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Module 6: Building Resilience into Coral Reef Management

Section 1: Social-Ecological Resilience

Learning Objectives

By the end of this module you will:

- Understand the term socio-ecological resilience
- Be able to incorporate resilience monitoring into a bleaching response plan
- Learn how to incorporate the concept of socio-ecological resilience into coral reef management
- Heard about examples of integrating social-ecological resilience into management in Marshalls, American Samoa, Kenya and Papua New Guinea.

Background

In previous sections we learned how to identify the impacts of climate change on ecosystems and socioeconomic systems of stakeholders. We also learned how socioeconomic information can help improve the coastal management under changing climate. This section discusses how we might incorporate social-ecological resilience into coral reef management. We provide principles of building social resilience and examples of cases in which social and ecological information can be integrated and used to adapt coral reef management planning. Resilience to climate change is an emerging concept in coral reef management, and much of the science behind resilience is still in the early stages. Likewise, incorporating social and ecological resilience into management is a relatively new concept for coral reefs. In this section we will seek input from managers on the practicality of strategies for incorporating resilience into management, and seek feedback on how manages perceive that these concepts may work in their respective regions.

On-the-Web

Reef Resilience R^2 Toolkit: http://www.reefresilience.org/

Publications and References

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Tompkins, E.L., Sophie A. Nicholson-Cole, Lisa-Ann Hurlston, Emily Boyd, Gina Brooks Hodge, Judi Clarke, Gerard Gray, Neville Trotz and Lynda Varlack. 2005. *Surviving Climate Change in Small Islands - A Guidebook*. Norwich, UK: Tyndall Centre for Climate Change Research, University of East Anglia.
http://www.tyndall.ac.uk/publications/surviving.pdf

Section 2: Responding to Bleaching Events: Interventions

Learning Objectives

By the end of this module you will:

- Understand that managers can do something locally to respond to mass bleaching events
- Understand coral reef “triage” and restoration options available for MPA managers to implement in response to severe mass coral bleaching
- Understand a range of short-term, local strategies for coral bleaching management:
    - Area closures: visitor/fishing pressure reduction
    - Cooling waters: experimental induction of localized upwelling
    - Water circulation manipulations
    - Shading strategies
    - Sea surface condition manipulations
    - Minimize human-induced sedimentation impacts
    - Improve water quality
- Understanding of the considerations for assessing whether restoration intervention is a viable strategy.
- Understand a range of options for restoration intervention:
    - Habitat & ecosystem function modification
    - Species re-introduction
    - Enhancement of recruitment
    - Disease treatment intervention programs
    - Coral transplantation

Background

Managers may feel helpless to act in the face of a mass bleaching event, but there are several intervention strategies that managers can take to help coral reefs resist and recover from temperature stress. This section provides a range of strategies to minimize additional stress on coral reefs during bleaching events, so that corals are given the greatest chance of resisting warm water events. Emerging strategies to impede the causes of mass bleaching are discussed, such as reducing the amount of light and heat reaching corals. We also discuss potential strategies to reduce physical stresses reduce corals’ ability to resist bleaching. These strategies include limiting activities such as snorkeling, diving and boat anchoring during bleaching. We also explore options that may accelerate natural recovery following bleaching mortality. We discuss the need for managers to weigh the value of reef restoration against the potentially high cost. Many of the proposed strategies in this section are still in the experimental and early developmental stages and their future success is largely unknown. Managers may contribute towards the urgent need to identify viable strategies for responding locally to bleaching events by piloting certain methods and sharing experiences with the rest of the scientific and management community.

This module considers whether meaningful actions can be taken during and after mass bleaching events to reduce ecological impacts. While above-average sea temperatures are outside the control of reef managers, other factors that influence coral reef resilience to mass bleaching are amenable to management. Ecosystem condition, which influences coral survivorship during mass bleaching events and reef recovery after bleaching-related mortality, can be maintained and improved by effective management of local stressors. However, it is the physical conditions: temperature, light, and mixing, that principally determine whether corals bleach. They also play a key role in determining the probability of mortality during bleaching events. While these factors are not amenable to intervention in conventional management approaches, concern about the future of coral reefs is driving new thinking about ways in which bleaching risk might be mitigated.

