park, Kona, Big Island; Kalaupapa National Historical Park, Molokai), NOAA (federal waters beginning at 3nm offshore and extending to 200nm) and within the northwestern Hawaiian Islands, the Papahanaumokuakea Marine National Monument. Permits may be needed for response activities and will require a prior mechanism in place to expedite the permitting process.

Outbreak Investigative Approach

For bleaching, disease or COTS outbreaks both biotic and abiotic causal factors will need to be examined. If a response is deemed necessary the Rapid Response Team will develop an Incident Action Plan which will include decisions as to which variables need to be measured and which methodologies will be used. Decisions will take into account the type and severity of the event, location of the event and available resources. To adequately document the event, data collection should include, at minimum, the spatial extent of the event, coral species affected, magnitude quantified as the number of colonies affected, and severity quantified as the percent coral tissue affected or mortality resulting from the outbreak. For a COTS outbreak, the number of animals within a defined area should also be recorded. Physical parameters (depth, water clarity, temperature, nutrient load, etc.), and anthropogenic impacts (pollution, runoff, sedimentation, etc.) that may be linked to the event should also be examined. Detailed disease assessments should include quantification of susceptible species, prevalence (proportion of corals affected) and the diagnostic description of lesions on individual affected corals including photographic records of the lesions. Microbiologic, molecular and histological analyses of disease processes will also be needed. These require coral and environmental samples to be taken. Methods for proper handling of samples during disease investigations are outlined later in this document. Disease outbreaks also require additional protocols for quarantine considerations.

Further analysis of these data will be required to extrapolate ecological questions such as which factors or attributes confer resistance and/or resilience to a reef affected by

bleaching or disease. This information will help develop hypotheses as to why the event occurred and allow the development of models for predicting future events.

Follow-up Investigation

Monitoring reefs through time will be required to document the ultimate affect of the event on the coral reef community structure (change in coral cover, species composition, rugosity, associated coral reef species (i.e., drastically reduced coral may result in loss of butterflyfish)) and to evaluate the effectiveness of any management actions taken. If there is recovery, then factors which confer resilience need to be determined e.g., species sensitivities, physical parameters such as irradiance levels at the site, habitat type, etc. Repetitive surveys will also be required to determine disease incidence (change in disease prevalence through time), spatial spread, and virulence of the disease (degree of harm to the colony). Transect lines and individual colonies will need to be marked for follow-up surveys using steel pins, cable ties or cow tags depending on the coral species affected and the reef habitat.

Field Investigative Techniques

There are many established field methods to survey coral reefs and a single set of methods would not fulfill all potential survey needs. Hence, it was decided to develop a toolkit of established methods, which the Rapid Response Team could refer to, when developing the Incident Action Plan. These methods are described in Tables 1 and 2 on the following pages.

Table 1. Broad Scale and Synoptic Survey Tools

Broad Scale/Synoptic Surveys			
Technique	**Description of Methods**	**Questions Addressed**	**Data Collected**
Community based reports and "Eyes of the Reef" network reports  Krista heide	A volunteer network is established and trained to identify coral bleaching, disease or crown-of-thorns sea star outbreaks. This network broadens the extent of reef monitoring coverage by taking advantage of those extra 'eyes and ears'. It also provides a means for reef users to act as reef stewards, thereby heightening the public's awareness of reef condition and climate change issues. (Marshall and Shuttenberg, 2006)	• Is bleaching occurring? • Is there a coral disease or COTS outbreak? • Where is it occurring?	• Presence/Absence • Location • Extent and severity • Species affected • See appendix for report form and instructions sheet (depending on volunteer training these data may be quite subjective)
Manta tow  www3. aims.gov.au	Divers on SCUBA or snorkel are towed behind a vessel to get a visual estimate of spatial extent of the event. Track lines are concurrently recorded with beginning and ending GPS points.	• Nature of event (B,D,COTS) • What is the spatial extent and severity? • Potential ecological impacts?	• Rapid estimates of dominant coral types affected • Rapid estimate of proportion of coral bleached, diseased or affected by COTS (Table 3). • Estimated severity of bleaching, disease, COTS (Table 5). • GPS points/tracks to map out extent

Towed diver surveys  PIFSC, CRED, NOAA	An integrated method for benthic habitat assessment where divers maneuver boards equipped with digital video, temperature, and depth recorders while being towed behind a small boat. The tow path is concurrently recorded by a GPS receiver, and a layback model is applied to more accurately map the data. Percent cover of salient benthic categories is quantified by-image analysis of still frames sampled at timed intervals. (Kenyon et al. 2006b.)	• Nature of event (B,D,COTS) • What is the spatial extent and severity? • Potential ecological impacts?	• Rapid estimates of dominant coral types affected • Rapid estimate of proportion of coral bleached, diseased or affected by COTS (Table 3). • Estimated severity of bleaching, disease, COTS (Table 5). • GPS points/tracks to map out extent
Diver propulsion device/ Jet boots  shoretrips.coastalliving.com	This method is useful to document coral condition in areas that cannot be reached by boat.	• Nature of event (B,D,COTS) • What is the spatial extent and severity? • Potential ecological impacts?	• Rapid estimates of dominant coral types affected • Rapid estimate of proportion of coral bleached, diseased or affected by COTS (Table 3). • Estimated severity of bleaching, disease, COTS (Table 5). • GPS points/tracks to map out extent

Swim Survey/Timed Swim  PIFSC, CRED, NOAA	Observers swim in straight or wandering lines within a certain depth range. Data are collected at timed intervals.	• Nature of event (B,D,COTS) • What is the spatial extent and severity? • Potential ecological impacts?	• Rapid estimates of dominant coral types affected • Rapid estimate of proportion of coral bleached, diseased or affected by COTS (Table 3). • Estimated severity of bleaching, disease, COTS (Table 5). • GPS points/tracks to map out extent

Table 2. Site Assessment Methods Toolkit.

*Length, width and number of transects used for all of the survey methods listed below will vary depending on type, severity, extent, habitat type, accessibility, weather and other event specific variables.
**For follow-up monitoring, permanent sites will need to be established for the techniques listed below.

SITE ASSESSMENTS			
Technique	**Description of methods**	**Questions Addressed**	**Data Collected**
Point Intercept	Multiple transects are laid out along depth contours and substrate type is recorded at set sampling intervals along transect line.	• Substrate characteri-stics	• Average percent coral cover • Severity of bleaching or disease • Proportion of cover affected.
Line Intercept	Transects are laid haphazardly within selected depth zone. The transect distance at every point where the type of substrate changes is recorded and where the level of bleaching or disease or COTS predation changes.	• Determine benthic characteri-stics • Bleaching severity • Disease severity • COTS predation severity	• Average percent coral cover • Severity of bleaching or disease • Proportion of cover affected
Belt Transect	Multiple transect lines are laid out along depth contours. A team of two divers swim along the transect, one diver IDs and enumerates coral colonies while the other diver records incidence of bleaching, disease or numbers of COTS and colonies affected. Corals are identified to species level and assigned to one of seven size classes (Table 5).	• Species affected • Colony size class structure • Prevalence of bleaching, disease, COTS or feeding scars	• Coral community structure • Colony size class structure, density, species • # COTS/m^2 • Proportion of colonies affected and bleaching severity. • Disease lesion descriptions

Video Transect	A digital video camera in an underwater housing is used to record the substrate underwater. At start and end of transects do a slow 360^{o} pan of the surrounding habitat to capture general topography and biotic community of the site. Record depth from depth gauge at beginning and end of transect. Maintain a constant altitude above transect tape ~1m and record benthos along transect. (From CRED Coral REA survey methods). Transect videos will then be digitally analyzed.	• Permanent record of the benthic community at different stages of an outbreak or event. • Means of measuring the ecological impacts from a bleaching, disease or COTS outbreak; changes in species diversity, relative abundance and dominance of different species, reef structure and habitat complexity, and susceptibility to other impacts	• Percent coral cover Proportion and species bleached, diseased, or affected by COTS. • Rate of mortality or recovery
Photo-quad Transect	Photograph site info from data board. Shoot 360 degrees at the beginning and end of the transect line to capture habitat information. Photograph bottom coverage along the entire length of a transect line. Photographs are taken, using a camera platform at set intervals with the transect line centered in each photograph using line marks as locators. Transect photographs will then be digitally analyzed.	• Permanent record for future reference. • Corals showing signs of disease, predation, abnormal growth, bleaching or direct human impact will be noted and characterized	• Average percent coral cover • Severity of bleaching, disease or COTS predation • Proportion of cover affected

Tagged colonies	Photograph and tag individual colonies using cattle ear tags, colored cable ties, steel pens, etc. Colonies should be selected haphazardly and cover a range of sizes.	• Rate of mortality or recovery and growth. • Relationship of severity of event to mortality • Addresses questions about resistance and resilience to subsequent outbreaks. • Time series of zoo-xanthellae community composition.	• Record and describe condition. • Record size of colony (height, width, length)

Table 3. Proportion of Corals Affected	
Category	% Affected
1	1-10
2	10-30
3	30-60
4	60-100

Table 4. Colony Size Classes	
Diameter	Size Class
0-5 cm	1
6-10 cm	2
11-20 cm	3
21-40 cm	4
41-80 cm	5
81-160 cm	6
>160 cm	7

Table 5. Bleaching and COTS Severity		
Category	Description of Bleaching Severity	Crown of Thorns # of Animals
1	Partially bleached-surface or tips are pale but not white	20-50
2	White	50-100
3	Bleached and partially dead	100-500
4	Recently dead (no algal overgrowth)	501-1000+

Protocols for Disease Investigations

Coral disease outbreaks require special response activities. Standardized approaches to coral disease investigations have recently been developed (Friend and Franson, 1999; Raymundo et al., 2008; Woodley et al., 2008; Work et al., 2008c). We have followed these recommendations and modified them to coordinate with Hawaii's Rapid Response Contingency Plan. The initial part of the investigation should document the spatial extent of the disease outbreak and investigate whether the outbreak could have resulted from a recent environmental perturbation (anomalous changes in water temperature, sewage spills, chemical contaminants, etc.). Dependent upon the initial findings, an Incident Action Plan can be developed as to the best methods for an in situ site assessment (number and width of transects, placement of permanent markers for follow-up surveys, etc.) and types of biological samples to be collected (mucus, tissue, water, sediment, etc). Investigating the site will require two dive teams: one to collect the biological information (survey team) and another team responsible for photo-documentation, placement of permanent site and individual colony markers and sampling colonies for follow-up lab analyses (sample team). A third team (support team), topside, will be required for sample inventory and on site sample processing.

