Module 3: Principles and Components of Resilience

Section 1: What is Resilience?

Learning Objectives

By the end of this lesson, you will be able to:

- Define *biological resilience* and explain it in clear terms
- Define *social resilience* and explain it in clear terms
- Explain the three components of *social resilience*

Background

Resilience refers to the ability of a system to maintain key functions and processes in the face of stresses or pressures by either resisting or adapting to change. There are two components of resilience: the ability to absorb or resist the impacts of stresses, such as mass bleaching or storms, and the ability to recover quickly from them. Resilience can be applied to both ecological systems as well as social systems. In this training, resilience is used in the context of global climate change; however a resilience-based approach can be integrated into management of any natural system.

Biological Resilience

Coral reef resilience is ultimately about coral reef health. Having a healthy 'immune system' helps coral communities withstand major stress events such as warming seas and recover rapidly from them. Building resilience into reef management means helping to build the immune system, and increasing the likelihood that coral communities will continue to thrive. Resilience can be applied to all marine systems—temperate, tropical, or polar. The general concepts and principles are the same across all areas, yet specific actions need to be adapted for the region or habitat of interest.

Social Resilience

The concept of resilience has also been applied to social systems and how they relate to management of natural resources. Social resilience focuses on the resilience of communities in adapting to and withstanding institutional, environmental and economic changes in their location. Often these changes take the form of policies and regulations that alter long-standing local habits and practices with more resilient communities more likely to comply and sustain change. But most importantly, changes take the form of reduction in supply of goods and services as a result of ecosystem impacts from climate change. Resilience of social systems is often related to three different characteristics:

1. the magnitude of shock the system can absorb and remain stable
2. the degree to which the system is capable of self-organization

3. the degree to which the system can build capacity for learning and adaptation

Although this training does not attempt to address the complexities of socio-ecological resilience, it is important for managers to use holistic strategies that acknowledge the importance of resilience in both the natural resources they manage and the communities that will be affected by management actions.

On-the-Web

The Resilience Alliance: http://www.resalliance.org

Resilience Science Blog: http://rs.resalliance.org

Ecology and Society: http://www.ecologyandsociety.org

Publications and References

Management of Mangrove Communities: **http://data.iucn.org/dbtw-wpd/edocs/2006-041.pdf**

How Resilient is Your Coastal Community: A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Hazards:
http://apps.develebridge.net/usiotws/13/CoastalCommunityResilience%20Guide.pdf

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Section 2: Four Principles of Resilience

Learning Objectives

By the end of this lesson, you will be able to:

- Identify and explain the four main principles of resilience
- Describe effective management fundamentals: communication, measuring up, adaptive management, and precautionary approach

Background

Until recently, resilience had never been explicitly defined or listed as a criterion for MPA selection or MPA design, nor had it been factored into large-scale ecoregional planning. Yet the concept of resilience demonstrates that there are positive actions we can take to counter potentially devastating impacts of climate-related bleaching. The Nature Conservancy developed a Resilience Model to help frame resilience in an easily understandable way. This model has evolved over time and continues to be refined. It is important to understand that this is a conceptual model, designed to emphasize the key aspects of managing for resilience, but does not guarantee resilience if all principles are addressed. Every situation is unique and it may not be possible to address each and every principle at a site. The principles of resilience are briefly explained below and in more detail later in the workbook.

Principle 1: **Representation and Replication** (and risk-spreading) can help increase likelihood of reef survival. By ensuring that resilient species and habitats are well represented and replicated throughout an MPA network, coral reef managers can decrease risk of catastrophic events, like bleaching, from destroying entire reef ecosystems.

Representation and replication help spread risk in event of a major lethal or sublethal disturbance. To capture the complete array of biodiversity, MPAs should be selected to represent the full national or regional range of coral reefs, and major reef habitat types (e.g., fore-reef, back reef, reef flat) and should include other functionally linked habitats such as sandy and rocky seabed, seagrass, mangrove, coastal, and riparian areas. If biodiversity of a system is fully represented in multiple examples, the likelihood of losing all of it to an event is substantially decreased. Because this applies to any disturbance, it is a 'no-regrets' strategy when designing and delineating protected areas.

