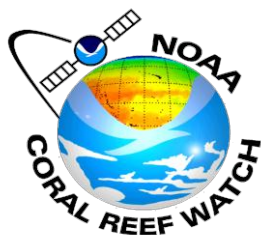




A Trainers Guide to *Reef Resilience and Climate Change* Training Workshop

Bali, Indonesia

June 2012



Australian Government
Great Barrier Reef
Marine Park Authority



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Reef Resilience and Climate Change Training Workshop**

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June 4-8, 2012

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Reef Resilience: Training of Trainers

Executive Summary

The Nature Conservancy, with support from the MacArthur Foundation and in collaboration with NOAA, is hosting the 2012 Training of Trainers Workshop, a comprehensive training workshop on how to develop training programs based on the Reef Resilience Toolkit and related resources. The overall objective of the workshop is to build the capacity of trainers to design and deliver their own Reef Resilience training programs.

The Reef Resilience and Responding to Climate Change curriculum is designed for up to 25 participants and lasts 5 days. Trainees can use the material and exercises in this curriculum when designing future training activities. The exercises that follow might also be used in refresher trainings. Once trained, trainers need continuing support, including further training. This provides a way to help trainers stay aware of new material and sharpen their training skills

This is the third in a series of four workshops to be held in different parts of the world over the next three years. We expect that each TOT will be unique and should be flexible to the needs of each group of participants. Even so, these trainings should include the following key components:

1. Background knowledge about basic Reef Resilience concepts and the programs' technical content – a trainer needs basic knowledge about the science and management behind Reef Resilience. Whenever questions related to the program's content arise – whether during training or follow-up activities, the trainer should be capable of responding adequately.
2. Presentation, Facilitation and Evaluation skills. Facilitating a training course and working interactively with a group of trainees requires a thorough knowledge of presentation, facilitation and evaluation skills.
3. Information about resources. Trainers need to be familiar with resources that can complement their knowledge of education, such as training guides, books on presentation skills and resources on content areas of training. The TOT workshop will provide opportunities to explore these resources.

In addition to conducting capacity-building trainings, the participants in this workshop can use the activities, presentations, and information to guide the local planning process for development of MPA networks, bleaching response and monitoring plans, communication plans, and more. This curriculum can easily be adapted to fit the needs of a stakeholder group that is working to develop any or all of these types of products.

The expected outcome of this training is the development of confident, competent trainers with the skills to design and implement a training program for managers and scientists, to ultimately advance the conservation strategies implemented in their geographies.

Acknowledgements

This workshop is funded through generous contributions from the John D. and Catherine T. MacArthur Foundation, the National Oceanic and Atmospheric Administration, and The Nature Conservancy.

We began conducting Reef Resilience training workshops in 2005 with the help of many people and organizations. Since that time, the curriculum has evolved, new information has emerged, and we have greatly improved the quality and content of this training. Below are the names of individuals and institutions that have made significant contributions to the product presented here:

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Tips for Facilitating this Training Session Presentation Skills

Focus

This workshop is focused on helping you learn training skills. We define ‘training’ as the development and delivery of information that participants will use after attending the training. This definition distinguishes training from other situations where people are provided with information, but are not necessarily expected to use the information they are given. The distinction between training and non-training is an important one because the process for developing and delivering the information differs between the two.

Effective training requires that you have a clear picture of how the trainees will need to use the information after the training. After this training, you will have a clear plan of action on how to implement your own Reef Resilience training program as the trainer. It also requires that people practice what they have learned before they apply it. During this specific module, trainers have the opportunity to practice their presentation skills.

Estimated Time

15 minutes – Powerpoint (maximum 25-30 students)

5 minutes – Discussion about presentation activity (full group)

10 minutes - Students can review materials and prepare their presentations

30 minutes – Video each student giving a 2 minute presentation, in two groups of 12-15

90 minutes - Group critique of video-taped presentations

Seating Arrangement/Group Size

Full session, maximum of 25-30 students

Individual content review

Group Activity - Two groups of 12-15 for video

Full session, maximum of 25-30 students

Learning Objectives

By the end of this module you will:

- ④ Learn the most important elements of a good Powerpoint presentation
- ④ Know how to give a great presentation, understand the fundamentals of content delivery
- ④ Understand how to trigger an emotional reaction in your audience

Recommended Reading to Prepare for this Discussion

When Good Presentations Happen to Bad Causes (included on your CD)

Materials Needed

- Powerpoint Presentation on 'Presentations'
- 2 sets of Video Equipment (Flip or cable-ready camera)
- TV or computer screen for video playback
- Flip Chart and Pens

General Guidance for Carrying Out this Session

There are two choices for this session with or without video:

Without video:

- Break out into 4-5 groups
- Each person will have 5 minutes to present on their work
- Presentations are then followed by round-robin critiques that provide 1 positive (first) and 1 constructive criticism
- Rotate presenters until each person has had a chance to present to the group

With video:

- Ask students to give their presentations in alphabetical order (by last name) or in small groups. If using video, make sure that the video equipment is ready.
- After all students have made their presentations, play them back to the group.
- Ask students to provide feedback after each playback, with a maximum of 2-3 minutes for feedback discussion per playback. Let the students guide the evaluation of each presenter, so that you retain facilitation credibility.

Audience Engagement

Think of the best trainer you ever had; list qualities that made them great; then identify your weak points as facilitator and try to improve.

Additional Resources

http://www.agoodmanonline.com/publications/how_bad_presentations_happen/index.htm

http://sethgodin.typepad.com/seths_blog/2007/01/really_bad_powe.html

Tips for Facilitating this Training Session

Facilitation Skills

Focus

This session focuses on developing skills for trainers to become successful trainers for their own workshops and conferences. By the end of this module you will understand what facilitation is – participants assess their facilitation skills, they identify roles and tasks of a facilitator, principles of facilitation, and competencies of the facilitator.

Estimated Time

15 minutes – Powerpoint, Full session

20 minutes – Group Activity/Icebreaker: Find the Missing Piece

20 minutes – Group Activity/Energizers and Closing exercises

15 minutes – Full session discussion, what makes a successful workshop facilitator

Seating Arrangement/Group Size

Full Session - Up to 25-30 students

Group Activities (Icebreakers/Energizers) - 4-5 students per group

Learning Objectives

- Ⓞ Why do meetings need facilitators
- Ⓞ How to prepare for workshops
- Ⓞ What are charters, agendas and ground rules – and how do you develop them
- Ⓞ How to keep a workshop on track
- Ⓞ Using Interventions
- Ⓞ Using Icebreakers, Energizers and Closing exercises
- Ⓞ Developing workshop data management techniques

Recommended Reading to Prepare for This Discussion

Basic Facilitation Skills: <http://www.uiowa.edu/~cqi/2002BasicFacilitationPrimer.pdf>

Materials Needed

-Powerpoint Presentation on Facilitation (from CD)

-Flip chart and pens

Handouts Needed (following this page)

-Icebreakers, Warm Ups and Closing Activities

-Powerpoint Handout - Navigating in Rough Seas

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation
- Go over Icebreakers (see worksheet) and ask the full session to divide into groups of 5. Ask each participant to take a turn leading an icebreaker.
- Go over Energizers and Closing Exercises and ask the session to divide into groups of 4. Ask each participant to take a turn leading an energizer or closing exercise.

- Lead a group discussion - ask students what they think makes a successful facilitator?

Recommended Reading to Prepare for This Discussion

Introduction to Planning and Facilitating Effective Meetings: Making the Most out of Group Meetings NOAA Coastal Services Center (hard copy included with your materials)

A Teachable Moment: A Facilitator's Guide to Activities for Processing, Debriefing, Reviewing and Reflecting, James Cain, Michelle Cummings, and Jennifer Stanchfield
Kendall/Hunt Publishing Company

Essential Elements of Facilitation, Simon Priest, Michael A. Gass, and Lee Gillis
Kendall/Hunt Publishing Company

Worksheet – Facilitation Ice Breakers, Warm Ups and Closing Activities

Three Questions - Participants write down three questions and find someone in the room they do not know well. Each participant then asks questions of the other. The participants then introduce their partners to the group by sharing both the questions and the answers.

Nametags - The trainer prepares a nametag for each participant and places the nametags in a box. Each participant picks a nametag from the box. Participants locate the person whose nametag they drew and introduce themselves. (This is especially useful for larger groups—20 or more.)

Find the Missing Piece - The facilitator prepares pieces of paper, enough for everybody in the group. The papers include words that are split into two, for example:

COCOA	BUTTER
MILE	STONE
ICE	CREAM

Each person picks one piece of paper and then begins to look for the person who has the matching word. When the participant has found her/his match, s/he should to know the other person. Then, they will be asked to introduce one another to the rest of the group.

An alternative is to use words that are opposites. For example:

BLACK	WHITE
UP	DOWN
LEFT	RIGHT
HOT	COLD

Fact or Fiction - Each person writes down four facts about themselves, one of which is not true. Each person takes turns reading their list aloud and the rest of the group writes down the one they think is not true. When all are done reading the lists aloud, the first person reads their list again and identifies the fact, which is not true. The group should compare their written responses with the correct answers.

Everyone's a Liar –

Step 1: The facilitator writes three statements on the board. Two statements are true, and one is a lie. Example:

I have been training for 10 years.
I have a pet dog called, "Dog."

I lived in Switzerland for a year.

Step 2: The participants ask "lie detector" questions to get further information, in order to determine which statement is false.