Disease Assessment Protocols for the Survey Team

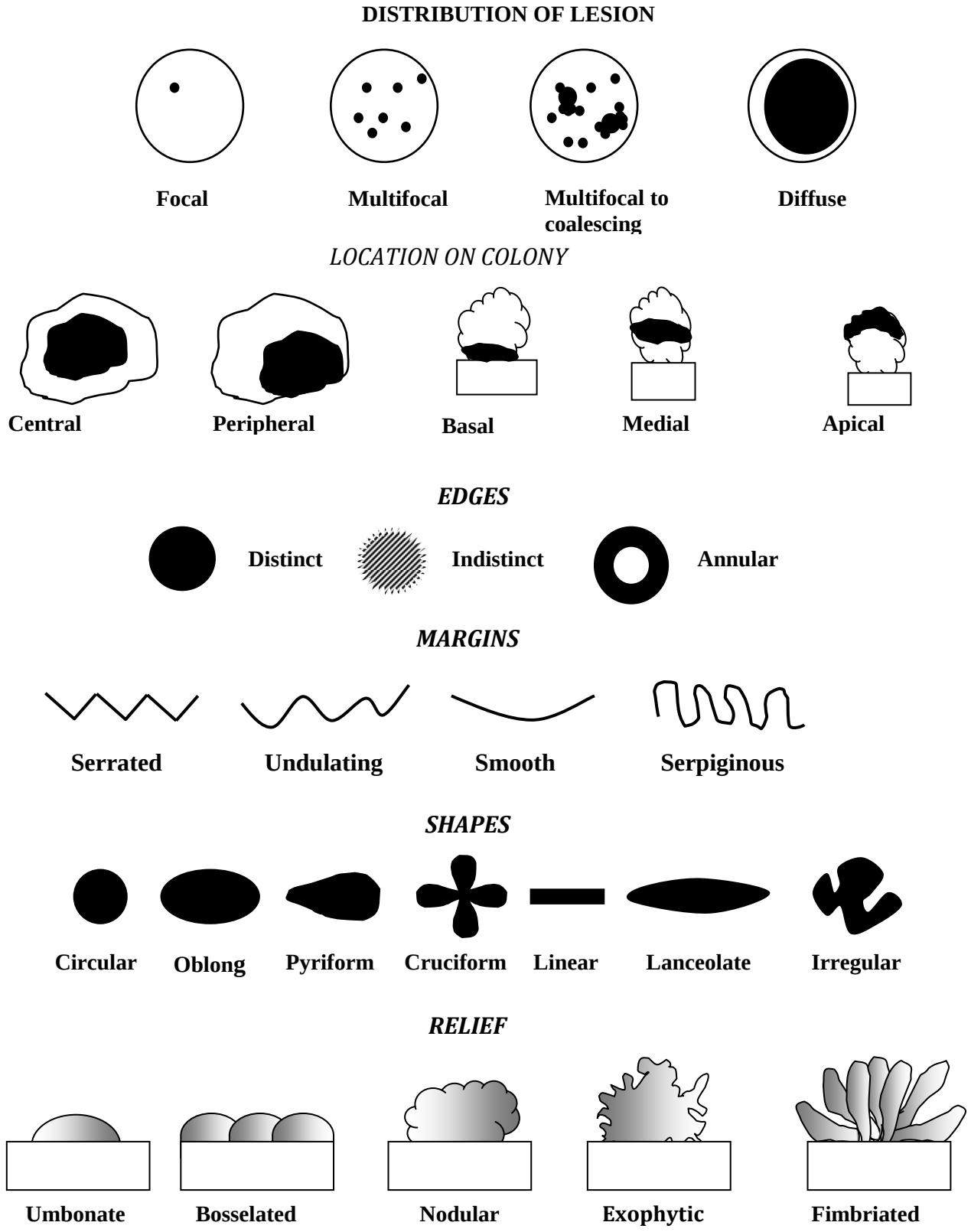
One diver identifies every colony within the belt transects exhibiting signs of the disease under investigation, recording the species, maximum diameter and diagnostic features of the lesion (see Figure 14 below). This diver also identifies corals for sampling, marks them (flagged fishing weights, floating chains) and assigns temporary numbered tags. Colonies for sampling should include representatives from all species affected by the disease of interest, as well as different stages in the progression of the disease ranging along a continuum from colonies that appear to be newly infected (small lesion that lack algal colonization) to older well established lesions (prominent large lesions with a gradation of algal colonization on exposed skeletal surface).

Diagnostic descriptions of lesions should be made for each colony exhibiting signs of disease within the survey area. Information should be recorded on the affected taxa, its size, and condition. The lesion should be described in terms of its physical characteristics with avoidance, or minimal interpretation, of processes producing the features. The following information in Table 6 should be recorded (after Work and Aeby 2006):

Table 6. Categories and terms used to describe a lesion. See examples of terms below (Work and Aeby 2006)

Category	Term
Distribution	Focal, multifocal, multifocal to coalescing, diffuse
Location	Basal, medial, apical, peripheral, central, colony-wide
Edges	Distinct, indistinct, annular
Margins	Serrated, undulating, smooth, serpiginous
Shapes	Circular, oblong, pyriform, cruciform, linear, lanceolate, irregular
Relief	Umbonate, bosselated, nodular, exophytic
Size	Small, medium, large, measurement
Number	Small, medium, large, actual count
Color	White, black, tan, brown, red, green, orange, pink, purple, blue, yellow
Texture	Rugose, smooth
Extent	Mild (1-20%), moderate (21-50%), severe (51-100%)
Time	Acute, subacute, chronic
Lesion	Tissue loss, discoloration, growth anomaly
Structures affected	Polyp, coenosarc, skeleton

Figure 14. Examples of lesion descriptions. Modified from Work et al., 2008c.



A second diver will conduct point-intercept along the transect line to measure coral cover and colony counts by size class within belt transects. Colonies falling at least 50% or more within the belt transect will be counted. Corals should be identified to species and placed within one of the following size classes (0-10cm, 11-20cm, 21-40cm, 41-80cm, 81-160cm, >160cm) (Table 4).

Photo Documentation

Divers should also use video or still digital photography to document the outbreak at the site as well as photograph affected colonies to help in characterizing morphology of lesions.

Disease Assessment Protocols for the Sample Team

A 2nd team of divers should be responsible for photographing colonies marked for sampling, recording and sampling disease colonies marked by the disease assessor and transporting samples to the boat for processing. Sampling may be needed for follow-up investigations such as histology, microbiology, protein analyses (stress proteins, biomarkers) or genetic analyses.

Collection Protocols for Biological Analyses (after Woodley et al., 2008)

Samples are material representatives of the problem and suitable for further laboratory analyses. The specimen may be tissues, mucus, environmental samples (e.g., water or sediment) or other flora or fauna that associate with the diseased corals. Photographs of the lesions and surrounding area provide a record of color, location and appearance of lesions. Both actual size and macro shots should be taken before and after removal of tissue biopsies. It is also important to include a color scale and metric to size and color correct photos. Properly trained individuals proficient in collection techniques are critical for the proper collection and preservation of samples. Due to time sensitivity of some samples, such as the tissue for protein analyses, a very specific sampling order should be adhered to. Typically, when a diseased colony is sampled, you should sample a portion of diseased and normal tissue from a given colony. Each sample should have with it the following data, and should be accompanied by a photograph:

- Collection Site
- Species
- Collection Date
- Colony Size

- Colony Identifier (if any)

For each site, samples may include the following, and should be determined during the development of the incident action plan:

- Water
- Sediment
- Mucus
- Tissue Samples for each analysis planned

Support Team

This team will consist of at least 2 members who will provide topside and field lab support. The primary job of the sample technician is to ensure the proper handling, documentation and stabilization of each sample collected. Each sample has a pre-determined experimental or analytical role, which determines how each will be processed on the boat and back on land. The Sample Technician of the Support Team will do most processing. Methods for collecting and processing samples for different biological analyses can be found in Woodley et al., (2008) or may be available through the laboratories that will be conducting the analyses.

QA/QC Considerations for a disease investigation

Minimizing Cross Contamination

- Visit sites with no signs of disease first
- Sample healthy coral first, then affected/diseased coral
- Use one set of sampling gear for healthy colonies and a separate set of gear for diseased colonies.
- On the boat, decontaminate collection equipment by soaking in dilute hypochlorite (5-10% bleach) solution for at least 10 minutes and rinsing in fresh water.
- Clean dive gear by soaking in decontaminating solution and rinsing in fresh water at the end of each dive.

**Laboratory experiments have been conducted to determine cleaning agents that are effective in disinfection, yet pose little threat to dive gear deterioration. The suggested agent to date is 5-10% bleach prepared fresh or 3% Lysol (diluted according to sanitization strength on packaging) (Woodley.et al., 2008).

Hawaii’s Rapid Response Contingency Plan

Management Framework for Response

Introduction

The protection of Hawaii's coral reefs are predominantly under the jurisdiction of Hawaii's Division of Aquatic Resources. It is the responsibility of the local managers to implement strategies to aid and/or abate damage to coral reefs during bleaching, disease or COTS events. Therefore, the input and involvement of managers in the development of the contingency plan has been a priority. This section details the proposed management framework, issues and management needs identified by different agencies during the Rapid Response Contingency Plan Drafting Workshop.

Formation of the response management team and recommended structure

The response management team will incorporate representatives from all agencies involved in the management of the coral reef natural resources. This should include state and federal agencies as well as non-governmental stakeholder groups. Table 7 on the next page lists all of the agencies that "should" hold positions on the coral bleaching, disease and COTS event response management team. The composition of the *working* response management team may vary dependent upon the location of the event but the legal framework will need to be established. Thus, the responsibilities, roles and liabilities of each agency will need further clarification.

Responsibilities of the Response Management Team and key management issues to address for response implementation

The Response Management Team will have the responsibilities of evaluating case reports to determine whether a response should be activated, evaluation of what, if any, management actions should be taken to facilitate recovery of the reefs, and communication of the event occurrence to stakeholders, decision makers and the media. Once the Response Management Team is formed the following key issues must be addressed in further detail in order to ensure a coordinated and timely response to bleaching, disease and COTS events:

Table 7. This table shows the agencies and organizations identified to be potential members of the management team. Each event will present a unique set of circumstances and require the input of different management team members. The location of the event will also determine which agencies will need to be involved.

MHI Management Response Team			
Resource Trustee (Main Management Team)	**Site Specific Resource Trustee**	**Other Relevant Consulting Agencies and Land Owners**	**Others to Engage**
State of Hawaii DLNR, Division of Aquatic Resources (DAR)	National Park Service (NPS)	Environmental Protection Agency (EPA), Coral Disease and Health Consortium (CDHC)	Resource Experts • University of Hawaii • HIMB
National Oceanographic and Atmospheric Association (NOAA)	Department of Defense (DOD)	Office of Hawaiian Affairs (OHA)	• Independent/ NGO scientists; TNC • Local community members • Traditional Ecological Knowledge practitioners (TEK)
Fish and Wildlife Service (FWS)		Counties, local landowners	Business owners
Hawaiian Department of Health (DOH)		United States Coast Guard (USCG)	Dive operators
		United States Geological Survey	Hui – partnerships within geographic areas

Decision Criteria for Response Activation

Every event will present a unique set of circumstances; however developing set criteria for response activation will aid in the decision process. Other regions have decision trees with the criteria for response activation outlined in an 'if–then' format. By determining the conditions that would necessitate a response for Hawaii, a decision tree will be built for this region by the Response Management Team. Some of the parameters that were put forth are:

- **Definition of an 'outbreak'.** Criteria defining what will trigger a response needs to be more clearly defined for each type of event (bleaching, disease, COTS) but an outbreak is commonly defined as an unexpected increase in occurrence in a time or place where it does not normally occur or at a frequency greater than previously observed (Woodley et al., 2008). To determine whether the event is unusual requires comparisons to baseline data. Fortunately, in Hawaii we have a

good start on baseline data for coral bleaching, disease and COTS and these data are currently being integrated into a comprehensive geospatial database which will be housed on the server at HIMB and will be available to management agencies and reef scientists <http://www.hawaii.edu/himb/ccmdgis/index.htm>.

- **The location of the outbreak.** If it is at a site of special importance regarding its ecology, species composition, genetic age, susceptibility, resistance or resilience, socio-economic or cultural significance then this should be considered when determining whether a response will be initiated.
- **Species affected.** Special consideration may be given to species that are rare, threatened or endangered.
- **Timing** is also of utmost importance, so how quickly a response must be initiated will need to be outlined.