Representation is about more than just habitats and species. Representation is about including the diversity of characteristics found in an area. There may be special physical features, latitudinal distributions, or energy regimes that should be considered. Neighboring habitats that are functionally linked to coral reefs by physical and ecological processes—including the transport of nutrients by currents or daily feeding migrations of reef species—are integral to the health and resilience of coral reefs.

Replication of distinct, representative habitats in MPA networks helps ensure that refugia for each community type remain after a catastrophic die-off. That will help maintain viable sources of larvae to seed the recovery of susceptible areas in times of stress. The suggested absolute minimum number of replicates of a particular habitat type is **three**; however, including more replicates should be a priority whenever possible.

Principle 2: **Critical Areas** are vital to survival and sustainability of marine habitats. These areas may provide secure and essential sources of larvae to enhance replenishment and recovery of reefs damaged by bleaching, hurricanes or other events. They also include high-priority conservation targets, such as fish spawning aggregations and nursery habitats.

Critical areas are vital to the survival and sustainability of marine habitats. These areas may provide secure and essential sources of larvae to enhance the replenishment and recovery of reefs damaged by bleaching, hurricanes or other events. They include high-priority conservation targets, such as nesting areas, nursery habitats, migration routes, or refuges from large-scale disturbances.

When identifying areas for protection and focusing management activities, it is important to include critical areas in the design of the MPA (or network) to promote healthy ecological systems capable of responding to, and sustaining, different kinds of stress. Being sure to account for ecological linkages and processes as well as including resistant and resilient communities in your management approach is fundamental in addressing this principle.

Principle 3: Connectivity influences the design of marine protected area networks. Preserving connectivity among reefs and their associated habitats ensures replenishment of coral communities and fish stocks from nearby healthy reefs, and may enhance recovery.

Understanding and maintaining the ecological patterns of connectivity is an important component of coral reef management. Connectivity describes the extent to which populations in different parts of a species' range are linked through the exchange of eggs, larval recruits, propagules, juveniles, or adults. Imagine what might happen if a particular reef is strictly protected while its neighbor reef, historically an important source for larvae recruits, is zoned as a high impact tourism area. The likelihood of a continued relationship (supplying coral recruits) is certainly reduced.

Recent advances in science and technology are providing answers to the connectivity questions, indicating that a substantial amount of self-recruitment occurs within reef communities and that there is great variation in dispersal distances. Models are also being used to predict the connectivity of adjacent or distant reefs. Because most locations don't have the benefit of focused scientific research to answer these questions, some rules of thumb for connectivity have been developed (For rules of thumb, see Module 3).

Principle 4: Effective Management is essential to meeting goals and objectives of an MPA, and ultimately keeping reefs vibrant and healthy. Reducing threats is the foundation for successful conservation and the core of our resilience-based strategies. Measuring effective management provides the foundation for adaptive management. Investments in human capacity and long-term financing are also crucial to sustaining effective management for the future.

Effective management is the most important principle in the Reef Resilience Model. Effective management refers to the daily activities required of managers, as well as larger community-based efforts to address such problems as local pollution, and poorly planned coastal development, and destructive fishing practices. All of these activities continue to be a priority, in the context of resilience-based management. In the face of global climate change, it is critical for managers to work with stakeholders to reduce and eliminate major threats to coral reef communities that occur locally.

Effective Management Fundamentals

Communication: Communication is often both the reason for success and the reason for failure of management strategies. Focusing on the two-way communication of information between stakeholders and managers is critical to achieving management goals and objectives. Making sure the community is fully aware of the rationale for management activities, as well as the intended outcome, will help gain support for current and future actions.

Measuring Up: In order to manage effectively, a manager must stay informed about changes and progress in the managed area. Understanding the impact certain threats are having, or the response a particular management action is having, helps managers make necessary adjustments, as well as justify management activities based on these trends. There are a variety of resources to help managers evaluate management of their sites, depending on the kind of information and resources available.