Training - Where have you conducted training? What have you taught?
What year did you start?

Pet - How old is Dog? What does Dog eat? Where do you keep Dog?

Switzerland - Where did you live in Switzerland? What language was spoken in that part of Switzerland?

Step 3: Participants vote on which statement is a lie. The facilitator reveals which are truths and which are lies.

Place participants in small groups (3 or 4 works well). Small groups repeat steps 1 - 3. have participants introduce each other to the large group.

Energizers

Animal Line-up

Number of People: 5 to infinity

Materials: none

Description: Have your participants line-up shoulder to shoulder. I address the group saying, "From this point forward you've lost the power of speech. I want you to think of your favorite animal. Once you've thought of it place your hand on your head." Once they're ready, issue the challenge. "Line yourselves up in order from smallest animal to largest animal. The only sound you can make is the sound your favorite animal makes." Someone invariably picks an animal that doesn't make a sound or makes very little sound. It's great to see their faces. Pretty quickly the room fills with the sounds of the jungle.

Also Known As: Noah's line-up, Ark Arrangement

Name Cha-Cha

Number of People: Big Group

Materials: People

Description: Big Circle. One person(Bill) starts by turning to another player and asking "What's your name?" They respond with their name (Jane). Bill then chants Jane...Jane...Jane, Jane, Jane. The same as a cha-cha style cadence. Chanters must move heels up and down with the words. Then Bill turns around with his back to Jane. Jane puts her hand on his shoulders and they move to another random participant. In front of Sue they perform the same actions, then Bill & Jane turn around. Now Jane is the lead and Sue is in the rear. The activity continues till everyone is in the line.

Rock, Paper Scissors Tournament

Number of People: An even number

Materials: Your two fists

Description: Have your group break into pairs. Each pair plays Rock, paper, scissors in a 2 out of 3 format. The loser of the match becomes his opponents(the winner) "Biggest Fan". It's the job of the player that didn't win to cheer their champion on as he seeks out another opponent. Each time a player wins, he gets all the "fans" the losing player had. The game ends when one player has all the fans. This gets loud, rowdy, and is a ton of fun!

Closing Exercises

Circle of Recognition

Number of People: 8 or more

Description: Have your group form a circle with you in the middle and close their eyes. Tell them to turn around and face away from the middle keeping their eyes closed. Now, shuffle everyone's positions so that they are unclear who is where. Pull one person into the middle (two if it's a big group), and have them open their eyes. Give the following direction, 'If you are the person in the middle, touch one or more people on the shoulder who have _____'. Typically, I have them touch people on the shoulder who have demonstrated good leadership, compassion, friendship, etc. I'll usually ask 3 questions then return them to the circle, shuffle a little, then pull the next person into the middle and repeat the process till everyone's had a chance. I use a wide variety of questions and repeat some. Once finished, I do a final shuffle and then have them turn around and open their eyes. I then ask, 'Did anyone learn something about themselves they would like to share?' This usually leads to some phenomenal revelations and discussions. As a facilitator you can also touch people on the shoulder during the process. Beware of doing this with the intent to not "leave someone out". Some of the best growth has been observed with this closing happened when someone was not touched.

Also Known As: Circle of Power

Tips for Facilitating this Training Session Evaluating Training Effectiveness

Focus

Measuring the effectiveness of training programs consumes valuable time and resources. As we know all too well, these things are in short supply in organizations today. It is important for us to make sure that we are clear about why we are hosting training. Many training programs fail to deliver the expected organizational benefits. Having a well-structured measuring system in place can help you determine where the problem lies. On a positive note, being able to demonstrate a real and significant benefit to your organization from the training you provide can help you gain more resources from important decision-makers.

Consider also that the environment is not standing still. Your competitors, technology, legislation and regulations are constantly changing. What was a successful training program yesterday may not be a cost-effective program tomorrow. Being able to measure results will help you adapt to such changing circumstances (from www.businessperform.com).

Estimated Time

10 minutes Powerpoint
15 minutes individual self evaluation
30 minutes Group Activity

Seating Arrangement/Group Size

Full Session (25-30 maximum)
Group Activity, groups of 5

Learning Objectives

By the end of this module you will be able to:

- ② Understand the terminology associated with evaluating training effectiveness
- ② Understand how to evaluate conservation training programs
- ② Be able to develop an evaluation program for your own training activities
- ② Heard about examples of using training evaluation in field environments
- ② Understand where and when training evaluation should take place

Recommended Reading to Prepare for This Discussion:

-‘Wildlife Conservation Society, Training and Capacity Building, Annual Report 2006’
[-www.thetrainingworld.com](http://www.thetrainingworld.com)

Materials Needed

-Powerpoint Presentation on Evaluating Training Effectiveness (from CD)
-Copies of handouts (3 per student)
-Flip chart and pens for discussion

Handouts Needed (following this page)

Evaluating Training Effectiveness Using the Kirkpatrick Model

Evaluating Reef Resilience Knowledge

Evaluating Training Effectiveness

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation
- Ask students to fill in the Evaluating Reef Resilience Knowledge worksheet
- Ask students to fill in the Evaluating Training Effectiveness worksheet
- Ask students to break into groups of five and create a plan of action for evaluating their own training effectiveness, based on the Kirkpatrick model. Students can include email surveys, phone calls and in person evaluation (worksheets, etc) as part of their evaluation.
- Each group can present their strategy to the full group, followed by group discussion. Ask students 'Why do we evaluate training effectiveness?'

Evaluating Training Effectiveness using the Kirkpatrick Model

The Kirkpatrick Model

The most well-known and used model for measuring the effectiveness of training programs was developed by Donald Kirkpatrick in the late 1950s. It has since been adapted and modified by a number of writers, however, the basic structure has well stood the test of time.

The difficulty and cost of conducting an evaluation increases as you move up the levels. So, you will need to consider carefully what levels of evaluation you will conduct for which programs. You may decide to conduct Level 1 evaluations (Reaction) for all programs, Level 2 evaluations (Learning) for “hard-skills” programs only, Level 3 evaluations (Behavior) for strategic programs only and Level 4 evaluations (Results) for programs costing over \$50,000. Above all else, before starting an evaluation, be crystal clear about your purpose in conducting the evaluation.

An evaluation at each level answers whether a fundamental requirement of the training program was met. It’s not that conducting an evaluation at one level is more important than another. All levels of evaluation are important. In fact, the Kirkpatrick model explains the usefulness of performing training evaluations at each level. Each level provides a diagnostic checkpoint for problems at the succeeding level. So, if participants did not learn (Level 2), participant reactions gathered at Level 1 (Reaction) will reveal the barriers to learning. Now moving up to the next level, if participants did not use the skills once back in the workplace (Level 3), perhaps they did not learn the required skills in the first place (Level 2).

Using the Kirkpatrick Model

How do you conduct a training evaluation? Here is a quick guide on some appropriate information sources for each level, with some bullets about what each level might include.

Level 1 (Reaction)

- completed participant feedback questionnaire
- informal comments from participants
- focus group sessions with participants

Level 2 (Learning)

- pre- and post-test scores
- on-the-job assessments
- supervisor reports

Level 3 (Behavior)

- completed self-assessment questionnaire
- on-the-job observation
- reports from participants and peers

Level 4 (Results)

- scientific reports
- new legislation
- new inter-agency management mechanisms

When considering what sources of data you will use for your evaluation, think about the cost and time involved in collecting the data. Balance this against the accuracy of the source and the accuracy you actually need. Will existing sources suffice or will you need to collect new information?

Think broadly about where you can get information. Sources include:

- technical reports
- interviews with participants, managers, users and regulators
- checklists and tests
- direct observation
- questionnaires, self-rating and multi-rating
- Focus Group sessions

Once you have completed your evaluation, distribute it to the people who need to read it. In deciding on your distribution list, refer to your previously stated reasons for conducting the evaluation. And of course, if there were lessons learned from the evaluation on how to make your training more effective, act on them.

Evaluating Reef Resilience Knowledge

	Level	of	Ability (0-10)
Competency	Initial Ability	Expected/Desired	Final Ability
Identify the impacts of climate change on reefs			
Define Resilience			
Explain the basics of bleaching			
Describe the role of herbivory in reef systems			
Describe the role of recruitment in reef systems			
Identify the biological and physical factors related to bleaching			
Identify key data layers and how to obtain them			
Identify types of resilient/resistant areas to include in MPA Design			
Understand management fundamentals and specific actions to consider			
Identify key communication tools to use			

Evaluating Training Effectiveness

1. Overall, how likely are you to use the information from this training in your life or work?
2. Has your understanding of coral reef resilience
 - increased
 - decreased
 - remained the same?
3. The information in this training was:
 - all new
 - mostly new
 - some new
 - no new information
4. The most useful part of the training was _____.
5. The least useful part of the training was _____.
6. Check all that applied to the trainers:
 - Answered questions
 - Provided useful examples
 - Knowledgeable
 - Prepared
 - Other: _____
7. Who do you work for?
 - Government
 - University/Academic
 - NGO
8. How many years of experience do you have?
 - Less than 1 year
 - 1-5 years
 - 5-10 years
 - More than 10 years
9. Other comments or suggestion

Tips for Facilitating this Training Session

Module 1 – Coral Reefs & Climate Change

Focus

This module focuses the impacts of climate change on coral reefs including coral bleaching and ocean acidification. It provides a brief explanation of ocean acidification as well as global bleaching trends. The purpose of this module is to emphasize how significant these problems are and that coral reef managers DO need to pay attention to these global-scale problems.