Data Collection, Sharing and Housing

Since management is the entity that ultimately decides whether or not there will be a response, they will need to be well informed on the nature, scope and intensity of the event. This requires background baseline data, which is often the property of another organization or research group. Baseline data for coral bleaching, disease and COTS for the Hawaiian Archipelago is currently being integrated into a comprehensive geospatial database, which will be housed on the server at HIMB and will be available to management agencies and reef scientists. However, data sharing agreements may need to be formed and should be in place before an event occurs.

Managers should also address which data needs to be collected, where it will be stored and what the levels of access will be. Table 8 shows the type of data that should be collected and housed with the resource trustee.

Table 8. Types of data that will need to be collected during the evaluation and response of an event.

Data Needed for Management Response			
Resource Data	**Process**	**Legal**	**Public**
Initial Site reports	Who called	Clarification of jurisdictions	Interest
Metadata	Reporting	Causes	Who released what info
Baseline	Timetable	Confidentiality	
Biological	Back logs		
Cultural	Qualitative		
Quantitative			
Follow up			
Monitoring			
Sensitive Species			

Communication

Communicating the event to the media and public is a critical aspect in gaining the public's support for management action. The resource trustee should handle public relations initiated during an event e.g., DAR for coastal waters in the main Hawaiian Islands, and the PMNM in the NWHI. These agencies should have press releases composed by PR personnel that will not exaggerate the event so as to maintain credibility. These agencies should also utilize non-governmental partners to convey information that the government cannot. Protocols will also need to be developed to handle legal issues regarding the media. In events where natural resources are in need of special care, the media can be a very useful tool to gain the help of the community and to educate them as well. Not only is it a good outreach medium but it can be used to acknowledge the groups and individuals that have been caring for the resource and aiding the situation.

Rapid Response Team Members, Boat and Equipment Sharing and Standards

A Rapid Response Team will be assembled and comprised of field biologists from different agencies and locations. Resource agencies that have personnel capable of responding to an event should be identified, and the support provided for their participation in the response team. Frequently, management scientists are overcommitted in their job responsibilities and so involvement in the response team needs to be

supported by their supervisors. It will also need to be decided whether or not there should be a central response team or a team of trained divers on each island. There will also need to be some sort of "in kind" agreement or contingency fund for the use of agency boats and equipment. Response kits are being compiled and will be made available to response team members. This will occur as the next step to the development of the response protocols and the formation of a response team. However dive gear and boat use will need to be provided by the resource agencies.

Diving and Diving Safety

Rapid response team members will have to use SCUBA to document and respond to most events. The current arrangement for diving reciprocity between agencies is that all divers must observe the diving regulations of the agency that provides the diving platform. This will require dive safety plans and letters of reciprocity to be in place.

Volunteers

Developing the capacity to utilize volunteer scientific divers would enhance broad-scale event response time and efficiency. With diving, however, come the issues of liability. Therefore, it would need to be established under which agency these volunteers would dive and diving records and certifications would have to be kept therein. If the capacity can be developed, perhaps volunteer responders could be offered course credit as scientific divers-in-training for divers in the Marine Option Program (MOP) at UH or for those involved in QUEST or Reef Check Hawaii. Having a sufficient number of properly trained response team members. On each island, regardless of whether they are management scientists or volunteer divers, would reduce the need for inter-island travel.

Memorandums of Agreement (MOA)

MOAs will need in place based upon the issues, needs and interagency responsibilities outlined in this document such as data sharing agreements, diving reciprocities, fund sharing, etc. Federal and State partners will have to work together to implement emergency permits to scientists and enact temporary closures or other management actions.

Permitting Issues

The different types of permits needed to respond to events will have to be identified and agreements formed with the responsible agency(s). A process needs to be in place to facilitate emergency permits or to create a blanket permit for response team participants.

Currently permits for disease events have been identified as the most difficult to address since protocols for quarantine will need to be put in place. Interagency permitting issues will also need to be addressed.

Funding

A separate pot of money or contingency fund needs to be set aside for emergencies and situations necessitating response activity. Whether or not this should be a Super Fund where federal and state agencies, along with other organizations, contribute to the pot will have to be decided. Regardless, it is imperative that the fate of any unused funds at the end of a fiscal cycle be determined. These contingency funds also need to have an objective statement established so that it is clear what exactly the funds can be used for and who can access them.

Management Actions to Mitigate Damage from Events and Facilitate Recovery

Managers are responsible for making informed decisions by weighing the socio-economic costs and benefits to preserve a resource. It is the job of the scientist to inform management of the state of the resource and the best practices for resource conservation. Here are some of the ideas that were put forth as potential management options to minimize damage from events and facilitate reef recovery.

Area Closures or Restrictions e.g. limited entry or access

During an event, whether it is bleaching, COTS or a disease outbreak, there are several actions available to managers to ease the stress to a reef and/or prevent further harm. For example, it is common practice in other regions to restrict the take of herbivorous fish so that algal grazers can keep algal blooms under control (Marshall and Shuttenberg 2006). Area closures or limited access could be applied to reefs that are heavily impacted by tourism. Temporary restrictions in an affected area would limit the amount of trampling and breakage to the reef from divers and snorkelers, anchor scars and other stressors brought on by human use.

Land-based Actions or Temporary Control Measures: Managing the Watershed

Terrestrial runoff and sedimentation are large sources of stress to coral reefs. Runoff from land is often polluted in waters adjacent to heavily populated areas. Chronic stress to reefs within regions with land-based pollution problems can result in reduced coral cover. Management of the watershed, which has great affect on coral reefs or reefs at

risk to events, would help build the resilience of the reefs. Actions such as temporary controls on agricultural pesticide use or construction zones may be management options. Controlling land-based pollution would be especially important during months when corals are spawning.

Diseased Coral and Quarantines

During a disease event, the set of protocols and the management actions taken will have to be specific to the unique conditions of the event. However, there are some standard protocols that can be implemented by managers, such as quarantines set up at reefs where outbreaks occur or around a suspected source of disease. Biosecurity measures will need to be implemented, including proper handling of diseased corals, reduction of movement between dive sites, and moving from clean sites to 'dirty' sites only (Friend and Franson 1999, Woodley et al,. 2008).

Suggestions for Minimizing Damage from Disease include:

- Culling and quarantine
- Isolation of disease vectors
- Removal of diseased parts
- The use of putty or shotcrete to cover diseased areas on coral
- Using antibiotic jelly on diseased corals

Shading

Small-scale experiments have shown that decreasing the intensity of UV light can reduce the intensity or severity of bleaching (Marshall and Shuttenberg 2006). So shading certain reef areas could be a management strategy in a bleaching event.

Recommendations for Next Steps

There are many issues that will need to be resolved in the final development of the Rapid Response Contingency Plan. A DAR coordinated effort to form the Response Management Team is the required first step. The Response Management Team should be composed of representatives from all agencies, non-governmental stakeholder groups and scientists that may be involved in future coral bleaching, disease or COTS events. They should be responsible for finalizing the RRCP and addressing the issues outlined in this document. One need that was identified during the workshop was for information on existing response plans from other regions to serve as models for development of Hawaii's contingency plan. To address this we have compiled two existing plans, the Great Barrier Reef Marine Park Authority's (GBRMPA) management response plan and

the Florida Keys National Marine Sanctuary (FKNMS) plan; see Appendix D for the source information. These two established plans could aid managers as they continue to develop Hawaii's rapid response contingency plan. The following summarizes issues or needs that should be addressed by the Response Management Team.:

- DAR should appoint a staff member to guide the RRCP process. They are the primary resource trustee and ultimately responsible for coordinating the response
- Cooperating agencies should identify which personnel will be on the Response Management Team and the Rapid Response Team
- Development of a decision tree for determination of response by the Response Management Team
- Establishment of a process for permitting issues for response and mitigative activities
- Development of MOAs between agencies, laboratories and for data sharing
- Determination of funding for response activities
- Development of agreements on availability of boat and equipment use for response and mitigative activities
- Agreement on responsible parties for dive plans and letters of reciprocity, etc.

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APPENDIX

Hawaii’s Rapid Response Contingency Plan

CCMD LAS TABLE OF OBJECTIVES

Hawaii's Climate Change and Marine Disease Local Action Strategy

Objective 1	Priority Rank	Funding Status
To support research that provides a scientific basis for managing impacts to reef ecosystems from climate change and disease.	**H, M, or L**	**Unfunded (U) /Partially Funded (PF)**
1.1 Develop baseline knowledge of the types, distribution and prevalence of diseases on the reefs throughout the State of Hawaii. (Separate for corals, key reef fish, turtles, non-coral invertebrates and algae)	**H**	**PF**
1.2 Develop sufficient knowledge about the epizootiology (susceptibility, virulence, mode of transmission, ecology, affect on community structure, etc.) of diseases of concern. This will allow managers to possibly mitigate the cause and effects in the population.	**H**	**U**
1.3 Determine links between disease and bleaching and other stressors such as land-based pollution, fishing effort and marine recreation.	**H**	**U**
1.4 Determine connectivity of reefs at large and small scales, including physical oceanography, genetics and larval dynamics.	**M**	**PF**
1.5 Determine potential effect global climate change may have on acidification, coral growth rates and calcification rates.	**H**	**PF**
1.6 Determine sub lethal impacts from stressors, climate change and disease.	**M**	**PF**
1.7 Identify gaps in existing data from the Marine Gap analysis produced for the main Hawaiian Islands and use that information to determine where further research or monitoring needs to occur.	**L**	**F**
1.8 Gain an understanding as to what factors enhance or inhibit the recovery of corals after a bleaching event.	**M**	**U**
1.9 Use data from the bleaching event that occurred in the MHI in 1996 and the NWHI in 2002 and 2004 to predict reefs at highest risk for bleaching in the MHI.	**M**	**U**
1.10 Develop a comprehensive database on coral reef health. Begin by integrating data from MHI-RAMP, CRAMP, WHAP and DAR on bleaching and disease.	**H**	**PF**
1.11 Develop a research facility capable of supporting	**M**	**U**

advanced disease studies.		
Objective 2	**Priority Rank**	**Funding Status**
To increase public awareness and engage stakeholders in monitoring and reporting bleaching and disease.	**H, M, or L**	**U / PF**
2.1 Develop Traveling Public Educational Display.	**M**	**U**
2.2 Develop a Public Monitoring and Reporting System.	**M**	**U**
Objective 3	**Priority Rank**	**Funding Status**
To develop a rapid-response contingency plan for events of bleaching and disease.	**H, M, or L**	**U / PF**
3.1 Develop infrastructure to collect reports of events and initiate response teams.	**H**	**U**
3.2 Establish rapid response protocols for events of bleaching or disease.	**H**	**PF**
3.3 Establish management protocols for events of bleaching or disease.	**M**	**U**
Objective 4	**Priority Rank**	**Funding Status**
To develop proactive and mitigative long-term management strategies to increase resistance and resilience of reef ecosystems to impacts from climate change and marine disease.	**H, M, or L**	**U / PF**
4.1 Develop design recommendations for a network of Marine Protected Areas in the Hawaiian Archipelago that focuses on impacts from bleaching and disease.	**M**	**U**
4.2 Develop plan to manage introduction and spread of introduced pathogenic microorganisms of demographic importance.	**H**	**U**
4.3 Recommend policy changes in support of management strategies, including the creation of a contingency fund.	**L**	**U**
4.4 Support advanced education in disease investigation through partnership with CDHC.	**M**	**U**
4.5 Conduct risk assessments of candidate factors influencing disease prevalence.	**M**	**U**
Objective 5	**Priority Rank**	**Funding Status**
To develop a program to monitor the impacts from climate change and marine disease on the reefs of the Hawaiian archipelago.	**H, M, or L**	**U / PF**
5.1 Develop protocols for post-event monitoring and the capacity to conduct periodic monitoring of reefs that have experienced mass bleaching or disease outbreaks to assess potential community level changes through time.	**H**	**U**