Adaptive Management: Once managers have collected information about progress and trends, decisions must be made about current and future strategies. Adjustments in management (e.g., regulations, zoning, or in protected area boundaries) are facilitated by having institutional flexibility incorporated into the management framework. Ensuring that both the community and legislative bodies are prepared for changes in the resource management approach will enable the process of change to occur more efficiently.

Precautionary Approach: Employing a precautionary approach whenever information is lacking is a reasonable way to proceed. The precautionary principle is defined as follows: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken, even if some cause and effect relationships are not fully established scientifically (Wingspread Statement's Definition, 1998). The precautionary principle suggests that caution be taken in decision-making, but that it does not lead to paralysis until perfect information is available. Designing MPA networks using local knowledge and customary management practices (when possible) can be important elements of a precautionary design, and can be accessed in situations when limited "formal" data have been acquired.

On-the-Web

Reef Resilience Toolkit: http://reefresilience.org/Toolkit_Coral/C1c0_Principles.html

Publications and References

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Section 3: Identifying Resilience

Learning Objectives

At the end of this lesson, you will be able to:

- Identify the three major factors of resilience.
- Explain the two main resilience ‘bottlenecks’ and what factors influence the role they play in reef resilience.
- Explain the genetic and species differences that influence corals’ response to temperature stress.
- Describe physical conditions that may increase resistance to temperature stress.

Background

As managers, it is helpful to have a good sense of what resilience looks like. Resilience is more than being able to recover from a major disturbance, surviving bleaching, or resisting bleaching. For a community to be resilient, it must also be able to continue to thrive, reproduce, and compete for space and resources. For example, coral communities that have experienced bleaching but not mortality may be weakened and less able to thrive, grow, and reproduce in the competitive reef environment

Multiple factors contribute to resilient coral communities, some of them known and others to be discovered. Scientists are working to identify important ecological, biological, and physical factors that managers can evaluate to determine the health or resilience of a coral community. It is important to be able to identify and better understand these factors, so management strategies can be focused on maintaining or restoring communities to these optimal conditions to maximize coral survival after stressful disturbances.

Ecological Factors

The ecological processes that maintain reef function and support thriving reef communities play an important role in maintaining resilience to major disturbances such as coral bleaching. Complex food-web interactions (e.g., herbivory, trophic cascades) reproductive cycles, population connectivity, and coral and fish recruitment are among the ecological processes that scientists have recently been studying in a reef resilience context.

Many questions remain about how, when and where these factors are important. Recently, scientific evidence demonstrates the consistent importance of the presence of top predators and large herbivores as well as the importance of coral and fish recruitment rates and patterns for reef resilience. This section discusses two ecological processes, herbivory and recruitment, that serve as resilience ‘bottlenecks’ in many reef systems and thus should be a focus in reef managers' activities.

Herbivory:

Prohibiting or limiting the take of herbivorous species should be a high priority for reef managers, and is critical for maintaining reef resilience. Recent research has demonstrated the importance of herbivores in facilitating coral recovery following major disturbances such as a bleaching event. Herbivores are known in many ecological systems as key actors regulating both community structure and function.

In the case of coral reefs, herbivores play a critical role in regulating the competitive relationship between macroalgae and corals. Macroalgae and corals compete for space and when herbivores are not present, the faster growing macroalgae often overgrow corals, depriving them of essential sunlight and causing their decline. For example, in the early 1980's Caribbean reefs experienced a sudden shift from coral dominated reefs to reefs with substantial macroalgae populations, following chronic fishing of herbivores and then subsequent die-off of a key herbivore, *Diadema antillarum*.

Managing Herbivory Regimes:

Reef managers should work to maintain a balanced assemblage of coral and algal communities. Once algae have taken over, it is difficult to reverse the trend. When this occurs, management activities should focus on rebuilding and protecting herbivore populations. Following a major disturbance event, herbivores play an important role in inhibiting algal growth, providing coral larvae opportunity to recolonize dead substrate. Recent studies have identified specific types of herbivores (large-bodied parrotfish) that seem to be more important, at least at the regional scale. Any management strategy that reduces algal cover may enhance the recovery of coral and the resilience of the community.