Estimated Time

45 minutes – Powerpoint Presentation: Coral Reefs and Climate Change

30 minutes – Group discussion

Seating Arrangement/Group Size

Full Session – Up to 25 students (absolute max is 30)

Learning Objectives

By the end of this module students will:

- ② Understand the causes of mass bleaching
- ② Understand ocean acidification and its potential impacts
- ② Understand the weather conditions that can lead to bleaching

Recommended Reading to Prepare for This Discussion

Read the following sections of the Reef Resilience Toolkit:

- All sections of *What's the Problem?*
http://www.reefresilience.org/Toolkit_Coral/C1a0_Problem.html
- All sections of *Bleaching Basics*
http://www.reefresilience.org/Toolkit_Coral/C2_BleachBasics.html
- All sections of *Ocean Acidification*
http://www.reefresilience.org/Toolkit_Coral/COA_OceanAcidification.html
- Jane Lubchenco's Video Demonstration of Ocean Acidification
<http://www.noaa.gov/video/administrator/acidification/index.html>
- Supporting resources listed at the bottom of each of the Toolkit pages for these sections

Materials Needed

-Powerpoint Presentation Module 1 (from DVD)

-Student Workbook for Module 1 (from DVD)

Handouts Needed

None

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation

- Facilitate discussion about what managers are experiencing locally, questions about climate change data, discussion of best way to represent climate information and the threat to coral reefs

Notes to the Instructor

- For the explanation of ocean acidification, if you are uncomfortable with the chemistry or think your audience will not be interested in the details, we suggest using Dr. Jane Lubchenco's video demonstration (either do your own or show hers). It is very simple and can be more effective than reviewing the chemistry. Jane's presentation is available on the R2 website on the *Ocean Chemistry Essentials* page or go directly to the link above in the suggested reading. We provide the chemistry in the presentation because some people really want to see it and it helps for them to understand just what happens.

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Module 1: Basics of Coral Reefs and Climate Change

Section 1: Global Climate Change

Learning Objectives

By the end of this module you will have:

- ② An update on current scientific knowledge on climate change
- ② An understanding of the causes of mass bleaching
- ② A grounding in bleaching physiology
- ② An understanding of ocean acidification and how it may affect reefs
- ② A background on the emerging connection between climate and coral disease

Background

(<http://www.ncdc.noaa.gov/oa/climate/globalwarming.html>) Human activity has been increasing the concentration of greenhouse gases in the atmosphere (mostly carbon dioxide (CO₂) from combustion of coal, oil, and gas; plus a few other trace gases). There is no scientific debate on this point. Pre-industrial levels of carbon dioxide (prior to the start of the Industrial Revolution) were about 280 parts per million by volume (ppmv), and current levels are greater than 380 ppmv and increasing at a rate of 1.9 ppm yr⁻¹ since 2000. The global concentration of CO₂ in our atmosphere today far exceeds the natural range over the last 650,000 years of 180 to 300 ppmv. According to the IPCC Special Report on Emission Scenarios (SRES), by the end of the 21st century, we could expect to see carbon dioxide concentrations of anywhere from 490 to 1260 ppm (75-350% above the pre-industrial concentration).

Global surface temperatures have increased about 0.74°C (plus or minus 0.18°C) since the late-19th century, and the linear trend for the past 50 years of 0.13°C (plus or minus 0.03°C) per decade is nearly twice that for the past 100 years. The warming has not been globally uniform. Some areas (including parts of the southeastern U.S. and parts of the North Atlantic) have, in fact, cooled slightly over the last century. The recent warmth has been greatest over North America and Eurasia between 40 and 70°N. Lastly, seven of the eight warmest years on record have occurred since 2001 and the 10 warmest years have all occurred since 1995.

Global mean sea level has been rising at an average rate of 1.7 mm/year (plus or minus 0.5mm) over the past 100 years, which is significantly larger than the rate averaged over the last several thousand years. Depending on which greenhouse gas increase scenario is used (high or low) projected sea-level rise in the next 100 years is projected to be anywhere from 0.18 (low greenhouse gas increase) to 0.59 meters for the highest greenhouse gas increase scenario. However, this increase is due mainly to thermal expansion and contributions from melting alpine glaciers, and does not include any potential contributions from melting ice sheets in Greenland or Antarctica. Larger increases cannot be excluded but our current understanding of ice sheet dynamics renders uncertainties too large to be able to assess the likelihood of large-

scale melting of these ice sheets. Healthy coral reefs can probably grow fast enough to keep up with moderate rates of sea level rise. There is some concern that reduced light availability may be a problem, especially for species that grow in deeper areas that may already be light limited. The biggest concern is that other climate factors, especially bleaching and ocean acidification have been shown to reduce coral growth rates. Slower-growing corals may not be able to keep up with rising sea levels.

(<http://www.pmel.noaa.gov/co2/OA/background.html>) The oceans have absorbed approximately 525 billion tons of carbon dioxide from the atmosphere, or about one third of the anthropogenic carbon emissions released. This absorption has benefited humankind by significantly reducing the greenhouse gas levels in the atmosphere and minimizing some of the impacts of global warming. However, the ocean's uptake of carbon dioxide is having negative impacts on the chemistry and biology of the oceans. Hydrographic surveys and modeling studies have revealed that the chemical changes in seawater resulting from the absorption of carbon dioxide are lowering seawater pH. The pH of ocean surface waters has already decreased by about 0.1 units from an average of about 8.21 to 8.10 since the beginning of the industrial revolution. Estimates of future atmospheric and oceanic carbon dioxide concentrations, based on the Intergovernmental Panel on Climate Change (IPCC) CO₂ emission scenarios and coupled ocean-atmosphere models, suggest that by the middle of this century atmospheric carbon dioxide levels could reach more than 500 ppm, and near the end of the century they could be over 800 ppm. This would result in an additional surface water pH decrease of approximately 0.3 pH units by 2100.

When CO₂ reacts with seawater, the reduction in seawater pH also reduces the availability of carbonate ions, which play an important role in shell formation for a number of marine organisms such as corals, marine plankton, and shellfish. This phenomenon, which is commonly called "ocean acidification," could have profound impacts on some of the most fundamental biological and geochemical processes of the sea in coming decades. Some of the smaller calcifying organisms are important food sources for higher marine organisms. Declining coral reefs due to increases in temperature and decreases in carbonate ion would have negative impacts on tourism and fisheries. Abundance of commercially important shellfish species may also decline and negative impacts on finfish may occur. This rapidly emerging scientific issue and possible ecological impacts have raised serious concerns across the scientific and fisheries resource management communities.



Worksheet or Activity

Discussion: What indications of Climate Change have you observed in your region?
What habitats do you manage that are susceptible to Climate Change?



On-the-Web

Intergovernmental Panel on Climate Change
<http://www.ipcc.ch/>

NOAA “Frequently Asked Questions” on climate change
<http://www.ncdc.noaa.gov/oa/climate/globalwarming.html>

NOAA background on Ocean Acidification
<http://www.pmel.noaa.gov/co2/OA/background.html>

NOAA ocean acidification tutorial
http://coralreefwatch.noaa.gov/satellite/oa/description/oaps_intro_oa.html

Sea Level Rise explorer in Google Maps
<http://www.globalwarmingart.com/wiki/Special:SeaLevel>



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Raupach, M.R., G. Marland, P. Ciais, C. Le Quere, J.G. Canadell, G. Klepper, and C.B. Field. 2007. Global and regional drivers of accelerating CO₂ emissions. *Proceedings of the National Academy of Science (PNAS)* 104(24):10288-102093.

Section 2: Rising Temperature, Mass Coral Bleaching & Bleaching Weather

Learning Objectives

By the end of this module you will have:

- 🌐 A background in rising sea surface temperatures around the world
- 🌐 An understanding of the connection between environmental conditions and coral bleaching
- 🌐 An understanding of the weather conditions that can lead to bleaching

Background

The number of regions reporting mass coral bleaching has increased substantially in recent years. The implications of mass bleaching received global attention in 1997–98, when increased sea surface temperatures associated with El Niño resulted in extensive bleaching of the world’s reefs. Prior to this event, coral bleaching was often considered a local problem—someone else’s problem—resulting from localized stresses. The event of 1997–98 distinguished mass coral bleaching from localized events because of the global extent of its impacts across reefs and reef regions of different condition, composition, and geography. It is attributed to causing mass mortalities of corals to many reef regions, in total ‘destroying’ an estimated 16 per cent of the world’s reefs. This event fuelled scientific curiosity about the causes of mass bleaching events and the implications of these events for future coral reef condition.

Using satellite data over the last 20 years, warming in most tropical areas is easily seen. Unfortunately, these warming trends are expected to continue into the future. Comparisons of expected sea temperature increases with bleaching thresholds suggest that the frequency and severity of mass bleaching events will increase, as the temperature is likely to rise faster than coral reef ecosystems can to adjust. This implies that, should tropical seas continue to warm, coral reef ecosystems are likely to undergo significant changes. These changes include losses to biological diversity and coral cover as well as economic losses to the fisheries and tourism sectors.