AGENDA
Development of Hawaii's Rapid Response Contingency Plan for Coral Bleaching and Disease Events

Wednesday, December 5th 2007, 8:30am-12pm
Bishop Museum, Paki conference room 1

Host: Division of Aquatic Resources, Hawaii Department of Land and Natural Resources

Facilitator: Petra MacGowan, NOAA Coral Fellow-DAR (587-0098)

Purpose: The purpose of this workshop is to begin development of Hawaii's Rapid Response Network to Coral Bleaching and Disease events

Objectives: The two objectives for this workshop are as follows:

1. To provide background information on the Climate Change and Marine Disease Local Action Strategy (LAS) and inform participants on basic biology and possible impacts of coral bleaching and disease outbreaks. Target output:
    a) Group understanding of the LAS
    b) A group understanding of the current project to develop RRCP for Hawaii and examples of the role of outreach providers/marine operators in coral bleaching and disease focused rapid response plans in other regions.
2. To develop a rapid response network to recognize, report and respond to bleaching and disease events in Hawaii. Target output:
    a) A draft system for the response network including the necessary reporting mechanisms
    b) Identification of the resources needed for the network
    c) Identification of who should be involved in the network
    d) Identification of who wants to be involved in the network

Hawaii's Rapid Response Contingency Plan

Agenda		
8:30-8:45	Workshop Welcome and Introductions Opening remarks Review and agree upon agenda Participant introductions	Petra
8:45-9:45	Overview Hawaii's coral bleaching and disease events and the Climate Change and Marine Disease Local Action Strategy Hawaii's Rapid Response Contingency Plan for CBD and the role of a rapid response network	Greta
9:45 – 10:00	BREAK	
10:00 – 11:30 45 minutes group work 30 minutes report back to larger group 15 minutes group discussion	Breakout sessions Group questions: • What would the system for the CBD response network look like in Hawaii? • What reporting mechanisms should exist? • What resources are needed for the network? Incentives for participation? • Who should be involved in the network? Report back to larger group Group Discussion Would your organization participate in a Rapid Response Network for CBD?	Petra, Greta, Melanie
11:30- 12:00	Next Steps	Petra
12:00	Pau	

Agenda
Development of Hawaii's Rapid Response Contingency Plan for Coral Bleaching and Disease Events

Wednesday, March 12th 2008, 3:00pm-5:00pm DAR Maui

Host: Division of Aquatic Resources, Hawaii Department of Land and Natural Resources

Facilitators: Melanie Hutchinson, CCMD Rapid Response Contingency Plan Workshop Coordinator & Petra MacGowan, NOAA Coral Fellow-DAR

Purpose: The purpose of this workshop is to facilitate development of Hawaii's Rapid Response Network for Coral Bleaching and Disease events

Objectives: The two objectives for this workshop are as follows:

1. To provide background information on the Climate Change and Marine Disease Local Action Strategy (LAS) and inform participants on basic biology and possible impacts of coral bleaching and disease outbreaks. Target output:

    a). Group understanding of the LAS
    b). A group understanding of the current project to develop RRCP for Hawaii and examples of the role of outreach providers/marine operators in coral bleaching and disease focused rapid response plans in other regions.

2. To provide an overview of the "Eyes of the Reef" rapid response network for recognizing, reporting and responding to bleaching and disease events in Hawaii. Target outputs:

    a). Identification of who wants to be involved in the network
    b). Identification of who should be involved in the network
    c). Identification of the resources needed for the network
    d). A discussion on the spatial analysis of reefs regularly visited and the fill-in form

Hawaii's Rapid Response Contingency Plan

Agenda		
3-3:15	Workshop Welcome and Introductions • Opening remarks • Review and agree upon agenda (ppt slide – Petra) • Participant introductions	Petra
3:15-3:45	Overview • Hawaii's coral bleaching and disease events and the Climate Change and Marine Disease Local Action Strategy (.ppt –Melanie) • Hawaii's Rapid Response Contingency Plan for CBD and the role of a rapid response network • Reef Check's role in network	Melanie
3:45 – 4:45	Discussion Session (ppt. slide - Petra) 1. What would system for the CBD response network look like in Hawaii? 2. What reporting mechanisms should exist? 3. What resources needed for the network? Incentives for participation? 4. Who should be involved in the network? 5. Would your organization participate in a Rapid Response Network for CBD?	Petra
4:45- 5:00	Next Steps	Petra
5:00	Pau	

Outreach Workshops Summaries

Introduction:
In the early stages of the development of the contingency plan, the need to engage the public for assistance in the early detection and reporting of coral bleaching, disease or COTS outbreaks was identified. Since Hawaii spans such a vast area with extensive coral reef habitat, scientific and management monitoring efforts would not be able to provide complete resource monitoring. Early detection is also necessary to mitigate the damage that these sorts of events have on the reefs. Therefore, it is essential to have a large network of coral reef users who are trained in the identification of coral bleaching, disease or COTS outbreaks statewide. To this end, two outreach workshops were held to begin the development of the rapid response contingency plan and response network for coral bleaching, disease and COTS events in Hawaii. The first workshop was conducted in December 2007 at the Bishop Museum on Oahu and the second was held in March of 2008 at the DAR Maui office. The following are the results from these workshops.

December 2007 Bishop Museum Oahu

Workshop Objectives:
1. To inform key outreach and education coordinators as well as local resource users about the Climate Change and Marine Disease Local Action Strategy's current project to develop the rapid response contingency plan for Hawaii.

2. To develop a rapid response network to recognize, report and respond to bleaching and disease events.

Workshop Outputs:
Four questions were posed to the participants in order to meet the workshop objectives. The following are the questions presented and the main points from the discussions that ensued. The actual minutes for the workshop are provided elsewhere in the appendix and contain a more detailed synopsis of the meeting.

Who should be involved in the network?

There are several organizations, clubs, Hui's or malama kai groups that spend a lot of time in the water or caring for a certain reef or watershed in the islands. This workshop was an effort to identify which organizations should be involved in a network like this. Several groups and organizations were identified in this session. Below is a list of reef users that may be important to engage in the organization of the response network.

- Reef Check Hawaii

- Commercial SCUBA dive operators
- University of Hawaii Marine Option Program (MOP) and QUEST
- Management (DAR/DLNR)
- Scientists/NGOs
- Schools with marine science or field programs
- Federal government

What reporting mechanisms should exist?

Examples of reporting networks from other regions such as the BLEACHWATCH program in the Florida Keys National Marine Sanctuary and on the Great Barrier Reef were presented to see how we could adapt a program like this to our island state. These are the needs that were put forth:

- Hotline
- Website
- Reporting form- it should be available online and provided on underwater paper to dive shops and participating organizations.
- A full time coordinator to collect, maintain and provide feedback on reports. Feedback on reports was revisited throughout the workshop as an important aspect to follow-up on. People need to feel that their reports are useful so they will continue to promote the program and report on the reef's condition.

What resources are needed for the network, including incentives for participation?

Funding was identified as the most important need for a network to be formed and be operational. Some possible sources of funding were identified such as the Castle Foundation and NOAA's Coral Program. Another suggestion was that a pool of funds be set aside by various organizations that are involved in the network to help support dive shops or private endeavors that aid in a response, e.g. for boat use for responders and foraccess to remote sites exhibiting signs of an event. Underwater cameras were also suggested as a useful item that should be made available by island or region for documenting an event. This would be more cost effective than flying a scientist to remote sites to confirm or negate a report. In terms of educational materials or incentives, the following were proposed by the groups:

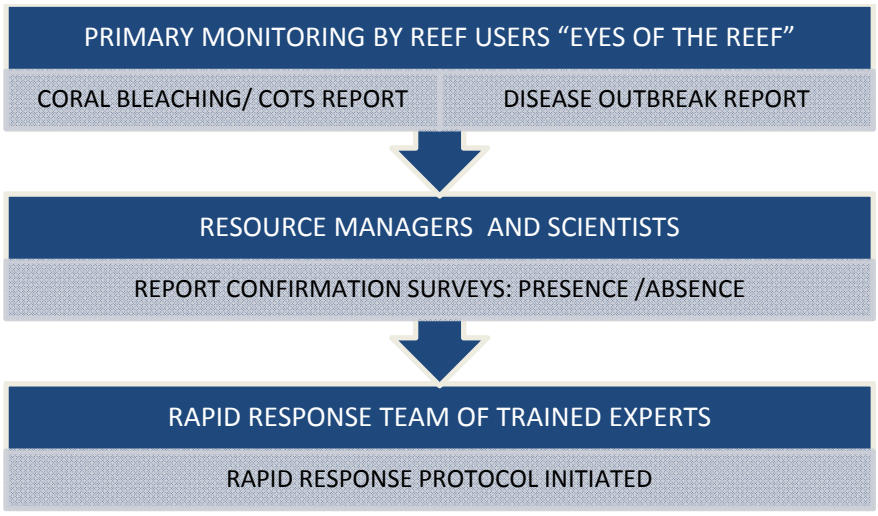
- Coral disease cards
- Underwater ID cards for bleaching
- Identification training for volunteers
- Posters, stickers, certificates for participation
- Incentives for marine recreation businesses to participate
    - Eco seal of approval or Hawaii Visitors Bureau Memberships

- Tax breaks
- Training opportunities for dive shops and instructor certifications

What would the response system for coral bleaching, disease and COTS events in Hawaii look like?

The system that was developed from this workshop took on a tiered structure. Three tiers were identified beginning with the first response, a public report or primary observation. This tier was named the Eyes of the Reef Network. The second tier would be the secondary assessment whereby trained personnel conduct an in water survey to confirm or negate a response. A third level response would involve management action, to conduct monitoring activities or initiate response protocols. The figure below gives a simple overview of the tiered contingency response plan.

Three tiered contingency response plan for coral bleaching, COTS or disease events in Hawaii.



A major gap that was identified at this workshop was the capacity to receive and house reports. After the workshop convened, representatives from Reef Check Hawaii volunteered the use of their website and phone line to place reports of coral bleaching, COTS or disease observations. A significant outcome for this workshop was that a partnership ensued between Reef Check Hawaii, DAR and the Hawaii Institute of Marine Biology (HIMB) to form the 'Eyes of the Reef' volunteer monitoring network.

March 2008 DAR Maui

This workshop was held as a follow-up to the Oahu Outreach workshop outlined above. It was an effort to engage Maui outreach coordinators, educators and field scientists in strengthening the developments from the first workshop and attaining input on the formation of the Eyes of the Reef network and reporting mechanisms.

Workshop Objectives:

1. To inform key outreach and education coordinators from Maui, as well as local resource users, about the Climate Change and Marine Disease local action strategy's current project to develop the rapid response contingency plan for Hawaii.

2. To provide an overview of the Eyes of the Reef rapid response network and to gain guidance, support and feedback on the structure and function of the network.

Workshop Outputs:

Identification of who should or would be involved in the network from Maui

The island of Maui has several very active and successful coral reef conservation outreach and education efforts. Representatives from the organizations listed below were present at this workshop and have become a part of the Eyes of the Reef reporting network.