Many of the strategies for management intervention during and following bleaching are based on emerging ideas that have yet to be fully tested. Some may turn out to be fruitful initiatives, especially those aimed at reducing local stressors; however, most should be considered experimental and undertaken in the spirit of adaptive management. The temperature anomalies that trigger coral bleaching events place substantial stress on coral colonies, even before there are any visible signs of bleaching. Once a coral is bleached, it is in a state of extreme stress, with reduced capacity for feeding and maintenance of essential physiological functions, such as injury repair and resistance to pathogens.

Ultraviolet light is known to be a key factor in coral bleaching, and small-scale experiments have shown that reducing intensities of UV light have reduced the incidence or severity of bleaching. These observations suggest that shading moderate sized areas during periods of greatest temperature stress may reduce the amount or severity of bleaching. However, practical considerations involved in implementing a shading strategy, as well as the potential for unwanted side effects, make this proposal particularly challenging. Small to medium-scale experimental tests of this strategy would be best accomplished through close science-management partnerships.

Although water temperatures are not amenable to management intervention at large spatial scales, there may be potential for temperatures to be manipulated in some localized circumstances. In situations where high water temperatures are due to the solar heating of shallow or contained water bodies, relatively small volumes of cool water may be adequate to maintain temperatures below critical bleaching thresholds for at least some species. Deep water adjacent to such sites may provide a readily available source of cool water. This strategy may become increasingly appealing at high use tourism sites should coral reefs continue to degrade because of temperature-induced stress. The feasibility of this idea has not been thoroughly investigated to date, and no field tests are known.

The amount of water exchange around a coral colony during thermal stress has been hypothesized to influence the severity of bleaching. Increased water flow is thought to increase the flushing of toxins that are the by-products of the cellular processes which lead to coral bleaching. Therefore, it is possible that increased flushing of toxins through greater water circulation around coral colonies may reduce the severity of bleaching or at least delay the onset of bleaching. If greater mixing could be achieved, it is likely that the amount of damage from a thermal stress event could be reduced. The role of water flow in determining the impacts of thermal stress on corals is still being studied, and the practicality of this strategy for management intervention has not yet been fully tested.

Snorkeling, diving, and boat anchoring are all activities that can cause physical injuries to corals if not carefully managed. A coral stressed due to bleaching is likely to be less capable of recovering from physical injuries due to these activities. Repair of even minor tissue damage may be hindered while the colony is in a stressed condition, increasing the risk of infection or overgrowth by competing organisms. Although the principles behind these theories are well established, there have not been any direct studies of the effect of bleaching on a coral's response to physical injury. However, reef managers may wish to explore the costs and benefits of minimizing activities that could expose stressed corals to increased risk, especially in high-visitation tourism sites.

Degraded water quality affects various life stages of corals, making it likely that it exacerbates the effects of coral bleaching. Acute increases in sediment and pollutants deliver additional stress to corals that must clear sediment from colony surfaces, which wastes precious physiological resources. Corals stressed from mass bleaching are likely to be less effective at defending against invasion by microalgae or at competing with macro alga. Additionally, nutrient inputs can significantly reduce coral recovery. In light of these implications, managers may wish to consider the timing of coastal activities during periods of increased temperature stress. Limiting coastal activities during bleaching events could reduce the risk of damage to coral communities that could result from negative interactions between stressors such as turbidity and temperature. Such a strategy could also reduce the risk that developers will be held responsible for any bleaching mortality.

Herbivores play a critical role in facilitating recovery of coral reefs after major disturbances. In many locations, the grazing activity of herbivores is essential to the maintenance of substrate suitable for coral recruitment. For this reason, should a bleaching event result in substantial coral mortality, a reef manager may wish to consider short- to medium-term initiatives to protect the herbivore function. This is most relevant in countries where herbivorous fish populations are under threat from fishing pressure. These initiatives are most effective if they are done in partnership with relevant stakeholder groups. Ideally, restrictions would be maintained until significant recovery is evident or until there is other evidence that adequate settlement substrate can be maintained despite fishing pressures.

