Adapting Coral Reef Management in the Face of Climate Change
Part II

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Introduction

This workshop was the second of two to explore how coral reef management is being adapted in response to climate change. Case studies demonstrated how some managers are engaging user and scientific communities to identify ecological & socio-economic vulnerabilities and to plan for climate change impacts on tropical ecosystems. Special attention was given to the proposal that tropical ecosystems should be "managed for resilience" as a strategy for responding to climate change. Analysis and discussion considered what it means to manage for socio-ecological resilience, what "resilient governance" might look like, and what scientific agenda is needed to underpin resilient management. The workshop then looked to how this scientific agenda might go beyond academic discussions and evolve a series of active steps by which to respond to future stress from global warming and ocean acidification.

Case Studies

1. 'A Reef Manager's Guide to Coral Bleaching'

Heidi Schuttenberg and Paul Marshall[4]

Release of the report *A Reef Manager's Guide to Coral Bleaching* (http://www.coris.noaa.gov/activities/reef_managers_guide/welcome.html) culminates a three-year collaboration between the National Oceanic and Atmospheric Administration (NOAA) and the Great Barrier Reef Marine Park Authority (GBRMPA) to identify strategies reef managers can implement in response to the significant, emergent threat of mass coral bleaching. Over the last decade, reef managers and reef users have become increasingly alarmed by the impacts of mass coral bleaching events caused by elevated sea temperatures. In many regions, coral bleaching has lead to widespread destruction of coral reefs, causing the U.S. Coral Reef Task Force to identify coral bleaching and climate change as one of the six biggest threats to coral reefs.

Developed through contributions and technical review by 50 world-renowned specialists, The Guide provides an accessible synthesis of evolving knowledge about how reef managers can respond during mass coral bleaching events (Part I) and what actions they can take to help reefs maintain resilience to mass bleaching and other climate-related threats over longer timeframes (Part II). Strategies for management response during a mass bleaching event include providing early warnings about the probability of bleaching, conducting rapid impact assessments, communicating the

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status of bleaching to stakeholders, and considering direct management interventions (e.g., shading reefs). Managing for resilience involves taking actions that support the capacity of coral reef ecosystems to successfully reorganize during stress and change rather than shifting to a predominantly algal state. This capacity is largely determined by ecosystem condition, biological diversity, connectivity between reefs, and local environmental factors. Two key strategies for supporting reef resilience are: adapting marine protected area design and management; and reviewing and revising management targets for recreation, water quality, and fishing.

Challenges

- Because it is not possible for coral reef managers to prevent the cause of mass coral bleaching (above-average sea temperatures), mass bleaching is sometimes perceived as an "unmanageable" threat.
- There is a risk that climate change can serve to undermine support for broader management initiatives to protect coral reefs if people believe that the benefits of good management efforts will inevitably be lost to climate-related threats.
- An important challenge has been to identify meaningful actions that can be taken at a local level in response to mass coral bleaching and climate change.

Recommendations

- Bleaching occurs as a sequence of events, and each stage in the process offers an opportunity for management.
- Some areas are more resistant or tolerant to bleaching. These "lucky" areas can be identified and given extra management protection so that they can serve as a seed bank to replenish areas that experience high coral mortality.
- Decreasing local stressors in general, and particularly during mass bleaching events, will help bleached corals to survive the event.
- Management efforts that protect, maintain and enhance the conditions that help coral reefs to recover after high levels of mortality are particularly valuable actions in the context of mass coral bleaching and climate change. These conditions are high coral cover, good water quality, good herbivorous fish populations, and good biological diversity.
- Managing for resilience represents a paradigm shift. Now we are not just managing to maintain the condition of tropical ecosystems the way they exist today, but we are recognizing that some level of change is inevitable and focusing management on the conditions that will allow ecosystems to recover and reorganize in response to disturbances.
- The ability to predict the onset and severity of mass coral bleaching is important because it allows managers to respond to these events proactively rather than reactively.
- Actions to predict, monitor and communicate about mass coral bleaching are valuable for creating the constituencies and political will to implement longer-term management strategies to support coral reef resilience to climate change.

2. Climate Change: The Reality, What We Have Learned, and How We Apply That Knowledge

Billy Causey[5]

Coral reef ecosystems in the Florida Keys, other portions of the Wider Caribbean and off the Pacific Coast of Central America have shown stress and degradation due to a changing climate since the late 1970's and early 1980's. Coral reef bleaching episodes in 1983, 1987, 1990, 1997 and 1998 in the Florida Keys have been largely responsible for a decrease in living coral cover in some coral reef habitats. The persistence of the same oceanographic and atmospheric conditions that preceded the massive coral bleaching events also resulted in the stress to or loss of other inhabitants and communities of the coral reef ecosystem.