- REEF volunteers (www.reef.org)
- DAR herbivore grazing study volunteers
- Ocean Awareness training
- Coral Leadership Network (www.coral.org)
- DAR rapid in-water assessments

Suggestions and concerns regarding the Reef Check Hawaii reporting website

This question was an effort to find out what the needs were for this website to be an effective means of reporting an event. There were several guiding suggestions that have been very useful for building a user friendly website, some of which are listed below:

- The website will need educational components on bleaching, COTS and diseases of corals with flowcharts to disease identification. It should also include what to rule out, e.g. predation or abiotic damage to corals
- The website needs to be user friendly and available to non-Reef Check members.
- There needs to be a way for DAR field scientists to enter anomalies e.g. fish diseases, COTS
- The website should have a map that links where reports are being generated

- The website needs to have links to other volunteer organizations such as Reef.org and Coral.org
- The website needs a page describing current research with links to resource/informational pages and databases

AGENDA
CLIMATE CHANGE & MARINE DISEASE Local Action Strategy
Rapid Response Contingency Plan Workshop

Where: Tokai University Conference Room 2241 Kapiolani Blvd.

When: May 20, 2008 8:30-5:00

Hosts: Division of Aquatic Resources, Hawaii DLNR

Facilitators: Greta Aeby, Climate Change & Marine Disease LAS coordinator, Kem Lowry, UH Dept. Urban and Regional Planning, Melanie Hutchinson, Workshop Coordinator, Petra MacGowan, NOAA Coral Fellow DAR

Meeting Objectives:

- Provide background on Climate Change and Marine Disease Local Action Strategy including accomplishments, status and the "Eyes of the Reef" program.
- Give a biological review, history and overview of coral bleaching, disease and Crown of Thorns outbreaks in Hawaii.
- Discuss the development of the rapid response contingency plan and introduce other plans already in place (references provided).
- Have managers, scientists and other participants develop protocols for bleaching, disease and COTs outbreaks in Hawaii.
- Review and agreement on draft coral bleaching, disease and COTs outbreak protocols.

Agenda

Time	***Activity***
8:30-8:45	Coffee and Introductions
8:45-9:00	Review objectives and agenda
9:00-9:30	Powerpoint Presentation: Information and background on CCMD LAS, coral bleaching, disease and COTS.
9:30-10:00 .	Powerpoint Presentation: Introduce Contingency Plan and resources. Report on the "Eyes of the Reef" network.
10:00-10:15	Coffee Break
10:15-10:30	Discuss group objectives, information in packets, assign groups.
10:30-12:00	Breakaway Sessions (3 groups; Managers, Bleaching & COTs, disease).
12:00-12:45	Lunch
12:45-3:30	Breakaway Sessions (3 groups; Managers, Bleaching & COTs, disease).
3:30-3:45	Break
3:45-4:45	Review products and integrated suggestions from groups and agreement on protocols
4:45-5:00	Next Steps
5:00	Pau

Rapid Response Contingency Plan Development Workshop Summary

Introduction:

The purpose of this workshop was to convene regional resource managers, academics and scientists to draft the response protocols for coral bleaching, disease and COTS outbreaks. Personnel from Papahanaumokuakea Marine National Monument (PMNM), Coral Reef Ecosystems Division (CRED) of NOAA, Division of Aquatic Resources (DAR), The Nature Conservancy (TNC), Bishop Museum, Oceanic Institute, National Park Service, University of Hawaii (UH) and the Hawaii Institute of Marine Biology (HIMB) were present at this meeting. The participants were arranged into three groups according to their areas of specialization and expertise, and consisted of coral bleaching and COTS, coral disease, and resource management. The workshop objectives for the participants are outlined below. Each focus group had a set of questions particular to that group. The results of their meetings are summarized in two parts and are contained in the following sections. The two parts are comprised of recommendations from the management group and those from the two biological groups: coral bleaching & COTS, combined with the recommendations from the coral disease group.

Workshop Objectives:

1. Discuss the development of the rapid response contingency plan and introduce other plans already in place.
2. Have managers, scientists and other participants develop protocols for bleaching, disease and COTS outbreaks in Hawaii.
3. Review and agreement on draft coral bleaching, disease and COTS outbreak protocols.

Coral Bleaching, Crown-of-Thorns & Coral Disease Groups
Objectives & Outputs

Introduction:

Coral bleaching events, disease, and Crown of Thorns (COTS) starfish (*Acanthaster planci)* outbreaks have been identified by scientists as threats to the health of coral reef ecosystems that are predicted to increase in severity and duration with global climate change (Hoegh-Guldberg, O., 1999). Local academic, governmental and non-governmental scientists, with extensive backgrounds and experience in different aspects of coral reef ecology, were assembled at this workshop and tasked with developing protocols for responding to reef events. They were divided into two discussion groups of coral disease specialists and coral bleaching and COTS specialists. The following are the combined results from the two groups. The COTS discussion results emerged as a small independent section and are presented first.

Objectives and Output Summary:

Crown-of-Thorns Starfish

Crown of thorns outbreaks are rare events in Hawaii. Two localized outbreaks occurred off Molokai in the late 60's (6,000-7,000 COTS identified) and early 70's (9,000-20,000 COTS identified) (Chesser, 1969: Branham et al., 1971). Another localized event occurred off Oahu in 2005 (Kenyon & Aeby, in press). COTS are a natural component of a healthy ecosystem, however elevated densities indicating a reef may be experiencing an outbreak ($\geq$ 1,500 sea stars km^{-2}; Moran and De'ath, 1992) can result in significant loss of corals cover on reefs, and it is still unclear what drives these population surges. Therefore creating response protocols for these events is an important proactive measure.

Predicting COTS outbreaks is difficult as the drivers of outbreaks in Hawaii are still unknown. Hence, responding to COTS outbreaks will depend upon reports from reef users, managers and/or scientists. Crown-of-thorns are present on reefs throughout the Hawaiian archipelago (Kenyon and Aeby, in press) and these baseline population densities will need to be compared with reported outbreak densities to determine if population numbers are increasing and if a response is required.

Coral Bleaching and Disease Events

Bleaching events are unique because they have been linked to increased sea surface temperatures, and can therefore be predicted. Because managers have access to sea surface temperatures produced by the NOAA hotspot satellite imagery, we will know about the physical parameters that can lead to bleaching before there is an event. For coral disease outbreaks, event predictors are not as clearly delineated as bleaching events and so early detection is dependent upon in situ observations, as it is with COTS outbreaks. For all of these events (bleaching, disease, COTS) observer reports will be collected through the Eyes of the Reef Network which is housed within Reef Check Hawaii. The development of the Eyes of the Reef Network has already been initiated and so rapid response protocols and/or contingency plans need to be developed. To that end, seven questions and the discussion summaries from the groups are listed below.

What are the biological criteria that would activate a rapid response?

Every event will present a unique set of circumstances; however determining some set criteria for response activation will aid in the decision process. Other regions have decision trees with the criterion for response activation outlined in an if–then' format. By determining the conditions that would necessitate a response for Hawaii, a decision tree can be built for this region. Some of the parameters that were put forth are:

- The location of the outbreak, and whether or not it is a site of special importance regarding its ecology, species composition, genetic age, susceptibility, resistance or resilience, socio-economic or cultural significance.
- Comparisons to baseline data and the amount of loss of coral cover and mortality (for disease and bleaching). Note: during the summer there is always a low level of bleaching up to approximately 20%. Therefore, a coral bleaching level of $\geq$25% should be set for initiating a response.
- Determining whether diseases are infectious or are caused by environmental conditions (non-infectious).
- If environmental – what is the stress event? For example, if increased water temperature is suspected then the degree heating weeks for the outbreak area can be determined.

Who are the potential response team members?

The next step in the development of a rapid response protocol is to establish and train the team of responders. Since a response will be a cross agency multi-stakeholder effort, it is essential that the groups identify which personnel from which agencies should be on the rapid response teams. The consensus was that DAR should be the primary resource

trustee responsible for coordinating the response with a standing crew of academics, scientists and managers from DAR, NOAA, HIMB, UH, MOP and QUEST.

What are the fundamental scientific questions that need to be answered to document the response and quantify the event?

During either a coral bleaching event or a coral disease outbreak, both biotic and abiotic causal factors will need to be measured. During the development of the incident event plan a decision should be made as to which variables need to be measured. The incident event plan will direct which survey techniques or methodologies will be employed.
For both bleaching and coral disease, many of the questions will be the same, including:

- What is the spatial extent of the event?
- Which coral species are affected?
- What is the severity of the event?

However, there are questions that will be unique to the type of event being documented, including:

Coral Disease Outbreaks:

- What are the prevalence, virulence, and intensity of the event?
- Have there been any recent environmental changes such as increased rainfall and sedimentation?
- What are the possible transmission factors? Microbiologic, molecular and histological analysis into disease agents will need to take place.

Coral Bleaching Events:

- What are the numbers of colonies that manifest bleaching?
- What is the species composition of the area?
- What are the environmental parameters of the area e.g. in situ temperature, light and water movement?
- What is the rate of recovery or mortality? Mortality needs to be measured through time with consistent methods. If there is recovery, then the factors which confer resilience need to be determined, e.g. species sensitivities, physical parameters such as irradiance levels at the site, habitat type, etc.

Further analysis of this data will be needed to extrapolate ecological questions such as which factors or attributes confer resistance and/or resilience to a reef affected by bleaching or disease. This information will help develop hypotheses as to why the event occurred and allow the development of models for predicting future events.

What are the specific protocols and survey techniques necessary for events?

There are several ways to respond to a coral bleaching or disease event. The nature and scale of the event and the resources available to responders will be the factors that determine the necessary response. The development of appropriate assessment protocols for a rapid and effective response is one of the major goals of this workshop. Several survey techniques were identified during the workshop. Determining spatial extent was identified as the primary response to get an overall picture of the event.

Spatial extent can be quantified with broad scale or synoptic surveys such as tow board surveys, timed swims or the use of diver propulsion devices such as jet boots. Large events can use tow-boards and fast response datasheets to minimize the amount of data for later analysis. For multi-focal events, GPS locations can be used to obtain measure of extent radiating out from the source. In addition, the perimeter of the bleaching event or disease outbreak can be identified and mapped.
Once scale has been established, a toolkit of methodologies should be developed for site assessments. Site assessments could include:

- Belt, Line Intercept and Point Intercept transects
- Video and Photo quad transects
- Tagged colonies for follow-up monitoring
- Permanent monitoring sites

During a disease outbreak investigation there will be additional protocols and sampling techniques required to effectively document and respond to the event. Some of these include establishing bio-safety protocols for risk management and reducing transmission between sites. These responses should utilize established protocols e.g. the Coral Disease and Health Consortium (CDHC) *Field Manual for Investigating Coral Disease Outbreaks* and/or the USGS *Field Manual of Wildlife Diseases*. Safe specimen collection and preservation techniques will need to be outlined. Site sampling and sample collections require standardized bio-safe methods. Many of the samples collected will have to be analyzed in specialized labs. These labs will need to be identified and certain protocols for sample shipment utilized. The CDHC manual has protocols delineated for sample shipment.

Equipment needs and ways to combine resources to provide needed equipment for a response

Every response will require equipment. Depending upon the location and nature of the event and the resource trustee of that area, there will be certain equipment needs that will not be met by the management agency. Therefore it would be useful to have lists of

equipment needs and resources from which these are available for use by response team members. Kits for data collection should also be assembled and made available for each island. For disease investigations, potential labs will need to be identified (both primary and secondary labs) for micro and histological assessment and agreements forged between the labs and funding agency. Boat availability will need to be determined by region and agreements forged for potential use.

The NWHI will have some unique needs due to the isolation and logistical difficulties associated with access. To address these issues a list of resources that are available by atoll should be assembled and someone trained in disease, bleaching and COTS outbreak assessment will need to follow-up on reports.