Sea temperature is the most reliable predictor of the occurrence and severity of large-scale coral bleaching events. An understanding of the factors that influence sea temperature can help managers predict the risk and severity of a bleaching event. Reef managers may get a very useful indication of whether their region is likely to experience increased heating in coming months based on climate predictions. Longer-term predictions, such as seasonal weather forecasts, can be used to assess the probability of weather conditions that contribute to increasing sea temperatures occurring over timescales of weeks to months. Shorter-term predictions, such as weekly weather forecasts, indicate whether sea temperatures will increase or decrease in coming days and weeks.

Our understanding of mass bleaching suggests that the future condition of coral reefs will be largely influenced by two factors: (1) the rate and extent of sea temperature increases; and (2) the resilience of coral reef ecosystems. The rate and extent of warming will determine the window of opportunity for reefs to adjust through acclimatization, adaptation, and other ecological shifts. For example, fewer and less intense temperature anomalies will reduce the frequency and severity of bleaching events, and slower rates of warming will allow more time for reefs to recover between events that do occur. These relationships mean that the effectiveness of broader efforts to address the rate and extent of warming will have significant implications for local management initiatives. However, such efforts are largely a matter for national and international policy. The focus of this workshop is to consider strategies local coral reef managers can implement to reduce the impacts of mass bleaching events and to restore and maintain the natural resilience of coral reefs to climate change.



Worksheet or Activity

Discussion: Have you witnessed mass bleaching on the reefs in your region?
What were the long terms impacts/recovery in your area?



On-the-Web

Encyclopedia of Earth article on corals and climate change
http://www.eoearth.org/article/Coral_reefs_and_climate_change



Publications and References

Hoegh-Guldberg, O., P.J. Mumby, A.J. Hooten, R.S. Steneck, P. Greenfield, E. Gomez, C.D. Harvell, P.F. Sale, A.J. Edwards, K. Caldeira, N. Knowlton, C.M. Eakin, R. Iglesias-Prieto, N. Muthiga, R.H. Bradbury, A. Dubi and M.E. Hatziolos. 2007. Coral reefs under rapid climate change and ocean acidification. *Science* 318(5857): 1737-1742.

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http://www.coris.noaa.gov/activities/reef_managers_guide/welcome.html

Wilkinson, C., Souter, D. 2008. *Status of Caribbean coral reefs after bleaching and hurricanes in 2005*. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, 152 p. http://www.coris.noaa.gov/activities/caribbean_rpt/

Section 3: Delving Deeper into Bleaching Physiology

Learning Objectives

By the end of this module you will have:

- 🌐 A deeper understanding of the mechanisms that cause coral bleaching
- 🌐 A background in how light and temperature combine to cause bleaching
- 🌐 An understanding of how this knowledge can help predict when and where bleaching may occur.

Background

It is often stated that high water temperatures “cause” coral bleaching. That is not strictly true, when you look more closely at the mechanisms within the coral itself.

It’s important to remember that corals host symbiotic algae within their cells, called zooxanthellae. These algal cells photosynthesize just like any plant, and the compounds they produce are a crucial energy source for the coral animals. Within the zooxanthellae there is a complex chemical “machinery” that carries out photosynthesis—pigments that absorb light energy from the sun, and a series of proteins and enzymes that convert the solar energy into sugars/carbohydrates that the plant (and its coral host) can use. During the highest-light periods of even a normal day, the system will be overwhelmed with too much solar energy coming in through the pigments. This excess energy is turned into oxygen free radicals, dangerous compounds that damage the photosynthesis machinery and other crucial parts of the cell. The zooxanthellae have another complex system whose job it is to repair this normal light damage. On normal days, all of the damage from excess light can be repaired.

Unfortunately, stressfully warm temperatures will disrupt the balance of damage and repair. The exact mechanism is not yet known, but the overall result is that the zooxanthellae cannot fully repair the daily light damage from the oxygen free radicals. If these conditions continue over several days or weeks, serious consequences will result. The coral can digest or expel the harmful zooxanthellae, so that they will not be further damaged. Since most of the color of a coral colony comes from the zooxanthellae, the coral will then appear pale or white (“bleached”).

The worst-case scenario is that the stressful conditions are so severe and long-lasting that the coral colony dies. Without its main food source, the coral may starve to death. The oxygen free radicals from the zooxanthellae and the stress from expelling the symbiotic cells may damage the coral’s tissues enough to cause it to die. However, if the stressful light and temperature conditions abate, the coral will be able to recover. The animal will repopulate its tissues with zooxanthellae cells, either from the water column or from reproduction of the few algae cells that remain in the coral tissue. Even if the bleaching doesn’t kill the coral, there are

long-term consequences from the stress of a bleaching event: drastically slowed growth rate, failure to reproduce that year, and higher susceptibility to coral disease infections.

It is clear that bleaching is caused by a combination of strong sunlight and warm temperatures. Clear skies, low wind, neap tides, and reduced sediment can quickly lead to very high light conditions for the corals. Many of those same factors also cause warming at the ocean surface, of course, which sets up the ideal conditions for coral bleaching.



Publications and References

Dove, SG and O Hoegh-Guldberg. 2006. The cell physiology of coral bleaching. In *Coral Reefs & Climate Change: Science and Management*. JT Phinney, W Skirving, J Kleypas & O Hoegh-Guldberg, eds. American Geophysical Union. pp 1–18.

Woolridge, S.A. 2009. Water Quality and coral bleaching thresholds: Formalizing the linkage for the inshore reefs of the Great Barrier Reef, Australia. *Marine Pollution Bulletin* 58:745-751.

Section 4: Ocean Acidification

Learning Objectives

By the end of this module you will have:

- 🌐 An understanding of the chemistry behind ocean acidification
- 🌐 Current scientific knowledge on what the future will bring
- 🌐 Background on how acidification affects coral reefs

Background

The global oceans are the largest natural reservoir for the excess CO₂ in the atmosphere, absorbing approximately one-third of the CO₂ from human activities each year. As a result, dissolved CO₂ in the surface ocean will likely double over its pre-industrial value by the middle of this century, representing perhaps the most dramatic change in ocean chemistry in over 20 million years.

As CO₂ reacts with seawater it forms carbonic acid, causing a reduction in pH. Seawater is naturally buffered against these pH changes, but the buffering process consumes carbonate ions. Carbonate ion is an essential ingredient in the creation of calcium carbonate (CaCO₃) shells and skeletons produced by many marine organisms.

Reef-building corals construct intricate three-dimensional frameworks by calcification (biological precipitation of CaCO₃). In order for the reef to grow over time, corals must produce CaCO₃ faster than the natural reef removal processes (dissolution, storm export, and bioerosion). Studies of CaCO₃ budgets on coral reefs suggest that these building and erosion processes are nearly balanced at most modern reefs, and net reef accretion is small. Many experiments show a reduced rate of calcification as a consequence of ocean acidification. Laboratory studies have examined the effects on many types of corals and coralline algae, revealing a range of responses from a 3% to 60% decline in calcification rate for a doubling of atmospheric CO₂. Recent field studies have also shown declines in coral calcification rates at the Great Barrier Reef, the Arabian Gulf, and Bermuda. These slower growth rates are probably caused, at least in part, by ocean acidification. Thus, a primary threat of ocean acidification is the potential to compromise the ability for reefs to maintain a positive net accretion, thereby resulting in the loss of habitat and coastal protection. This effect is particularly critical because of sea level rise.

Recent work has also shown secondary effects that suggest there is still a lot to learn about how acidification affects coral reefs. A recent lab study shows that lower pH increases a coral's susceptibility to bleaching. Other potential effects include a reduced capacity to tolerate ultraviolet radiation, and increased bioerosion rates.



On-the-Web

Encyclopedia of Earth article:

http://www.eoearth.org/article/Ocean_acidification

Tutorial on OA and coral reefs, from NOAA Coral Reef Watch:

http://coralreefwatch.noaa.gov/satellite/oa/description/oaps_intro_oa.html

Wikipedia entry:

http://en.wikipedia.org/wiki/Ocean_acidification

Scientific information from a global network of researchers:

<http://ocean-acidification.net/>



Publications and References

Feely R. A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of anthropogenic CO₂ on the CaCO₃ system in the oceans. *Science* 305: 362-366.

Langdon C. and M. J. Atkinson. 2005. Effect of elevated pCO₂ on photosynthesis and calcification of corals and interactions with seasonal change in temperature/irradiance and nutrient enrichment. *Journal of Geophysical Research* 110 (C09S07).

Sabine C. L., R. A. Feely, et al. 2004. The oceanic sink for anthropogenic CO₂. *Science* 305: 367-371.

Section 5: Global Climate Change and Coral Disease

Learning Objectives

By the end of this module you will have:

- 🌐 An understanding of hypotheses regarding the increase in disease prevalence worldwide
- 🌐 An update on current scientific knowledge on coral diseases
- 🌐 A background on the emerging connection between climate and coral disease
- 🌐 An understanding of the challenges to managing coral diseases
- 🌐 A grounding in field assessment of diseases and other known impacts to corals

Background

Disease is a part of all natural systems. However, when a disease increases in spatial or temporal extent or in its capacity to cause mortality, it can become problematic, necessitating active management. Disease of corals and other reef animals is an emerging issue in marine science and management. Because corals provide the living and self-repairing foundation for reef communities, diseases that cause significant mortality to the primary reef building species are of major concern. This concern is based on evidence that diseases are apparently having greater impacts than before, and at a time when reefs are subjected to increasing threats despite global management efforts. This increase is thought to be brought about by a number of drivers, several of which have an anthropogenic link: 1) degradation of nearshore water quality that stresses benthic organisms and may lower their immunodefense capabilities, or expose them to elevated concentrations of pathogens (e.g., white pox disease of *Acropora palmata* in the Caribbean, caused by a sewage-associated bacterium *Serratia marcescens*); 2) increases in species introductions from shipping and the aquarium trade; 3) extension of the geographic range of pathogenic or parasitic species as a result of warming coastal water (e.g., *Perkinsus marinus*, the protist that causes the disease “dermo” in oysters); 4) introduction of novel pathogens to naïve hosts (e.g., *Aspergillus sydowii*, a soil fungus that causes aspergillosis in Caribbean sea fans); and 5) a change in the virulence or infectiousness of a pathogen as a result of a change in its environment (e.g., *A. sydowii* becomes more virulent in slightly warmer water).