Unfortunately, the linkages between the environmental stressors that contribute to climate change, coral bleaching and the loss of coral cover and a reduction in coral recruitment, as well as the loss of other coral reef inhabitants, has not been supported by a minority of scientists. This has resulted in an open, public scientific debate in the popular literature (newspapers) about the causes of coral reef decline. The minority scientific viewpoint has searched for single causes for coral decline, while the majority of coral reef scientists and managers on a global scale recognize the influence of multiple stressors, complicated by the stress of climate change, in the deterioration of coral reefs. The stress of land-based sources of pollution, habitat degradation, and overfishing, exacerbated by stress from climate change has been largely responsible for the complex set of influences on the declining health of coral reef ecosystems. The unfortunate reality of this scientific debate is that it has given some decision-makers the rationale for not taking action to address the major problems and impacts of climate change. In light of the overwhelming evidence that climate change was an over-arching environmental stress affecting the health of coral reefs, over two decades of possible management actions were lost.

One of the important lessons that Sanctuary managers learned early on in the Florida Keys was to utilize the knowledge and experience of those who were most familiar with the coral reef resources of the area. Managers learned the impact of climate change on the marine environments of the Florida Keys was not disputed by those members of the waterfront community who make their living or recreate on the waters of the Keys and had the background of past observations and the changes they were witnessing. Diving and snorkeling is the number one commercial and recreational activity in the Keys. Frequent observations and personal anecdotal assessments of the condition of the coral reef resources by these groups has resulted in, generally, a very knowledgeable and experienced user public when it relates to the causes for change in the coral reef community in the Keys.

As early as the 1987 coral bleaching event, Sanctuary managers in the Florida Keys were able to predict the onset of coral bleaching due to specific oceanographic and environmental conditions that had been observed during previous bleaching episodes. Weeks before the 1990 coral bleaching event, Sanctuary managers and scientists noted the environmental conditions and predicted a pending coral bleaching episode if those conditions persisted. Word was spread amongst the dive community that coral

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bleaching was anticipated due to the persistent stressful environmental conditions that existed. When the corals began to bleach, an immediate and clear reaction by the dive community and the media was one of confidence in Sanctuary managers to predict coral bleaching. More important was the manager's ability to point to a cause for coral reef decline, as opposed to a continued scientific debate about what was or was not affecting the health of the primary resource that supports their business.

Unfortunately, the realization by some that addressing climate change was beyond the capacity of local managers and the public can have a negative effect. A feeling of helplessness was often heard, and the blame and solutions were thought to be outside the capability of local control or action. Communicating the fact that there are actions that can be taken at the local, regional and global scales to address climate change impacts was the greatest challenge to coral reef managers in the Keys. In large part, such communication with the local public has been facilitated and enhanced through the success in predicting coral bleaching events, but more precisely due to a frequent and open dialog with the community and the media. In addition, a very positive action has been to involve the waterfront community in monitoring the condition of the coral reef prior to the onset of coral bleaching and to report any observations. This involvement of a volunteer team of observers has been formalized in an initiative called Coral Bleach Watch which is managed by Mote Marine Laboratory and sponsored by the National Oceanic and Atmospheric Administration.

These actions by Sanctuary managers in the Florida Keys served to begin increasing social resilience to climate change and the predictable impacts of coral bleaching. By preparing the community for what to expect and using observations from past climatic trends, coupled with anecdotal information gleaned from the waterfront community of the Florida Keys, Sanctuary managers were aided in compiling a base of information that could be articulated to decision makers via the waterfront community. The goal was to enlist the help of people who knew the marine resources of the Keys and turn them into spokespersons about the threat of a changing climate. This has served to encourage observers to report their observations and become involved in the informal monitoring of the health of the coral reefs of the Keys during stressful events. More importantly, it is a way to empower people who are economically dependant on a healthy coral reef to engage in the climate change debate with the goal of spreading the word on the impacts of climate change to the 4 million people who visit the Florida Keys every year. Who better to enlist as spokespersons about the impacts of climate change than those who are most directly affected?