Recommendations to management for mitigating an event or a disease outbreak

Managers are responsible for making informed decisions by weighing the socio-economic costs and benefits to preserve a resource. It is the job of the scientist to inform management of the state of the resource and the best practices for resource conservation. Here are some of the ideas that were put forth:

- Reduce coral reef stressors
- Culling and quarantine
- Isolate disease vectors
- Remove diseased parts
- Use putty or shotcrete to cover diseased areas on coral
- Use antibiotic jelly

What type of follow-up is needed post response?

Follow-up monitoring is necessary to document change on the reef that may occur due to the event. Follow-up monitoring should include changes in spatial extent, severity and differences in recovery of species affected. It is also necessary to determine whether any management actions taken to mitigate the effects of the event were effective. A final report on the event complete with a debriefing from responders should also be part of the follow-up process and housed with the resource trustee.

Hawaii’s Rapid Response Contingency Plan

NOVICE REPORT FORM

Reef Check Hawai'i/ Hawai'i Institute of Marine Biology/DAR

EYES OF THE REEF Network

Coral Bleaching/Disease/COTS Reporting Form

Online Forms: www.reefcheckhawaii/eyesofthereef

We value your time and assistance.

Please direct any questions to: Krista Heide- Program Coordinator-Reef Check Hawai'i

Phone: (808) 953-4044 Email: contact@reefcheckhawaii.org

A. OBSERVER INFORMATION: **Date of Visit:**_____ **Time :**_____

Name:_____ Phone:_____ Email:_____

Address:_____

(*please circle*): Resident Visitor Tourism Industry Commercial Research Education Other

Vessel/Organization (*if applicable*):_____

B. SITE INFORMATION: **Latitude:**_____ **Longitude:**_____

Island:_____ Location/Site Name:_____ Max. Depth:_____

Buoy #/ Area of Reef:_____ Estimated area affected:_____

C. INCIDENT INFORMATION **ARE PHOTOGRAPHS AVAILABLE?**

Did you observe signs of bleaching? If yes continue to Section D. ____Yes ____No

Did you observe signs of disease? If yes skip to Section E.

Did you observe signs of a Crown-of-Thorns Sea Star (COTS) outbreak? If yes skip to section F.

D. BLEACHING INFORMATION (Please enter a check mark (√) into the appropriate space.)

Types of Corals Bleached? (Table 2)	*Percent of coral bleached?*	*In general, how severe was the bleaching?*
*Describe:*_____	____0%	____Bleached only on upper surface
_____	____1-10%	____Pale (very light brown, purple or yellowish)
_____	____11-30%	____Totally Bleached White
_____	____31-50%	____Bleached Coral with Algae
_____	____51-75%	*Depth where bleaching was observed?*
_____	____76-100%	____MIN (ft) ____MAX (ft)

E. DISEASE INFORMATION

Types of Corals Affected? (Table 2)	*Percent of coral affected?*	*Lesion type?*
*Describe:*_____	____0%	_____Tissue Loss?
_____	____1-10%	_____Growth Anomaly?
_____	____11-30%	_____Discoloration?
_____	____31-50%	*Describe:*_____
_____	____51-75%	_____
_____	____76-100%	_____

F. CROWN-OF-THORNS INFORMATION

Types of Corals affected? (Table 2)	*Percent of Corals affected?*	*Estimated number of animals?*
*Describe:*_____	_____1-10%	____1-50
_____	_____11-30%	____51-100
_____	_____31-50%	____101-250
_____	_____51-75%	____251-500
_____	_____76-100%	____501-1000
_____		____1001+

PAGE TWO OF REPORT FORMS

Table 1: Percent Live Coral

This figure is to help estimate percent cover. It can be used first to determine what proportion of the reef is covered with live coral (& coral cover) (Section B) then to estimate the proportion of corals on the reef that are affected by bleaching or disease (% of corals bleached or diseased) (Section D, E, F).

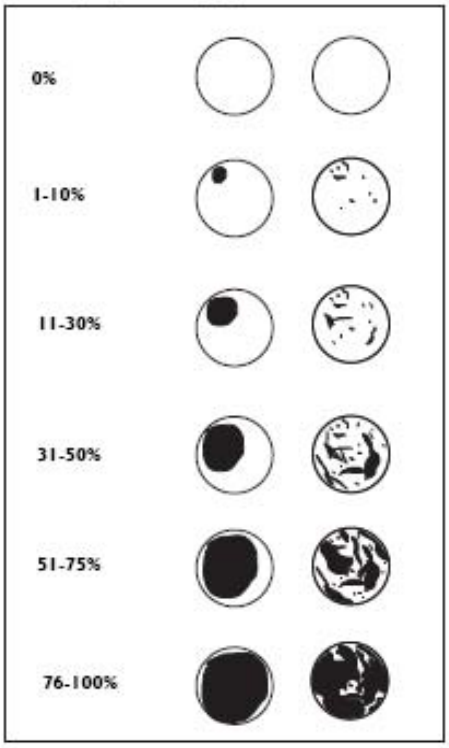
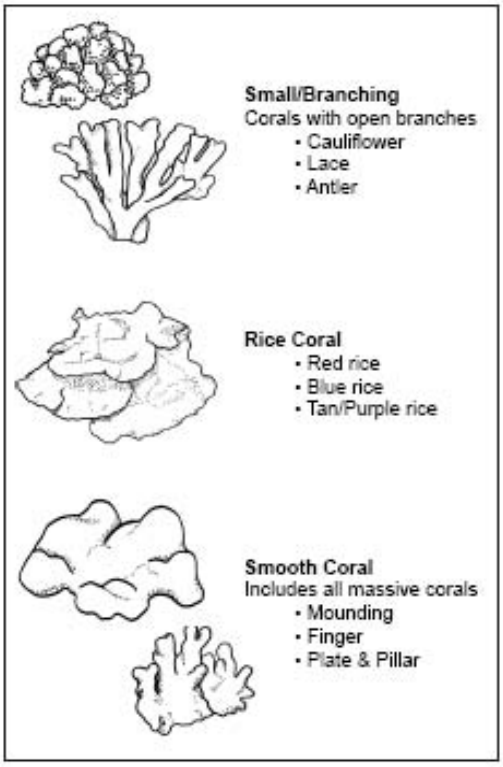


Table 2: Coral ID Key

The table below helps identify major groups of corals by shape and ones found in Hawai'i. More experienced observers are encouraged to identify by family, genus and/or species.



Fold, tape and mail this form to Eyes of the Reef Network, Reef Check Hawai`i using the self-addressed panel below. You may also report online at http://www.reefcheckhawaii.org/eyesofthereef.html

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Place
First Class
Stamp
Here

Eyes of the Reef Network
Reef Check Hawai`i
P.O. Box 621
4224 Waialae Ave.
Honolulu, HI 96816

ADVANCED REPORT FORM

Reef Check Hawai'i/ Hawai'i Institute of Marine Biology/DAR

EYES OF THE REEF Network

Coral Bleaching/Disease/COTS Reporting Form

Online Forms: www.reefcheckhawaii/eyesofthereef
We value your time and assistance.
Please direct any questions to: **Krista Heide**- Program Coordinator-Reef Check Hawai'i
Phone: (808) 953-4044 Email: contact@reefcheckhawaii.org

A. OBSERVER INFORMATION: **Date of Visit:**_____ **Time :**_____
Name:_____ Phone:_____ Email:_____
Address:_____
(*please circle*): Resident Visitor Tourism Industry Commercial Research Education Other
Vessel/Organization (*if applicable*):_____

B. SITE INFORMATION: **Latitude:**_____ **Longitude:**_____
Island:_____ Location/Site Name:_____ Max. Depth:_____
Buoy #/ Area of Reef:_____ Estimated area affected:_____
Environmental Conditions (if available)
Wind Speed: _____ Air Temp: _____ Water Surface Temp:_____ Water Bottom Temp:_____
Cloud Cover (circle): Clear Partly Cloudy Mostly Cloudy Overcast
Reef Condition (please circle)
Percent of live coral cover? 0% 1-10% 11-30% 31-50% 51-75% 76-100%
Most abundant coral type? (Table 2) Smooth _____ Distinct Branching _____ Rice _____ Other:_____

C. INCIDENT INFORMATION **ARE PHOTOGRAPHS AVAILABLE?** ___Yes ___No
Did you observe signs of bleaching? If yes continue to Section D.
Did you observe signs of disease? If yes skip to Section E.
Did you observe signs of a Crown-of-Thorns Sea Star (COTS) outbreak? If yes skip to section F.

D. BLEACHING INFORMATION (Please enter a check mark (√) into the appropriate space.)

Types of Corals Bleached? (Table 2)
_____Smooth Coral (*Porites*)
_____Mounding (*P. lobata*)
_____Finger (*P. compressa*)
_____Plating (*P. rus*)
_____Rice Coral (*Montipora*)
_____Red rice (*M. capitata*)
_____Blue rice (*M. flabellata*)
_____Tan/Purple rice (*M. patula*)
_____Distinct Branching Coral (*Pocillopora*)
_____Cauliflower (*P. meandrina*)
_____Lace (*P. damicornis*)
_____Antler (*P. eydouxi*)
_____Other_____(specify)

Percent of coral bleached?
_____0%
_____1-10%
_____11-30%
_____31-50%
_____51-75%
_____76-100%

In general, how severe was the bleaching?
_____Bleached only on upper surface
_____Pale (very light brown, purple or yellowish)
_____Totally Bleached White
_____Bleached Coral with Algae

Depth where bleaching was observed?
_____MIN (ft)
_____MAX (ft)

E. DISEASE INFORMATION

Types of Corals affected? (Table 2)
_____Smooth Coral (*Porites*)
_____Mounding (*P. lobata*)
_____Finger (*P. compressa*)
_____Plating (*P. rus*)
_____Rice Coral (*Montipora*)
_____Red rice (*M. capitata*)
_____Blue rice (*M. flabellata*)
_____Tan/Purple rice (*M. patula*)
_____Distinct Branching Coral (*Pocillopora*)
_____Cauliflower (*P. meandrina*)
_____Lace (*P. damicornis*)
_____Antler (*P. eydouxi*)
_____Other_____(specify)

Lesion type?
_____Tissue Loss
_____Growth Anomaly
_____Discoloration

Percent of coral affected?
_____0%
_____1-10%
_____11-30%
_____31-50%
_____51-75%
_____76-100%

F. CROWN-OF-THORNS INFORMATION

Types of Corals affected?
_____Smooth Coral (*Porites*)
_____Mounding (*P. lobata*)
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_____Plating (*P. rus*)
_____Rice Coral (*Montipora*)
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_____Blue rice (*M. flabellata*)
_____Tan/Purple rice (*M. patula*)
_____Distinct Branching Coral (*Pocillopora*)
_____Cauliflower (*P. meandrina*)
_____Lace (*P. damicornis*)
_____Antler (*P. eydouxi*)
_____Other_____(specify)

Estimated number of animals?
____1-50
____51-100
____101-250
____251-500
____501-1000
____1001-3000
____3000+

Reef Check Hawai'i • Hawai'i Institute of Marine Biology • DAR

EYES OF THE REEF NETWORK

MONITORING NETWORK FOR CORAL BLEACHING & DISEASE, COTS AND MARINE INVASIVE SPECIES

Report Form Instruction Sheet

Thank you for participating in the Eyes of the Reef Monitoring Network. Your time and efforts as part of the Eyes of the Reef team are greatly appreciated. Your information is an important element of an early warning system for coral bleaching, coral disease and crown of thorns (COTS) in Hawai'i.

A. Observer Information: Fill out the date and time of your visit and personal information. If you have previously sent in a report, you need not complete the personal information. Also indicate your status (resident, visitor, etc.) and, if pertinent, vessel and organization.

B. Site Information: Fill out the information as completely as possible and to the best of your knowledge. Latitude and longitude are very important, so if possible, please provide GPS coordinates.