It would be helpful to understand how certain key concepts are currently used and defined. As managers, understanding these key concepts will contribute greatly to creating a global body of reef workers who are all “speaking the same language”.

Disease – any impairment that interferes with normal function.

Infectious disease – disease caused by a transmissible agent, such as a bacterium or virus.

Non-infectious disease – disease caused by a non-infectious agent such as a toxin, congenital defect, or environmental stress.

Pathogen – any disease-producing agent; usually a microorganism such as a bacterium, virus or protist.

Outbreak – occurrence of disease at a rate above what is expected in a given population.

Prevalence – the number of disease cases among individuals in a population or area at a given point in time.

Incidence – a change in the number of disease cases within a population or area between two points in time.

Because the science of coral disease is very new, limited empirical evidence exists for a link with climate change. However, several recent key studies have reported compelling associations between elevated sea surface temperature and increased prevalence of white syndrome, bacterial bleaching and black band disease in the Indo-Pacific. In laboratory experiments, black band disease progressed faster within a sick coral, and was transmitted more rapidly between corals, in warmer water. Warmer temperatures have been demonstrated to increase the virulence of the bacterium *Vibrio shiloi* which causes bleaching in *Pocillopora damicornis*. In the Caribbean, disease outbreaks, particularly yellow band disease, have been observed to follow major bleaching episodes, killing corals that survive and apparently recover from bleaching. Extensive work with aspergillosis in sea fans has shown that the host gorgonian (*Ventalina* spp.) has reduced defensive chemistry, while the fungal pathogen (*Aspergillus sydowii*) shows increased virulence, at warmer temperatures. These lines of evidence suggest that disease impacts are likely to increase with rising ocean surface temperatures. However, other consequences of climate change such as rising sea level, which may increase the depth at which many coral communities exist, and ocean acidification, which may have impacts on coral health other than calcification rates, remain unstudied at present.

Coral disease is, therefore, both a new source of coral mortality and reef decline, and a consequence of reef degradation from other stressors. As a developing science, it is challenged by the rather urgent need for management tools which currently do not exist, or have not been adequately tested. In other words, we must, as managers and scientists, develop and test management tools for diseases with inadequate scientific knowledge of how these diseases are operating. We know much about human disease, less about disease in domesticated vertebrate animals and cultured plants, still less about diseases of wildlife, and almost nothing, in comparison, of diseases in lower invertebrates. Our management strategies of diseases for humans and domesticated animals and plants--culling, quarantine, vaccination, and education--are difficult or impossible to apply to a coral reef, with the exception of education. But, whom do we educate and what do we communicate? How do we manage the spread of disease and minimize mortality? Current thinking is that the best proactive management tool for coral disease may simply be to improve and protect water quality and ecosystem function to facilitate the coral's natural immunodefense mechanisms and optimize resilience. At present, this is chiefly accomplished via establishing and enhancing Marine Protected Areas (MPAs). A growing body of evidence is pointing to a number of ancillary benefits of MPA establishment aside from fishery protection and coral health is one such benefit. However, additional tools

will undoubtedly be needed, particularly in cases of disease outbreaks where active response may be needed to mitigate impacts and promote recovery.



Worksheet or Activity

Discussion: What coral diseases and other impacts to coral have you seen in your region? Are there any signs that you have not seen before (i.e., potential new or emerging diseases)? Are there signs that appear to be more common or frequent than before? Do you notice any signs of disease that occur more or less frequently in different seasons (i.e., rainy vs. dry; cool vs. warm)?



On-the-Web

Intergovernmental Panel on Climate Change
<http://www.ipcc.ch/>

NOAA “Frequently Asked Questions” on climate change
<http://www.ncdc.noaa.gov/oa/climate/globalwarming.html>

Coral Reef Targeted Research and Capacity Building for Management
<http://www.gefcoral.org>



Publications and References

Bruckner AW (2002) Priorities for Effective Management of Coral Diseases. National Oceanic and Atmospheric Administration. Washington, D.C. 54 pp.

Bruno JF, Petes LE, Harvell CD, and Hettinger A. (2003) Nutrient enrichment can increase the severity of coral diseases. *Ecology Letters* 6: 1056-1061.

Bruno JF, Selig ER, Casey KS, Page CA, Willis BL, Harvell CD, Sweatman H, and Melendy AM (2007) Thermal Stress and coral cover as drivers of coral disease outbreaks. *PLoS Biology* 5(6):e124.

Muller EM, Rogers CS, Spitzack AS, and van Woesik R. (2008) Bleaching increases likelihood of disease on *Acropora palmata* (Lamarck) in Hawksnest Bay, St John, US Virgin Islands. *Coral Reefs* 27:191-195.

Sutherland KP, Porter JW, Torres C (2004) Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals. *Marine Ecology Progress Series* 266:273-302

Raymundo LJ, Couch CS, Harvell CD (2008) *Coral Disease Handbook: Guidelines for Assessment, Monitoring and Management*.

Raymundo, LJ, Halford AR, Maypa AP, and Kerr AM (2009) Functionally diverse reef-fish communities ameliorate coral disease. *PNAS* 106(40):17067-17070.

Whelan KRT, Miller J, Sanchez O, and Patterson M. (2007) Impact of the 2005 coral bleaching event on *Porites porites* and *Colpophyllia natans* at Tektite Reef, US Virgin Islands. *Coral Reefs* 26:689-693.

Tips for Facilitating this Training Session

Module 2 – Components of Resilience

Focus

This session focuses on introducing the components of resilience in the TNC Resilience Model. This information is the basis for all other training modules that follow in this course. To help students understand how this information may change their approach to management strategies, we do a before-and-after activity. It is important to take your time with this session as everything else builds on it.

Estimated Time

15 minutes – Principles of Resilience Activity Part 1

45 minutes – Powerpoint Presentation: Principles & Components of Resilience

15 minutes – Principles of Resilience Activity Part 2

10 minutes – Group Report Back

Seating Arrangement/Group Size

Group Activity – 5 students per group max with coach

Full Session – Up to 25 students (absolute max is 30)

Learning Objectives

By the end of this module students will be able to:

- ④ Define biological and social resilience
- ④ Explain the three components of social resilience
- ④ Identify and explain the four main principles of resilience from the TNC model
- ④ Identify the three major factors of resilience and explain the resilience bottlenecks
- ④ Explain the genetic and species differences that influence coral stress response
- ④ Describe physical conditions that may increase resistance to temperature stress

Recommended Reading to Prepare for This Discussion

Read the following sections of the Reef Resilience Toolkit:

- *What is Resilience?*
http://www.reefresilience.org/Toolkit_Coral/C1b0_DefResil.html
- All sections of *Principles of Resilience*
http://www.reefresilience.org/Toolkit_Coral/C1c0_Principles.html
- All sections of *Identifying Resilience*
http://www.reefresilience.org/Toolkit_Coral/C3_Identifying.html
- Supporting resources listed at the bottom of each of the Toolkit pages for these sections

Materials Needed

- Powerpoint Presentation Module 2 (from DVD)
- Student Workbook for Module 2 (from DVD)
- One flip chart per group (5-7)
- Multi-colored markers – 1 pack per group

Handouts Needed

NONE

General Guidance for Carrying Out this Session

- Begin with the Hypothetical MPA Design Activity
- Give Powerpoint Presentation
- Do Part 2 of the Design Activity
- Have groups report out and discuss what changed between their first and second attempt to design an MPA

Activity Instructions: Principles of Resilience

Purpose: To demonstrate how resilience principles impact our thinking in design and zoning of MPAs.

Exercise Part 1 Using the maps you brought to the workshop as a base: **(15 MINUTES)**

1. Use provided criteria for MPA selection
2. Put MPA boundaries in place and feel free to have zones for different uses.

** Note, the assumptions about the area will be pre-determined at the workshop so participants will not spend time deliberating about what their 'situation' is.

AFTER POWERPOINT PRESENTATION, PARTICIPANTS WILL REVISIT MAP AND COMPLETE PART 2

Exercise Part 2: **(15 MINUTES)**

1. Review original MPA design, change if necessary to incorporate resilience based on the model just presented.

Notes to the Instructor

- Concept Emphasis – If managers do nothing more than strengthen their current management strategies, they will be making great strides toward resilient systems
- Concept Emphasis – If managers can, work to reduce the take of these species. They are CRITICAL to reef health
- Concept Emphasis – This is critically important. Only recently have scientists been able to document how important healthy coral communities are to fish populations and vice versa. Fisheries managers will finally see why they should care about healthy coral reefs.
- Concept Emphasis – Ask audience if they can think of places where they have seen lots of new recruits or baby corals – is there anything special happening there? Anything different about that place?