The formal coral reef monitoring programs for the Florida Keys National Marine Sanctuary have identified coral reef habitats that have been impacted more by the stress of climate change, as opposed to other more resilient habitats. Patch reef habitats have maintained greater coral cover as compared to some of the shallow coral reefs along the outer reef tract. These observations are consistent with those made by the local divers and snorkelers. Furthermore, these observations are consistent with those of managers and scientists around the world that some coral reef habitats are more resilient in their response to the stress of climate change than others. Future actions will involve the use of local expertise and knowledge, coupled with data from more comprehensive coral monitoring programs, to identify resilient areas of the coral reef community. Such information, coming from those who make their living from the coral reefs, will provide managers and scientists with critical

information that can be used in the increased protection and conservation of the more resilient coral reefs. This will lead to social resilience of the waterfront communities who are dependent on healthy coral reef environments.

Challenges

- Recognising that climate change in combination with multiple local stressors—including degraded water quality and overfishing—are the causes of coral reef decline in the Florida Keys.
- Recognising disease as a secondary symptom of bleaching events.
- Empowering stakeholders to engage in responsive actions, rather than feeling powerless in the face of the immensity of climate change and mass bleaching.
- Building support among decision-makers to address the stressors causing coral reef ecosystem decline.

Recommendations

There are strategies for supporting socio-ecological resilience, including:

  - A manager's ability to predict the on-set of mass coral bleaching builds the trust and confidence of local stakeholders;
  - Involving local stakeholders in monitoring is empowering;
  - Identifying coral reef areas that are resilient to climate change by using scientific and local knowledge will be useful in making future management decisions;
  - Stakeholders whose livelihoods are being impacted by climate change and reef degradation can become powerful spokespeople for changes to address key threats to the reef.

- Bleaching events can be predicted by using *in situ* and remote sensing data. In the Florida Keys some important signals to look for are (strategies for predicting mass bleaching are described more fully in *A Reef Manager's Guide to Coral Bleaching*):
  - Elevated SSTs
  - Doldrum periods
  - Minimal water circulation
  - Low cloud cover
- There is a need for targeted research on specific topics, for example:
  - The effects of synergistic interaction multiple stressors on coral reefs
  - The increase of disease incidence after coral bleaching events
  - Economic losses associated with coral bleaching
  - Microbial communities in corals during stress events

3. Great Barrier Reef: Vulnerability, Partnerships and Resilience-based Management'

Andrew Skeat[6], Laurence McCook[7] and Paul Marshall[8]

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The Great Barrier Reef (GBR) stretches more than 2,000 km along the coast of Queensland, Australia. It is an iconic natural wonder that underpins industries worth more than $5 billion dollars annually. Pressures on the Reef have included fishing, the declining quality of water entering the Reef lagoon, tourism and natural disturbances, such as cyclones. More recently, climate change has also been recognised as a key pressure affecting ecosystem health, with major coral bleaching events occurring in 1998 and 2002.

Current management response to this new pressure involves a range of actions which will be coordinated within a Great Barrier Reef Climate Change Action Plan. Firstly, scientists and stakeholders are engaged in vulnerability assessments, gaining an understanding of how the ecosystem as a whole will be affected, as well as the likely impact on reef-based industries and communities. Secondly, impacts on the Reef are being actively minimised through management actions aimed at increasing the resilience of the ecosystem. These include a program to halt and reverse the decline of water quality entering the reef lagoon. Finally, partnerships are being formed with stakeholders to improve the adaptive capacity of key industries.

Developing further management responses more specifically targeted at the impacts of climate change provides considerable challenges for the science-management interface. Traditionally, science has identified impacts of human activity and identified their causes; management responses then aim to reduce or remove the source of the impact, in preference to modifying the ecosystem. For climate change, the most critical and cost-effective response (reduction in greenhouse gas emissions) is beyond the scope of marine management agencies, thus requiring new management approaches. This challenge is increased by factors such as: the scale of impacts; the likely synergistic interactions between climate-related stressors and between impacts on different elements of the ecosystems; by the considerable uncertainty in our knowledge of impacts; and by lack of knowledge of the ecology and physiology of much of the biota (95% of the area of the Great Barrier Reef Marine Park is habitats much less well studied than coral reefs).

Challenges

- New management approaches are needed to respond to climate change because the direct cause—increased greenhouse gases—is beyond the control of marine management agencies
- There is uncertainty about the multiple and synergistic ways climate change may cause changes in coral reef ecosystems and the people that rely on them

Recommendations

The GBRMPA has three strategies for responding to climate change:

- Supporting ecosystem resilience through the Reef Water Quality protection plan and rezoning the reef to protect representative habitats throughout the ecosystem (20% of each of 70 bioregions)
- Conducting a vulnerability assessment about the ways climate change will impact the species and habitats of the GBR system, as well as the industries that rely on GBR ecosystem services

    - Working with stakeholders, particularly the tourism industry, to raise awareness about climate change and to support adaptation strategies that are simultaneously good for the industry and the ecosystem
- The tourist industry is also investigating bleaching mitigation possibilities, such as shading of reefs or water sprinklers that increase reflectance, however this is only possible on small scales and for high value sites.