- Estimated area: How large of an area is affected? Visually estimate size of area affected.
- Reef Condition: How much of the reef bottom is covered with live coral? Visually estimate percent cover of coral (Table 1). What is the most common type of coral? Identify the most abundant coral type by major group (Table 2.

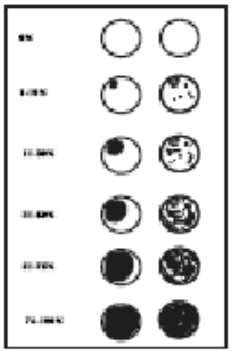


Table 1: Amount of live coral and/or affected coral.
This figure is designed to help you in estimating percentage cover. It can be used to estimate the percentage of living coral covering the seafloor (Sec. B: Reef Condition); and to estimate the percentage of living coral that is affected by bleaching, disease, or COTS.

C. Incident Information: Based upon the type of event (bleaching, disease, COTS), follow directions to the correct section for reporting. Photographs are invaluable so please forward any you may have of the event.

D. Bleaching Information:

- Types of corals bleached: Please indicate the types of corals bleached by checking off relevent categories, using Table 1 as a reference. Some coral species are more susceptible to bleaching than others so not all types of coral may be bleached in an area.
- Percent of coral bleached: Indicate the proportion of live coral at the site that is bleached using Table 2 as a reference. For example, if there was only 11 - 30% of live coral cover at your site and all of it was bleached, than the percent bleached would be 76 - 100%. This will enable us to monitor the progress and severity of the bleaching at this site.

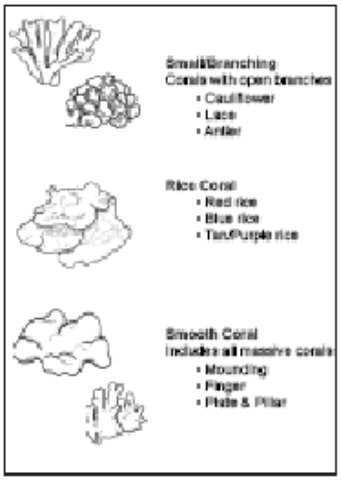


Table 2: Coral ID Key
This figure is a guide to the main shapes of corals. Coral structure is a good general indicator of the type of coral, although more experienced observers are encouraged to identify coral to higher levels of resolution (i.e. genus or species) where possible.

- Severity of bleaching: How white is the coral? Check the line that best describes the severity of the coral bleaching.

- Depth where bleaching was observed. Give the depth at which you observed the bleaching. Did bleaching only occur in shallow water or did it extend deeper? Bleaching is a result of warmer water temperatures and so water depth can play an important part in the amount of coral bleaching.

E. Disease Information:

- Types of corals with lesions: Please indicate the types of corals affected by disease by checking off relevant categories, using Table 1 as a reference. Some species are more susceptible to disease than others so not all types of coral may be affected in an area.

- Lesion type: Check the line that best describes the type of disease (tissue loss, discoloration, growth anomaly).

- Percent of coral diseased: Indicate the proportion of live coral that is diseased using Table 2 as a reference. For example, if the affected reef area had only 11 - 30% of live coral cover and half of it was diseased, than the percent diseased would be would be 31-50%. This will enable us to monitor the progress and severity of disease at this site.

F. Crown of Thorns Information:

- Types of corals that are eaten by COTS: Please indicate the types of corals affected by COTS. COTS prefer certain species of corals, but do feed on other coral types. Providing correct coral types provide valuable information for understanding COTS damage to reefs in Hawaii.

- Estimated number of animals. Check the appropriate line.

How to send in your data:

- Fill out our online reporting form at **http://www.reefcheckhawaii.org/eyesofthereef.html**

- Download a copy of the reporting form at **http://www.reefcheckhawaii.org/eyesofthereef.html**. Complete the form, fold and tape it, affix a postage stamp and send to the address on the back.

There are many questions about coral bleaching, coral disease and COT outbreaks. For more information and references for filling out the reporting forms, please visit our website at:

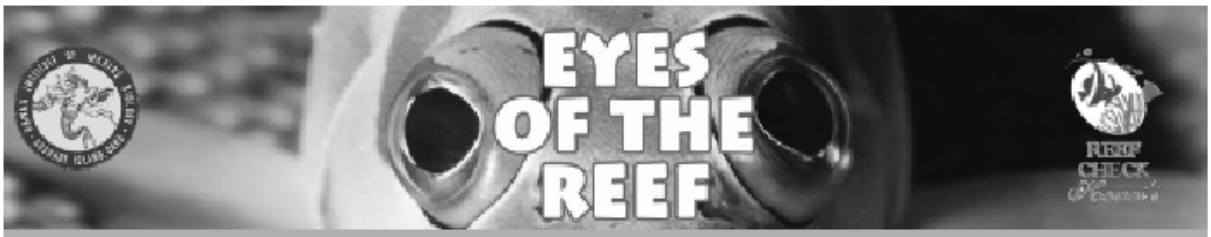
http://www.reefcheckhawaii.org/eyesofthereef.html

Or you may contact us by email at: **contact@reefcheckhawaii.org**

Or mail to:

Eyes of the Reef Network
Reef Check Hawai`i
P.O. Box 621
4224 Waialae Ave.
Honolulu, HI 96816

Once again, thank you for your participation and help in gathering this important infomation.



MONITORING NETWORK FOR CORAL BLEACHING & DISEASE, COTS AND MARINE INVASIVE SPECIES
HAWAII: (808) 953-4044 WWW.REEFCHECKHAWAII.ORG/EYESOFTHEREEF.HTML

Eyes of the Reef Network Overview

The Eyes of the Reef Network was developed to increase public awareness and engage stakeholders in the monitoring and reporting of coral bleaching and disease, marine invasive species and crown-of-thorn sea star (COTS) outbreaks. The statewide network is the first tier of a rapid response protocol developed by the Division of Aquatic Resources and the Climate Change and Marine Disease Local Action Strategy, implemented by Reef Check Hawaii. The Eyes of the Reef Network is comprised of regular reef users (including recreational users, tourism professionals, researchers, and fishers) who voluntarily monitor and report on conditions at reefs that they visit regularly.

The EOTR Network can make a difference.

Pollution, climate change, and poor land use practices create environmental conditions that foster coral disease and coral bleaching, support the spread of invasive species and threaten reef health. Detecting the early signs of any of these events on our local reefs requires a wide network of observers providing regular reports of conditions throughout the region. The Eyes of the Reef Network has been designed to provide reliable reports on bleaching, disease, and changing reef conditions throughout Hawaii.

Coral Bleaching & Disease:
Even small environmental changes may lower coral's resistance to disease or bleaching. There are many types of disease, some extremely virulent that can spread quickly. In recent decades, the unusually high water temperatures caused by climate change have been the major cause of coral bleaching events worldwide. When water temperatures increase above average, severe and widespread bleaching can occur (known as a 'mass-bleaching event'). Detecting the early signs of mass-bleaching or coral disease is critical so that action can be taken to minimize the damage from these events.

COTS and Marine Invasive Species:
Invasive species can be introduced or native marine species can spread out of control, often as a response to environmental changes. If left unchecked, these events can be devastating to our reefs. Early detection is critical in controlling COTS outbreaks and invasive algae and invertebrates.

We need your help!!

Hawaii's reefs are numerous and widespread and scientists and managers are only able to monitor a small fraction of them. More trained eyes are needed to catch these events early on. Without these initial sightings by the local "eyes" on our reefs, such occurrences may go unnoticed until it is too late.

How can you join?

Whether you are a recreational ocean user, recreational or commercial fisherman, tourism operator, researcher or student, you can help us learn more about when and where these events occur by keeping an eye out for signs of change when visiting the reef. Participation is simple: attend a training workshop and use your eyes!

For information on how to join Eyes of the Reef, please email contact@reefcheckhawaii.org or contact the Reef Check Hawaii Coordinator at (808) 953-4044.

Supported by:

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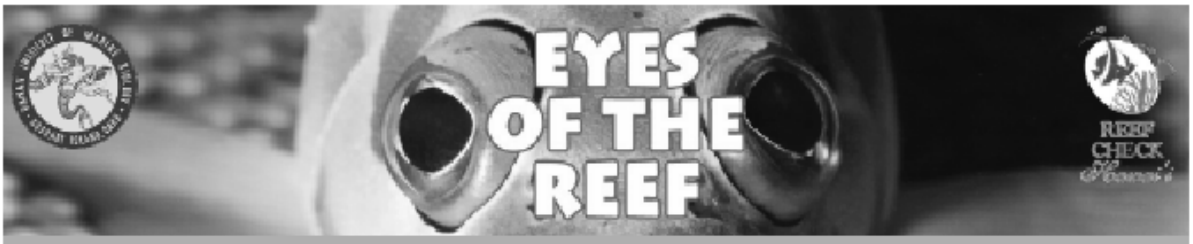

Coral Bleaching Facts

What is coral bleaching?

Zoxanthellae in coral polyps

A coral colony is made up of numerous individual coral polyps. Corals use their tentacles to feed on zooplankton, but depend primarily on microscopic, algae known as zooxanthellae located inside their tissues to provide them with food. Corals are very dependent on this symbiotic relationship, receiving up to 90% of their energy from the zooxanthellae. Healthy corals usually appear tan, brown or green from the presence of the algae within their tissues. Some types of corals have additional pigments so may appear more blue or purple.

Bleached coral polyps

Coral bleaching is a stress response that occurs when the coral-algae symbiotic relationship breaks down. The term "bleaching" describes the loss of color that results when zooxanthellae are expelled from the coral polyps or when chlorophyll within the algae are degraded. When the zooxanthellae leave the coral, the white of the coral skeleton is then clearly visible through the transparent coral tissue, making the coral appear bright white or 'bleached'. Some corals, such as our lobe coral, have additional pigments in their tissue, so when they 'bleach' they may turn a pastel shade of yellow, blue or pink rather than bright white.

Montipora capitata bleaching at Maro Reef, NWHI photo: Greta Smith Aeby

What causes coral bleaching?

Coral bleaching can be caused by a wide range of environmental stressors such as pollution, oil spills, increased sedimentation, changes in salinity, low oxygen, or disease. However, the primary cause of mass coral bleaching is increased sea temperatures. Corals are very sensitive animals so water temperatures need only increase 1-2° C above normal levels for bleaching to occur. The corals are still alive after bleaching but begin to starve. Most corals struggle to survive without their zooxanthellae. If the stressful conditions return to normal rather quickly, the corals can regain or regrow their zooxanthellae and survive. If the stressors are prolonged, the corals are more susceptible to disease, predation, and death because they are without an important energy source.

Not all corals are equally susceptible to bleaching. Fast-growing branching and plate corals are often the first to bleach and are more likely to die from bleaching. Slower growing massive corals usually take longer to bleach and tend to be able to survive for longer in the bleached state.