Critically Important herbivores in the Caribbean: *Scarus vetula*, *Sparisoma viride*, and *Sparisoma aurofrenatum* (P. Mumby, pers. comm.)

Recruitment:

Recruitment is the measure of the number of young individuals (e.g., fish and coral larvae, algae propagules) entering the adult population, in other words, it is the supply of new individuals to a population. Recruitment can play a critical role in the resilience of coral populations through the number of individuals and different species that repopulate a reef. Its importance for community dynamics and coral populations varies by species, habitat and reef location. The rates, scales, and spatial structure of dispersal among populations drive population replenishment, and therefore have significant implications for population dynamics, reserve orientation, and resilience of a system. For dispersing larvae, the number of new recruits entering a population is primarily related to five factors: physical oceanographic processes, abundance of larvae, larval behavior, availability of settlement habitat, and ecological factors such as competition and predation.

All of these processes affecting the magnitude of recruitment into a system can influence the spatial patterns of coral reef species communities and assemblages. For coral bleaching, larval recruitment is a particularly critical component of the recovery process. Reefs that have been severely damaged are reliant on the arrival of larvae from corals that have survived the bleaching event elsewhere and their successful settlement, survival and growth.

Biological Factors

Bleaching is a dynamic process and there are few data with which to predict the capacity of corals to withstand climate change. However, several known biological factors of both coral and zooxanthellae influence the degree of resistance or resilience to coral bleaching. Resilience or resistance to bleaching is highly variable, with differences observed among coral colonies of the same species, between colonies of different species, and within individual coral colonies. Different responses of species and individuals to thermal heat stress can be partially attributed to biological factors of individual coral and symbiotic zooxanthellae.

Genetic Differences: Within species, susceptibility to bleaching and mortality can differ, even under the same environmental conditions. These differences between individuals suggest that genetic variation within coral populations can create resilience to increased thermal stress. (See R2 Toolkit for more details)

Species Differences: From a colony perspective, species that are characterized by fine-structured, branching or tabular growth forms, and thin or well-connected tissue, tend to be less resistant to bleaching. Corals that are less resistant to bleaching tend to be those corals that are quick to colonize free space, are fast growing, and often short-lived. Coral species that are more resistant to bleaching can be characterized by massive growth forms, thick or less-integrated tissues and slow growth rates.

Knowledge of biological factors of individual corals enhances the ability to understand factors that confer resilience and guide management actions in response to threat of elevated sea temperatures and bleaching.

Physical Factors

Certain physical factors may *increase* resistance to bleaching caused by high sea surface temperatures (SSTs):

Cooling: Oceanographic conditions that cause mixing of heated surface waters with cooler deeper water can reduce temperature stress.

Shading: High island shadow or overhanging vegetation may reduce the harmful effects of sunlight.

Screening: Naturally occurring suspended or dissolved matter reduces sunlight penetration and may reduce bleaching.

Stress Tolerance: Coral communities that are exposed to extreme conditions regularly are often populated by species with a high tolerance for stress. Others do not survive.

Conditions only become stressful outside of normal ranges tolerated by the species at its location change. A coral at higher latitudes, for example, may be acclimatized to much lower water temperatures than the same coral species at the equator. A rise above its normal temperature threshold would cause bleaching at temperatures easily enough to cause bleaching when they deviate significantly from those tolerated by the same species at the equator.

On-the-Web

Reef Resilience Toolkit: http://reefresilience.org/Toolkit_Coral/C3_Identifying.html

ARC Center of Excellence for Coral Reef Studies Web Seminar Series:
http://www.coralcoe.org.au/events/webseminar/iyorwebseminar.html

Anticipating Ecological Surprises: Managing Reef Resilience by Terry Hughes:
http://www.coralcoe.org.au/events/webseminar/iyorvideos/terryhughes.html

Bahamas Biocomplexity Project: http://bbp.amnh.org/website/hwg.html

How to kill a coral reef: Lessons from the Caribbean by Bob Steneck:
http://www.coralcoe.org.au/events/webseminar/iyorvideos/bobsteneck.html

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