Synthesis Presentation: Key Questions in Managing Reefs for Resilience to Climate Change

David Obura[9]

The immediate threat to coral reefs from climate change is serious, and both scientists and managers are racing to develop knowledge and tools that may help limit the vulnerability of reefs to climate change. A working group on coral bleaching, resilience and climate change has been established through IUCN to facilitate the exchange of information and experience between scientists and managers that are working on these issues. Membership of the group will draw from leading scientists and managers active in coral reef research and management initiatives. The group intends to streamline the identification and testing of management interventions and research hypotheses to mitigate the impacts of climate change on coral reefs. The objectives of the IUCN Climate Change and Coral Reefs (CCCR) Working Group are to:

- Identify priority information gaps and issues;
- Provide a mechanism to focus scientific contributions from different leading research groups;
- Synthesize emerging information and experience to bridge gaps between theoretical science and management application;
- Facilitate the reciprocal flow of information between scientists and managers to continually update and improve recommended management practices for mitigating climate change threats to coral reefs.

As the final case study in the ITMEMS theme on 'building resilience into coral reef management' (conference theme 1), this presentation called for discussion on research questions that flowed from the management case studies discussed throughout the theme. The purpose was to confirm the relevance of these questions as priorities for further exploration by the IUCN CCCR Working Group. The questions were grouped into areas that relate to the bleaching and recovery dynamics of reefs, and scope for management action. Emerging concepts about resilience were used to frame both of these. The priority research questions identified and discussed were:

Challenges

- There is a strong need to provide clear information to decision-makers and to avoid provoking inaction by the scale of the problem.
- Expand targeted research from coral to ecosystem-based levels, as many other components of coral reefs and other ecosystems are also vulnerable to climate change.

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- Expand the scope of understanding to broader changes in land use under a changing climate, and how this might affect synergistic stressors (see previous Workshop)
- Improve integration across the dimensions of coral bleaching, such as between stressors and management actions, ecological and social sciences, from molecular to ecosystem scales, etc.
- Develop strategies to deal with tabloid science which works by undermining credibility of ongoing science and represents vested interests?
- Develop national science-management linkages to meet national and local context and needs. Customize training manuals and guides by translating them into relevant languages

Priority Science-Management Linkages

1. What are the most important resilience variables that need to be monitored and used in management? How to select the priority ones and develop suitable monitoring methods for a range of country contexts and resource levels. Specific areas identified for work include:
    - Which herbivores are most important for resilience?
    - Promote the incorporation of coral size class parameters into monitoring programmes.
    - Use modelling tools to evaluate different methods and outcomes.
2. Which ecosystem functions are most important for resilience? How to preserve these to help ecosystems survive long enough to enable adaptation to new climate regimes?
3. We may not know of many critical species and processes, and managing for resilience will help avoid loss of the 'unknown unknowns'. In this way resilience is a proactive formulation of the Precautionary Principle, and empowers its use in management.
4. Need to understand the interaction between stressors and how these interactions affect management plans and actions.
5. Increase the use of scenario-based modelling to better understand the current situation and provide choices for decision makers, e.g.
    - Evaluate and model past bleaching events and management responses to better understand how to respond in the future.
    - Can we expand scenarios based on current degradation in the Caribbean to predict potential outcomes for the Indo-Pacific?
    - Use scenarios to better understand how fast reefs and management systems have to change to keep up with climate change.
    - Adopt new scenario approaches based on future CO_2 stabilization targets to explicitly define end-points and impacts at those end-points, and to base coral reef impact assessments on the same end-points and scenarios as being used in economic and political circles.
6. More research is need on changes that will be brought about by changes in water chemistry, in particular acidification. How will these interact with bleaching impacts? Will they become more important?