- Concept Challenge – Physical factors are hard to relate to. Try to use some real world examples from your site about locations that differ from each other in their physical conditions (e.g., cooler areas vs warmer areas)
- Concept Challenge – Shading examples are not always intuitive/obvious depending on where you are in the world. Use local examples from our geography that demonstrate this such as reef walls, high mountains, shaded areas depending on the time of day. (Sometimes the shading occurs because of underwater topography – not just above the sea) Ask trainees to think about differences in the communities at those sites.
- Concept Challenge – People confuse natural turbidity with human-caused turbidity. Be sure to clarify that human-caused turbidity is bad for reefs. Try to find examples where currents/tides naturally cause some turbidity and talk about differences in the health of the communities at those locations (compared to human-caused).
- Concept Challenge – Use examples of areas that experience frequent stress – perhaps a shallow bay that gets very warm, an area most likely to be in a hurricane’s path, a broad tidal range leaving reef exposed at times.

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Module 2: Principles and Components of Resilience

Section 1: What is Resilience?

Learning Objectives

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

- ④ Define *biological resilience* and explain it in clear terms
- ④ Define *social resilience* and explain it in clear terms
- ④ 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>

Folke, C., Carpenter, S.R., and Elmqvist, T. 2002. Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio* 31: 437–40.

<http://www.geog.mcgill.ca/faculty/peterson/PDF-myfiles/responseDiv.pdf>

Holling, C.S. 1973. Resilience and stability of ecological systems. *Institute of Resource Ecology, University of British Columbia, Vancouver, Canada* 4: 1-23.

<http://arjournals.annualreviews.org/doi/abs/10.1146/annurev.es.04.110173.000245>

Nyström, M., and Folke, C. 2001. Spatial resilience of coral reefs. *Ecosystems* 4: 406–417.

Section 2: Four Principles of Resilience

Learning Objectives

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

- ④ Identify and explain the four main principles of resilience
- ④ 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



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Section 3: Identifying Resilience

Learning Objectives

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

- ④ Identify the three major factors of resilience.
- ④ Explain the two main resilience 'bottlenecks' and what factors influence the role they play in reef resilience.
- ④ Explain the genetic and species differences that influence corals' response to temperature stress.
- ④ 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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Tips for Facilitating this Training Session

Module 3 – Resilient MPAs and Networks

Focus

This session focuses on applying the resilience principles to MPA and MPA Network design. (Or in the case of existing protected areas and networks – applying to zoning/use). Students will use what they have learned to begin the process of designing an MPA for their site or rezoning their site for a resilience-based management approach. It provides rules of thumb for size, spacing, and shape as well as ways to address connectivity when biological data are lacking (which is almost always the case).

Estimated Time

45 minutes – Powerpoint Presentation: Resilient MPAs and Networks

120 minutes - Group Activity: MPA Design Activity: Reef Classification & MPA Zoning

30 minutes – Poster session where groups circulate around the room visiting other groups, asking questions, providing feedback on the map classifications and zoning

Seating Arrangement/Group Size

Group Activity – 4-5 students per group max with coach – students should be coming from same geography so they can work on their real-life example

Full Session – Up to 25 students (absolute max is 30)

Learning Objectives

By the end of this module students will be able to:

- ② Identify the three factors of representation to consider and account for in planning/zoning MPAs
- ② Describe the reason for replication and several of the guiding principles to use when applying replication to MPA design
- ② Identify representative and resilient reefs and replicates for selection for MPAs/zoning
- ② List types of significant areas to consider for protection
- ② Explain the concept of connectivity and how it can be applied in MPA design and management
- ② Describe the rules of thumb for size, space, and shape in MPA design
- ② Identify the ecosystem services that should be considered in MPA planning

Recommended Reading to Prepare for This Discussion

Read the following sections of the Reef Resilience Toolkit:

- All sections and subsections of *Resilient MPA Design*
http://www.reefresilience.org/Toolkit_Coral/C5_ResilMPADesign.html
- Supporting resources listed at the bottom of each of the Toolkit pages for these sections
- Case Studies for:

British Virgin Islands

[http://www.reefresilience.org/Toolkit Coral/C8 BVI.html](http://www.reefresilience.org/Toolkit%20Coral/C8%20BVI.html)

Kimbe Bay, PNG

[http://www.reefresilience.org/Toolkit Coral/C8 Kimbe.html](http://www.reefresilience.org/Toolkit%20Coral/C8%20Kimbe.html)

Raja Ampat

[http://www.reefresilience.org/Toolkit Coral/C8 RajaAmpat.html](http://www.reefresilience.org/Toolkit%20Coral/C8%20RajaAmpat.html)

Materials Needed

- Powerpoint Presentation Module 3 (from DVD)
- Student Workbook for Module 3 (from DVD)
- Large map or navigational chart (best available map information) for each geography represented (min size of 24x24 – bigger is better) – ask participants to bring these if possible
- Mylar paper (to draw on top of map, make changes, etc. without damaging the map) – can use either a large roll and cut to size of maps, or use pre-cut sheets, generally a minimum size of 36x48. We’ve never had left-over plastic so it doesn’t hurt to have extra sheets on hand.
- Dry-erase markers (5 colors minimum) 1 pack per group
- Dry eraser and/or dry eraser fluid if available
- Tape & scissors
- Notepad and pen to record decisions made during activity

Handouts Needed (on CD)

Rules of Thumb Checklist

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation
- Do Part 1 Activity: MPA Design: Reef Classification
- Do Part 2 Activity: MPA Design: Zoning
- Poster Session to conclude and give students opportunity to share

Activity Instructions: MPA Design

PART 1: Reef Classification (60 Minutes)

Goal: To develop a classification map of the major reefs types and zones for your region

Purpose: The reef classification map will be used in the next exercise to identify representative and resilient reefs and replicates for selection as MPAs/zones. It can also be used to develop the sampling design for a rapid response plan for a major coral bleaching.

Instructions:

1. Delineate major reef types (e.g., atolls, barrier, fringing, patch) and zones (e.g., fore reef, back reef, spur and groove) on your map
2. Identify three factors that explain major coarse divisions in coral reef communities across your region (e.g., wave energy, ocean circulation, isolation)
3. Identify three factors that explain finer level differences (e.g., depth, salinity, turbidity)
4. Apply these factors to differentiate among the reef types and zones on your map
5. Draw divisions on your map and note the reasons.

This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. **Record your decision-making process** in the notes section so that you may return to this activity in the future.

OUTPUT: Country map with reef areas classified

HELPFUL HINTS FOR COACHES:

1. Ask group to think about the direction of prevailing winds, where their weather comes from, where the water is rough or calm, where the sheltered/exposed areas are, where you find strong currents. Then ask them what types of habitats they find in those locations.
2. Have group divide reefs out by windward/leeward, north/south/east/west (where lat/long differences are likely), patch reef, barrier reef, fringing reef. For example: windward patch reef.

Part 2: MPA Design/Zoning (60 MINUTES)

Purpose: Using information developed in the reef classification exercise, identify representative and resilient reefs and replicates for selection for MPAs/zoning schematic. This preliminary work can be used to begin the process of designation or consideration of zones in existing managed areas with stakeholders at your site(s).

Instructions:

Based on the information you developed in the classification exercise and the criteria listed below, choose a portfolio of MPA sites for your country or zoning scheme for your site. This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. **Record your decision-making process** in the notes section so that you may return to this activity in the future.

Step 1: Review criteria below to further describe your area

- Good example of reef or habitat type
- Good condition
- High biodiversity
- Low level of threat
- Survived bleaching
- Recovering well from bleaching mortality or disturbance
- High habitat complexity
- Replicates of the above at regular intervals (20 km where possible) by Latitude/Longitude

Step 2: Identify Critical Areas

Step 3: Choose a portfolio of MPA sites for your country or zoning scheme for your site using what you've learned about resilience and rules of thumbs for connectivity, critical areas, size, shape, spacing, and socioeconomic criteria

Step 4: Peer review your work within your group (if more than one country)– prepare to report back in a 30-minute poster session at end of exercise

OUTPUT: Country map with MPA or MPA network design/zoning scheme

Notes to the Instructor

- Concept Emphasis – Connectivity is the 'holy grail' for coral reef managers. Few places have connectivity data. It is something we should be continuing to try for – but we have rules of thumb that can be used in place of data.

Rules of Thumb Checklist for MPA/Network Design

Representation & Replication

- Good representation of habitat types, structure, function, physical conditions
- Minimum of 3 replicates of each habitat type/condition (classified area)

Critical Areas

- Inclusion of important nesting, breeding, and nursery grounds
- Inclusion of special areas (e.g., likely resilience/resistance to bleaching, ecologically sensitive areas)

Connectivity

- Inclusion of known 'source' areas
- Protection of habitat linkages (e.g., reef to seagrass to mangrove)

Size, Spacing, Shape

- 10-20 km diameter at minimum width
- Fewer large better than many small
- 10-20 km between core zones or MPAs
- Regular shapes easy to delineate and enforce (e.g., squares, rectangles, straight lines)

Socioeconomics

- Consider locations away from industrial areas or other high impact land use areas
- Consider existing activities that may be impacted or have negative impact on MPA (e.g., traditional use, commercial use, recreational use)
- Consider user conflicts to minimize future problems

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Module 3: Resilient MPAs and MPA Networks

Section 1: Representation and Replication

Learning Objectives

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

- ④ Identify the three factors of representation to consider and account for in planning MPAs
- ④ Describe the reason for replication and several of the guiding principles to use when applying replication to MPA design

Background

Representation focuses on ensuring that all ecosystems and habitats within the region are represented in the MPA network. Representation at the habitat scale assumes that by representing all habitats, most elements of biodiversity (species, communities, physical factors, etc.) will also be represented in the network. Biodiversity changes locally, regionally, and with latitude. To address the changes in biodiversity across space, each MPA should be carefully placed to capture linked habitats, and to include the diversity of characteristics/conditions of the area. In addition to the biological characteristic of an area, the physical factors across an area need to be represented within the network of MPAs. This helps to build in the resilience by including a variety of conditions that may confer resilience.