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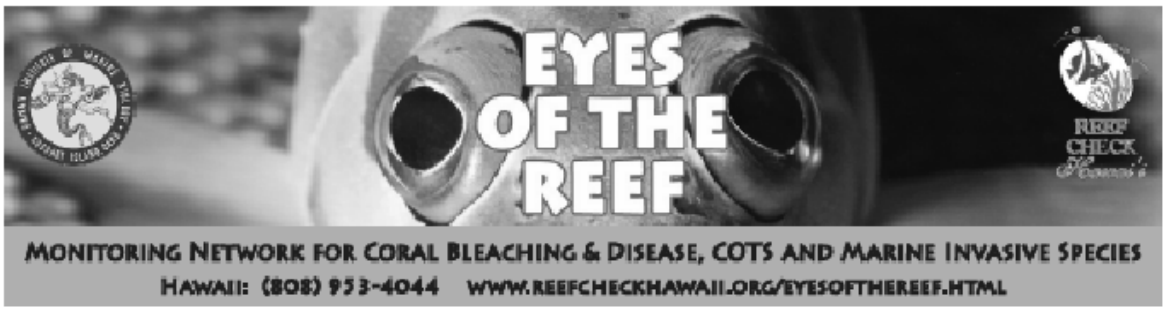
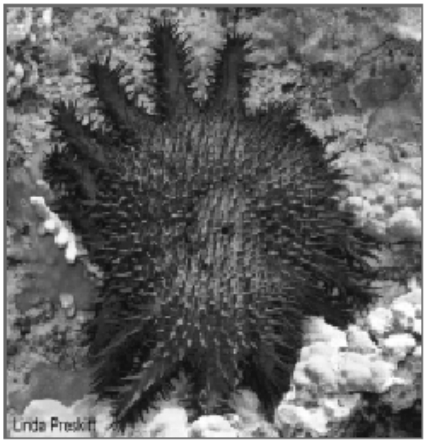


Crown-of-Thorns Sea Stars (COTS) Facts

What are COTS?

Crown-of-thorn sea stars (COTS) are unusually large sea stars that can grow to almost a meter in diameter. They have up to 19 arms, with the entire upper surface covered with sharp venomous spines and can move up to 20 meters an hour. Due to their voracious appetites for live coral, COTS are one of the best known sea stars.



Top: Adult crown-of-thorns sea star.
Bottom: Closeup of spines and feet.

Crown-of-thorns can take over coral reefs quickly due to their ability to spawn millions of eggs a year. Once fertilized, eggs grow into planktonic larvae in 24 hours, which drift in ocean currents. The juveniles are 1-2 mm across when they settle onto the reef and live among rocks and rubble, eating encrusting coralline algae. At approximately six months of age they start to eat coral and begin to grow more rapidly, reaching reproductive maturity when they are 2-3 years old, breeding up to 7 years. Each female can produce up to 60 million eggs during a single spawning season. As COTS have the highest measured fertilization rate of any invertebrate, a small population of COTS has the potential to produce a very large number of offspring. COTS feed on coral by pulling its stomach out of its mouth with its tube feet and placing it on the coral. Digestive enzymes kill the live coral and the stomach absorbs the tissue, leaving the white calcium carbonate skeleton.

COTS on Hawaiian Reefs

Triton's trumpet (*Charonia tritonis*), a predator of COTS.

In Hawai'i, COTS primarily feed on rice, lace and cauliflower corals. Healthy reef systems can support small populations of COTS for many years with only a small reduction in coral cover. But when a COTS outbreak occurs, there can be many animals per square meter, and competition for food forces them to eat all coral species, killing most of the living coral in the area. It can take decades for the reef to recover.

Natural controls include the high mortality of the larvae, high predation of juvenile COTS, and feeding on adults by Triton's trumpets, Harlequin shrimp, and stripebelly puffers.

What causes COTS outbreaks?

COTS outbreak, Oahu, Hawaii, 2005.

Natural fluctuations in populations. Natural fluctuations in temperature, salinity or planktonic food availability could all contribute to improving the survival of COTS larvae.

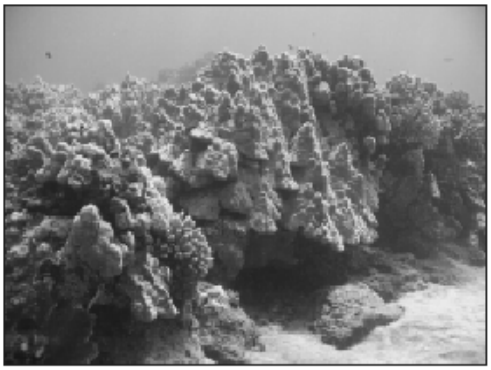
Removal of natural predators. Loss of natural predators that feed on the juvenile and adult COTS can be costly. Predation on juveniles decreases the number of COTS that reach reproductive maturity.

Increased nutrients lead to increased planktonic food, improving larvae survival. Crown-of-thorn sea stars have been present on reefs for millions of years, but major outbreaks were not observed until the 1960s. Outbreaks sometimes occur in areas with high levels of nutrients, which generally accumulate from terrestrial runoff.

During outbreaks, crown-of-thorns sea stars not only eat live, adult coral, but also prevent the recruitment of juvenile corals. This prevents coral population growth, hindering a coral colony's ability to recover from predation. Each sea star can eat up to a meter-squared of coral each month, so when their populations become large they can quickly kill entire coral colonies. Once the sea stars deplete one area of live coral, they move on to adjacent regions. Outbreaks of crown-of-thorns typically last between 1-5 years, although on large complex reef systems an outbreak can last 15-20 years. This is due to the fact that many reefs are in close proximity, which allows the crown-of-thorns to spread from reef to reef. After an outbreak, the reefs begin to recover, but it may take one or many decades for them to reach original levels of coral cover. In some case studies, the reef's community structure completely changes as the reef shifts from coral to algae dominated.

You can help stop a COTS outbreak.

There are few options to manage outbreaks of COTS and it is impossible to eradicate COTS from reefs where they are in outbreak densities. However, with sufficient effort, small areas can be protected. Because sea stars can quickly move from one area to another, control of a specific area must be an ongoing effort and may be required on a daily basis. Thus, early detection and reporting of any unusual numbers of COTS can help reef managers minimize the impact of a COTS outbreak.



Help monitor our coral reefs

Join the Eyes of the Reef network and let us know if you see coral bleaching or disease, COTS outbreaks or marine invasive species. If you are a scuba diver then also join Reef Check Hawaii where you can get trained to collect scientific data on the condition of Hawaii's reefs.

Supported by:

For information or to join Eyes of the Reef Network:

http://www.reefcheckhawaii.org/eyesofthereef.html

Hawaii’s Rapid Response Contingency Plan

Websites and Information Resources

Coral Reef Monitoring Programs, Manuals andResponse Plans from Other Regions

Atlantic and Gulf Rapid Reef Assessment (AGRRA):
http://www.coral.noaa.gov./

Australian Institute of Marine Science

- Long Term Monitoring Program:

http://www.aims.gov.au/pages/research/reef-monitoring/reef-monitoring-index.html

- Crown-of-thorns starfish Information:

http://www.aims.gov.au/docs/research/biodiversity-ecology/threats/cots.html
http://data.aims.gov.au/waCOTSPage/cotspage.jsp

Bass DK and Miller IR (1996). Crown-of-thorns starfish and coral surveys using the manta tow and scuba search techniques. Australian Institute of Marine Science. Townsville, Australia.

Bunce L and. Pomeroy R (2003). Socioeconomic monitoring guidelines for coastal managers in Southeast Asia: SOCMON Draft under final revision.
http://ipo.nos.noaa.gov/coralgrantsdocs/SocMonSEAsia.doc

Bunce L, Townsley P, Pomeroy R, and Pollnac R (2000). Socioeconomic manual for coral reef management, 2nd edition. Australian Institute of Marine Science, Townsville, Australia.
http://www.aims.gov.au/pages/reflib/smcrm/mcrm-000.html

Caribbean Coastal Marine Productivity Program (CARICOMP):
http://www.ima.gov.tt/caricomp.htm

Climate Change Group (2007) *Great Barrier Reef Coral Bleaching Response Plan Summer 2007-2008.* Great Barrier Reef Marine Park Authority, Townsville, Qld. Australia.
http://www.gbrmpa.gov.au/__data/assets/pdf_file/0004/23908/coral_bleaching_response_plan2007-08.pdf

Coral Reef Degradation in the Indian Ocean (CORDIO):
http://www.cordio.org/

Coral Disease and Health Consortium: A National Research Plan
http://www.coralreef.gov/library/pdf/FInal%20CDHC%20plan.pdf

English S, Wilkinson C, and Baker V (1997). Survey manual for tropical marine resources, 2nd edition. Australian Institute of Marine Science, Townsville, Australia.

Friend M and Franson JC (1999). *Field Manual of Wildlife Diseases General Field Procedures and Diseases of Birds*. U. S. Geological Survey. Washington, D.C.

Great Barrier Reef Marine Park Authority

- Bleaching Response Plan

http://www.gbrmpa.gov.au/corp_site/key_issues/climate_change/management_responses/coral_bleaching_response_plan

- BleachWatch Program

http://www.gbrmpa.gov.au/corp_site/key_issues/climate_change/management_responses/bleach_watch2.html

- Management Plan

http://www.gbrmpa.gov.au/corp_site/management

Global Coral Reef Monitoring Network (GCRMN)
http://www.gcrmn.org/

International Coral Reef Action Network-Methods for Ecological Monitoring
http://www.icran.org/pdf/Methods_Ecological_Monitoring.pdf

Marshall P and Schuttenberg H (2006). *A Reef Manager's Guide to Coral Bleaching.* Great Barrier Reef Marine Park Authority, Townsville, Australia.

Mote Marine Laboratory-BleachWatch
http://isurus.mote.org/Keys/bleachwatch.phtml

NOAA

- Coral Disease Identification Page

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

- Coral Reef Information System (CoRIS)

http://www.coris.noaa.gov/

- Coral Reef Watch

http://coralreefwatch.noaa.gov/satellite/

- Florida Keys National Marine Sanctuary Management Plan

http://www.sanctuaries.noaa.gov/management/welcome.html

Oliver J, Marshal P, Setiasih N and Hansen L (2004). *A Global Protocol for Assessment and Monitoring of Coral Bleaching*, World Wildlife Fund, Indonesia.

Raymundo L, Couch C and Harvell D (eds.) (2008). *A coral disease handbook: Guidelines for assessment, monitoring and management.* Coral reef targeted research and capacity building for management program. St. Lucia, Queensland, Australia

ReefBase Monitoring protocol for coral bleaching available soon
http://www.wcmc.org.uk/data/database/reefbase.html

Woodley C M, Bruckner A W, Mclenon A, Higgins J and Galloway S B (2008). *Field Manual for Investigating Coral Disease Outbreaks*. National Oceanic Atmospheric Administration, Silver Spring, Md.

Coral Reef Monitoring Programs and Resources for Hawaii

Climate Change and Marine Disease GIS Database
http://www.hawaii.edu/himb/ccmdgis/index.html>.

Climate Change and Marine Disease Local Action Strategy
http://hawaii.gov/dlnr/dar/coral/coral_las_ccmd.html

Division of Aquatic Resources
http://hawaii.gov/dlnr/dar/coral/coral_monitoring.html

Eyes of the Reef Network
http://www.reefcheckhawaii.org/eyesofthereef

Hawaii Coral Reef Assessment and Monitoring Program:
http://cramp.wcc.hawaii.edu/

NOAA

- Coral Reef Ecosystems Division

http://www.pifsc.noaa.gov/cred/

- Papahanaumokuakea Marine National Monument

http://hawaiireef.noaa.gov/welcome.html

QUEST
http://www.kmec.uhh.hawaii.edu/quest.htm

Reef Check Hawaii
http://www.reefcheckhawaii.org

ReefBase-summary bleaching report.form:
http://www.reefbase.org/input/bleachingreport/index.asp

Salm RV and Coles SL, (eds). 2001. *Coral Bleaching and Marine Protected Areas*. Proceedings of the Workshop on Mitigating Coral Bleaching Impact Through MPA Design. Bishop Museum, Honolulu, Hawaii, May 29-31 2001. Asia Pacific Coastal Marine Program Report # 0102, The Nature Conservancy, Honolulu, Hawaii, USA: 118pp.