Overall Workshop Summary

This workshop consisted of four presentations: two case studies (Florida Keys, USA and Great Barrier Reef, Australia) and two synthesis papers (*A Reef Manager's Guide to Coral Bleaching* and the IUCN CCCR Working Group). Both case studies identified three key themes. First, that current and future reef condition will be the result of multiple, synergistic stresses to coral reef ecosystems. Recognizing this, the GBRMPA has launched a major initiative to better understand the vulnerabilities that climate change poses across the ecosystem, both in terms of species and habitats. Second, both sites are involved in identifying areas that may be resilient to climate change. In the Florida Keys, the effort to identify coral reef habitats or areas that are more resilient is being implemented through a partnership of government, environmental groups, and academic researchers using both scientific and local knowledge. Third, both case studies identified a need to engage stakeholders through dialogue and community-oriented monitoring programs. Both case studies noted that stakeholders are increasingly aware of the threat climate change poses to coral reefs and identified the importance of being able to offer solutions for moving forward.

A Reef Manager's Guide to Coral Bleaching offers such solutions for taking action in response to mass bleaching and climate change. It is one of the first attempts to go beyond the 'alarm calling' and start to suggest the practical steps that managers can take toward responding to the serious implications of climate change (warming and acidification of coral reef waters). The *Guide* outlines an approach manager's can take to respond during mass bleaching events to build constituencies for coral reef management and to better understand ecosystem resilience. The *Guide* also describes emerging approaches to managing coral reefs for resilience by describing the stages of a mass bleaching event and identifying the opportunities for management at each stage in the process. The Guide's recommendations were developed through an experts' workshop, a synthesis of existing scientific information, and a review of existing management experiences. The IUCN CCCR Working Group aims to provide this function of synthesizing new scientific findings and evolving management experience into the future. By bringing together leading scientists and practitioners to answer key questions about climate change and coral reefs, the working group intends to expedite learning and to strengthen management practices to help support coral reef resilience to climate change.

Through the workshop discussions, the following challenges, management recommendations and research questions were identified:

Challenges

- Climate change, in combination with local threats to reefs, is having significant impacts on coral reef ecosystem condition. This threat is projected to escalate significantly over the next 30 years.
- Unlike local threats to coral reefs, the ultimate cause of climate change—increases in greenhouse gases in the atmosphere — is well beyond the control of local managers.
- Stakeholders are increasingly recognizing that climate change poses a serious threat to coral reef ecosystems; however, until recently it has been difficult to articulate meaningful solutions to this problem that can be implemented locally.
- Managers are increasingly responding to climate change by taking management actions that can increase the socio-ecological resilience of reefs and the stakeholders that rely on them; however, it is difficult to know exactly how to

implement these strategies. There is a serious need to underpin management with meaningful science aimed at developing understandings and new approaches to the massive challenge of climate change.

Management Recommendations and Future Research Questions

1. Coral reef habitats and areas respond to mass bleaching differently. Some areas seem to be more resilient to mass bleaching than others. More resilient areas can be identified and protected as "seed-banks" to provide new coral larvae for areas that experience high levels of coral mortality

Associated research questions:

a) What strategies are useful for measuring resilience? What variables are most instructive?

2. Future coral reef condition will be determined by the combined and synergistic impacts of climate change and local threats to coral reefs. Removing or minimising local threats to reefs—such as degraded water quality, overfishing, destructive fishing, or irresponsible tourism—increases the chances corals will be able to survive mass bleaching events.

Associated research questions:

a) How do multiple stressors interact with each other to determine coral and coral reef ecosystem condition?

3. Because coral reef managers cannot mitigate greenhouse gas emissions, they are increasingly responding to the threat of climate change by implementing strategies to support ecosystem resilience. Managing for resilience represents a paradigm shift. Rather than managing with an expectation that coral reef ecosystems will exist in their current condition into the future, managing for resilience recognizes that change is inevitable and aim to support functions and processes that will facilitate ecosystem recovery and reorganization. Attributes that support coral reef ecosystem recovery include good water quality, strong herbivorous fish populations, connectivity between reef areas, high coral cover, and high biological diversity.

Associated research questions:

a) Which ecosystem functions are most important for resilience?
b) How can the recovery of reefs after mass coral bleaching and mortality be enhanced?
c) Which herbivores are most important for resilience?

4. Climate change will affect not only coral reef ecosystems, but also the stakeholders that rely on reefs for food and income. Managers can support the social resilience of stakeholders to ecosystem change by informing and empowering them. Predicting the onset of mass bleaching, involving stakeholders in community monitoring, and engaging stakeholders in dialogue about the impacts of climate change and options for responding are all strategies for supporting social resilience.

Associated research questions:

a) What strategies can be used to prevent bleaching at small, high value tourism sites? Can shading or other strategies be effective?

b) What important features of reefs can be reinforced to lessen the impact of mass bleaching and mortality events?
c) What factors can support the social resilience of stakeholders that rely on good reef condition?
d) What barriers are there to implementing changes in resource use and management in response to climate change?

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