When assessing representation for MPA network design, three universal factors should be considered and accounted for in the planning:

- Biodiversity composition: each habitat supports a unique community, and most marine animals use more than one habitat during their lives.
- Biogeographic structure: the environmental/latitudinal gradients in habitats and species composition that should be represented.
- Ecosystem integrity: maintenance of the ecological processes of the system is as important as representing all habitats.

Biodiversity Composition

MPAs should contain many different reef zones and habitats to maintain a full complement of biodiversity, and a steady, varied supply of larvae to replenish damaged areas and to replace dead or emigrated organisms.

Different reef types, depths, and zones within reefs are characterized by different coral assemblages, and different responses to temperature stress and bleaching. There are different species of corals and community types found in shallow lagoons, reef flats and reef crests. Others are found down the reef slope, and may only occur deeper than ~20 meters. Dominant corals and coral diversity differ in each assemblage. For example, sheltered reefs may have dense overlapping colonies of staghorn coral (*Acropora*) or large whorls of leafy corals (*Montipora*, *Pachyseris*, *Echinopora*) that are aesthetically pleasing, but have few species. Such reefs may be valuable for tourism, but are less so for conserving a representative range of biodiversity. They also tend to be more susceptible to bleaching.

To identify representative and unique habitats, a simple multidimensional classification of habitat, including, but not limited to, depth, exposure, substrate, and dominant flora and fauna is essential in MPA design. In practice, three categories of habitats should be considered for inclusion in coral reef MPAs to attain adequate representation:

1. Coral habitats
2. Contiguous habitats (i.e., submerged, intertidal, or above water)
3. Habitats linked across far distances

Biogeographic Structure

To address the biogeographic structure of the area, the reef type and major reef zones of each bioregion should be protected and geographically represented (e.g., at different latitudes) to reduce potential threats at each site. The MPA should aim to capture the onshore-offshore or habitat-habitat ontogenetic (or life-stage) shifts of species. For example, the MPA should capture the gradient from mangrove to reef as fish move from larval to adult stages, respectively.

Ecosystem Integrity

Ecosystem integrity refers to the degree to which a given area (potential MPA site) functions as an effective, self-sustaining ecological unit. Distinct processes and physical attributes give rise to different coral reef communities; for example, seaward reefs endure greater wave stress than back reef lagoons. These distinct processes are reflected in variations of coral assemblages and zonation patterns. The protection of ecosystem processes is equally important as the protection of all habitats. Representation of physical factors of the area helps to build resilience into the MPA network. MPAs should be placed in areas that capture all major physical characteristics including:

- Exposure
- Energy regimes
- Wave energy

- Weather patterns
- Eddies
- Strong currents

Replication is the inclusion of multiple samples of habitat types in MPAs and networks to spread the risk of large-scale events, such as bleaching. Replication of protected resistant and resilient coral communities at multiple sites increases the probability that some reefs will survive bleaching, and helps the recovery of affected areas.

MPA networks are most effective when each habitat type is represented in more than one MPA. The goal of representation could be met by having only one MPA for each biodiversity element; however, if the habitat is destroyed in the one MPA, representation of that diversity would be compromised, as there would be nothing under protection. Replication provides a buffer against catastrophic loss of an MPA.

To spread the risk of damage or extinction by ensuring that habitat types are replicated in the network, the following guidelines are recommended:

- At the very minimum, three replicates of habitat type should be included, but more is always better. The number of replicates of each habitat type must be a balance between ensuring representation and ensuring effective monitoring and enforcement.
- For large biogeographic areas (100s–1000s km), the MPA should conserve a representative example of each bioregion.
- For smaller areas (1 km–100s km), the MPA should include reef types and major reef zones, which can serve as proxies (or substitutes) for community types.

Replicate MPA sites enable the dispersal of marine species between areas. Many marine species follow a stepping stone model, in which populations exchange larvae with adjacent populations. Replicate MPAs can be designed to accommodate dispersal patterns of species, and facilitate connectivity between the sites. Spacing considerations will also influence fulfilling the stepping stone role of MPAs.

Replication of MPAs also provides analytical power for management comparisons. With more than one MPA, reference, or control sites, can be incorporated into the monitoring program to evaluate the biological changes in and between each of the MPAs. This type of comparison facilitates adaptive management.



Activity: Part 1

Application Exercise: MPA Design: Reef Classification Activity

Goal: To develop a classification map of the major reefs types and zones for your region

Purpose: The reef classification map will be used in the next exercise to identify representative and resilient reefs and replicates for selection as MPAs/zones. It can also be used to develop the sampling design for a rapid response plan for a major coral bleaching.

Group Exercise

Instructions:

1. Delineate major reef types (e.g., atolls, barrier, fringing, patch) and zones (e.g., fore reef, back reef, spur and groove) on your map
2. Identify three factors that explain major coarse divisions in coral reef communities across your region (e.g., wave energy, ocean circulation, isolation)
3. Identify three factors that explain finer level differences (e.g., depth, salinity, turbidity)
4. Apply these factors to differentiate among the reef types and zones on your map
5. Draw divisions on your map and note the reasons.

This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. Record your decision-making process in the notes section so that you may return to this activity in the future.

Output: Country map with reef areas classified



On-the-Web

Reef Resilience Toolkit:

http://reefresilience.org/Toolkit_Coral/C5a0_Representation.html



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Roberts, C., Halpern, B., Palumbi, S., Warner, R. 2001. Designing Marine Reserve Networks: Why Small, Isolated Protected Areas Are Not Enough. *Conservation* 2(3): 10-17.

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<http://www.bioone.org/doi/abs/10.1641/B570707>

Section 2: Managing Critical Areas

Learning Objectives

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

- ② Identify representative and resilient reefs and replicates for selection for MPAs/zoning schematic (using information developed in the reef classification exercise).
- ② List types of biologically and ecologically significant areas to consider in MPAs
- ② Identify critical areas to consider in MPA design
- ② List resistant and resilient factors in coral reefs

Background

It is important to protect communities and systems that are naturally positioned to survive global threats. These areas serve as refuges to secure and maintain sources of larvae to replenish damaged areas. Protection of areas that are known to be resistant or resilient to threats, including bleaching events or other localized impacts, is also important. This section is intended to highlight the importance of considering special biological and ecological elements of a coral reef system.

Ecologically Significant Areas

Biologically and ecologically significant areas include:

- Sources of larvae and spawning aggregations;
- Nursery and breeding grounds of fish and other marine organisms;
- Developmental and feeding habitats; and
- Migration corridors
- Sea turtle nesting areas

Unique or Vulnerable Habitats

The presence of rare, endangered, relict, restricted-range species, and populations with unique genetic composition should be considered for MPA placement. Including unique places in the network will ensure that the network is comprehensive and adequate to protect biodiversity and known sensitive or unique areas. Some marine habitats are more vulnerable to natural and human impacts than others. These habitats include:

- coral reefs
- deep-sea coral communities
- oyster reefs
- salt marshes
- seagrass beds
- mangroves

Resistant Characteristics

Representation of reef communities or coral types that display resistance to bleaching is a vital component of an MPA, and should be afforded high levels of protection, and should be buffered within larger management areas. If a coral reef is resistant, it is more likely to withstand environmental fluctuations or unexpected catastrophes. These resistant communities can play a critical role in reef survival, by providing the larvae to recruit and enable recovery of affected areas.

Resistance Factors in Coral Reefs

Determinants of resistance to bleaching have been identified in some coral communities and species. For example, coral communities that are exposed to extreme conditions on a regular basis (e.g., shallow water or intertidal corals) maintain a higher resistance to bleaching than other non-exposed corals. The following list of resistance factors in coral communities should be considered in any MPA design.

- Localized upwelling of cool water
- Areas adjacent to deep water
- Regular exchanges (cooler waters replace warm water)
- Permanent strong currents (eddies, gyres, tides)
- Wind topography (narrow channel, peninsulas and points)
- High wave energy
- High tidal range
- Shade (from high land profile, undercut coastlines or reef structure)
- Steep slope from coral assemblages and structure
- Presence of naturally turbid water
- Cloud cover
- Exposure to elevated water temperatures (warmer waters in shallow back-reef lagoons)
- Frequent exposure and emergence at low tide
- High diversity and abundance of reef species
- Wide range of coral colony sizes and species distribution
- History of coral survival after bleaching

Considering the above mentioned resistance factors, the following guidelines are recommended:

1. Survey MPAs and their adjacent areas for the presence of environmental factors that cause bleaching resistance, and identify coral communities protected by them.

2. For resistant coral communities *inside* established MPAs, consider securing high levels of protection for them by revising zone boundaries, or establishing special zones to encompass these sites.
3. For resistant coral communities *outside* established MPAs, consider extending MPA boundaries to incorporate these sites, if feasible, or creating new MPAs to include them.