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. Coral reef managers face a difficult role in determining to what extent we decided to implement intervention methods of enhancing recovery in natural reef ecosystems. However, with increasing degradation on coral reefs being witnessed globally we must consider whether taking an active part in reef restoration is a viable option. Considerations in taking these actions include: Is the action ethical? Is restoration the best use of MPA resources? Will it provide for the purported benefits, and can I afford the costs of monitoring to evaluate for success of the project(s)? What are the appropriate techniques for my region or reef type? Are the methods cost-effective, and can I identify partners to share the costs? What scientific issues and philosophical questions will be raised? Do I have the legal authority, and can these authorities be used for restoration activities in support of my MPA?

Restoration includes direct interventions such as transplantation, as well as indirect management measures to remove impediments to natural recovery. Interventions to improve habitat community structure and increase available space for recolonization by corals might include re-introductions, like sea urchin populations (e.g. *Diadema* in Florida). Coral transplantation, coral recruitment enhancement, and habitat modification are all methods of reducing the natural recovery time of damaged reefs. In the Florida Keys National Marine Sanctuary, on and offsite compensatory restoration projects are implemented to address human-induced impacts to natural resources by coastal construction or vessel grounding activities. Compensatory restoration decreases the time for recovery from anthropogenic impacts. Funds, generated through injury assessments on groundings or as mitigation for coastal development impacts, can be channeled into coral rescue, relocation, recovery and coral aquaculture programs.

On-the-Web

Restoration:

Mote Marine Lab: http://www.mote.org

Mote Magazine Articles on MML Coral Reef Research: *Science to the Rescue: Focusing on Coral's Future; Slime Sleuth*; *Coral Bleaching*; *Propagating Polyps; etc.*
http://www.mote.org/index.php?src=directory&view=magazine

Mote Marine Lab Microbiology Program:
http://isurus.mote.org/Keys/marine_microbiology.phtml

Coral Spawning: Deep Sea 3D IMAX http://www.imax.com/deepsea/
An IMAX film that includes stunning shots from 2005 coral spawning event at the Flower Garden Banks National Marine Sanctuary. **IMAX Corporation**, New York
Romi Schutzer: rschutzer@imax.com

TNC Community-based Staghorn and *Diadema* Restoration (Johnson/Nedimyer)
http://www.frrp.org/workshop/staghorn_restoration.pdf
http://www.nature.org/magazine/winter2006/misc/art20978.html?src=s2

The New York Times Planet Us: Coral Man video:
http://video.on.nytimes.com/?fr_story=fab4b739c612604ce3c6169cf41bccd4f0852815

Community-Based Restoration Partnerships:
http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/index.html

Florida Keys National Marine Sanctuary Coral Reef Restoration:
http://floridakeys.noaa.gov/resource_protection/grounding_restoration.html

NOAA DARP Homepage: http://www.darp.noaa.gov/

General:

The Nature Conservancy Florida Reef Resilience Program:
http://www.frrp.org/

The Florida Keys National Marine Sanctuary
http://www.floridakeys.noaa.gov/

Florida Keys National Marine Sanctuary Blue Star Program
http://www.sanctuaryfriends.org/whatwedo_bluestar.cfm

Mote Marine Lab BLEACHWATCH
www.mote.org/Keys/bleaching.phtml

Mote Marine Lab Marine Ecosystem Event Response & Assessment (MEERA)
www.mote.org/Keys/meera.phtml

Event Reports: www.mote.org/Keys

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Precht, William F. 2007. *Coral Reef Restoration Handbook.* Taylor & Francis Group, U.S.A.; 2006. 384 p. (ISBN 0849320739)
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Lessons Learned from the Intensification of Coral Bleaching from 1980-2000 in the Florida Keys, USA: 60-66 pp. Billy D. Causey, 33 East Quay Road, Key West, FL 33040, USA. billy.causey@noaa.gov

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Available for download from:
http://www.coris.noaa.gov/activities/caribbean_rpt/
www.gcrmn.org