Resilient Characteristics

Representation of coral reefs or their components that demonstrate resilience to environmental fluctuations or threats (e.g., bleaching, hurricane, etc.) need to be included in zones with high levels of protection, and should be managed to maintain conditions that facilitate successful coral recruitment and recovery. To maximize both strong and reliable recruitment of all species within the community, and the likelihood that a portion of the recruits will enter surrounding areas, it is important that the MPA includes resilient features.

Resilience Factors in Coral Reefs

The following list of resilience factors in coral reef systems should be considered in any MPA design.

- Availability and abundance of local larvae recruits
- Evidence of recruitment success
- Diversity and abundance of different coral reef taxa, especially high herbivore densities and representative community structure
- Low abundance of bioeroders, corallivores, and diseases
- Effective management regime supported by legal framework, participation and enforcement
- Larval transport and connectivity by currents
- Concentration of larval supply

Considering the above mentioned resilient factors, the following guidelines are recommended:

1. Survey MPAs and their adjacent areas for the presence of environmental factors that cause bleaching resistance and identify coral communities protected by them. See Florida Keys and Mesoamerican Reef Case Studies as examples in the R2 Toolkit.
2. For resilient coral communities *inside* established MPAs, consider securing high levels of protection for them by revising zone boundaries or establishing special zones to encompass these sites.

3. For resilient coral communities *outside* established MPAs, consider extending MPA boundaries to incorporate these sites, if feasible, or creating new MPAs to include them.



On-the-Web

Reef Resilience Toolkit:

http://reefresilience.org/Toolkit_Coral/C5b0_IncludeCriticalAreas.html

Link to recent SST map:

http://www.ssec.wisc.edu/data/sst/latest_sst.gif

<http://www.osdpd.noaa.gov/PSB/EPS/SST/climo.html>

Link to real-time currents:

<http://www.oscar.noaa.gov/datadisplay/index.html>

The Angle of the Sun's Rays:

<http://www-istp.gsfc.nasa.gov/stargaze/Sunangle.htm>

Society for the Conservation of Reef Fish Aggregations

<http://www.scrfa.org>



Publications and References

The Science of Marine Reserves A Literature Review of Biophysical Guidelines for MPA Network Design and Implementation <http://www.piscoweb.org/publications/outreach-materials#booklets>

IUCN-WCPA. 2008. Establishing Marine Protected Area Networks - Making It Happen. IUCN-WCPA, National Oceanic & Atmospheric Administration, & The Nature Conservancy, Washington, D.C.

West, J.M., and Salm, R.V. 2003. Resistance and resilience to coral bleaching: implications for coral reef conservation and management. *Conservation Biology* 17(4): 956-967.

Section 3: Incorporating Connectivity

Learning Objectives

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

- ② Identify the main aspects of connectivity to consider in MPA design
- ② Describe what is meant by connectivity between adjacent habitats and between distant habitats
- ② Identify ways to consider larval dispersal and adult population movement patterns into MPA design

Background

A network of MPAs should maximize connectivity between individual MPAs to ensure the protection of ecological functionality and productivity. In this training, connectivity and ecological linkages include:

- Connections of continuous or adjacent habitats such as coral reefs and seagrass beds, or among mangrove and seagrass nursery areas and coral reefs
- Connections through regular larval dispersal in the water column between and within MPA sites.
- Regular settlement of larvae from one MPA to inside another MPA
- Marine life adult movements in their home range, from one site to another, or because of spillover effects from MPAs

It is important to take a system-wide approach in the design of MPA and MPA networks, one that recognizes patterns of connectivity within and among ecosystems (including the linkages among coral reefs, seagrasses, mangroves, watershed, etc.), as well as the connectivity between two populations. The strength of connectivity between locations depends on the abundance and fecundity of source populations, how far larvae disperse before settling to adult habitat, spawning sites and movement patterns of adults, as well as oceanographic effects (e.g., current patterns and retention features).

Adjacent Habitats

Ocean habitat types are connected through the movements of juvenile and adult organisms and through the transfer of materials and nutrients. Adjacent habitat systems are linked through the flow of matter, energy, and organisms. The following adjacent habitat types should be considered in the design of the MPA network:

Reef Flats

Back-reef Lagoons

Seagrass Beds and Sand Flats
Mangroves
Beaches and Dunes

Distant Habitats

Coral reefs are linked to distant areas by dynamic processes (e.g., currents, rivers, and species movements) and may be influenced by activities occurring in remote areas. Distant sources of stress, such as deforestation and development in a watershed, can cause erosion and release sediments that smother reefs. The distant sources of stress may be difficult to identify from a coral reef management perspective, and even more difficult to control.

While watersheds are not obvious or easy candidates to include in coral reef MPAs, they may be connected to reefs by streams and coastal currents. Damaging activities in a linked watershed will need to be controlled by a “ridge to reef” approach to MPA planning, or by coastal zone management approaches that complement MPA planning and management.

Larval Dispersal

Many fish, invertebrates and corals release great numbers of eggs and young into the open ocean. The pelagic larvae can remain floating or moving through ocean currents for hours, days, or even months, traveling distances of 1-1000s of km prior to settling. The distance and the patterns of larval dispersal are influenced by several factors which act synergistically over the pelagic larval duration including: larval behavior and duration, food resources, predators encountered, and currents.

When species-specific larval dispersal data are limiting, dispersal information for a broad range of taxa can be used. Dispersal of a particular species is not as important for the MPA network design as the sum of the larval dispersal for all the species of concern. Generally, species in a community display a range of larval dispersal distances that can be used as a guideline for MPA size and spacing in order to accommodate the dispersal distances of either focal species or the broadest range of species.

The following MPA design principles are recommended to address larval dispersal:

- To compensate for constantly changing ocean conditions, which have impacts on larval dispersal patterns, MPAs should be located in a wide variety of places in relation to the prevailing currents.
- In areas where currents are complex (e.g., eddies or reverse flows), an even spread of MPA locations is recommended.

- In areas where currents are strongly directional, MPAs sited in upstream locations will be more likely to support recruitment to the rest of the management areas than those in downstream locations.
- A network of MPAs linked to each other by prevailing currents will facilitate the recovery of damaged areas, and the maintenance of biodiversity through larval exchange.

Adult Movement Patterns

The movement patterns of adult species are important to consider in MPA design. How much protection an MPA affords a species depends (to some degree) on movement habits and distances of the individual (both as adult and larvae).

If adults move widely, the ocean neighborhood is large and diffuse. If adults are sessile, then the ocean neighborhood might be small and distinct.

The following MPA design principles are recommended to address adult movement patterns:

- Gather information on target species adult movement distances and patterns. Information about the species' ocean neighborhood can provide insights to help guide MPA size and spacing. For example, the size of the MPA can be based on adult neighborhood scales of highly fished species to ensure that at least some adults remain protected during the adult life stage.
- Ultimately, an MPA that accommodates species with the largest adult movement patterns should protect species with smaller adult movement distances as well. For example, MPAs designed to ensure self-seeding for species that move up to 100 km as adults should be sufficient for self-seeding of species that move only 10 km as adults.



On-the-Web

Reef Resilience Toolkit:

http://reefresilience.org/Toolkit_Coral/C5c0_IncorpConnectivity.html

CCAR Real-Time Altimeter Data Group http://argo.colorado.edu/~realtime/gsfc_gom-real-time_ssh/

PISCO <http://www.piscoweb.org/>



Publications and References

Jones, G.P., Srinivasan, M. and Almany, G.R. 2007. Population connectivity and conservation of marine biodiversity. *Oceanography* 20(3):12

Kinlan, B.P. and Gaines, S.D. 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. *Ecology* 84 (8): 2007-2020.

Managing Mangroves for Resilience

http://www.reefresilience.org/pdf/Managing_Mangroves.pdf

Palumbi, R.S. 2004. Marine reserves and ocean neighborhoods: The spatial scale of marine populations and their management. *Annual Review of Environment and Resources* 29: 31-68.

http://www.tos.org/oceanography/issues/issue_archive/issue_pdfs/20_3/20.3_jones_et_al.pdf

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Section 4: Size, Shape, and Spacing

Learning Objectives

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

- ④ Describe the basic guidelines on sizing for MPAs
- ④ Describe core-zones
- ④ Identify the two main aspects of spacing that need to be considered in MPA design
- ④ Describe the two components of shape to consider in the design of an MPA

Background

The size, shape and spacing of individual MPAs in an MPA network greatly influence the degree to which conditions in the wider environment affect the features of the MPA, and exchange of individuals between the MPA and adjacent environment. The three components of size, spacing, and shape should be considered in design of the MPA network to facilitate and promote connectivity between and within the MPA network.

Deciding how many, how large, and how far apart MPAs should be is a challenge. Ultimately, size, shape and spacing design of an MPA network will vary with the goals and objectives of the MPA, as well as the social and economic environment in which it is located. However, there are some general design guidelines on size, shape and spacing of each MPA that will help to ensure maximum benefits to individual MPAs within a larger MPA network

Size Matters

The size of an MPA should take into consideration the need for large populations to insure against catastrophes, as well as the patterns of connectivity. Even small sized MPAs can provide positive benefits, in terms of fish biomass, size and abundance, but a single, small MPA provides insufficient protection to large populations of many species. In general, bigger MPAs can protect more habitat types, more habitat area, larger populations of species, and a greater number of species in the ecosystem.

The ideal size of MPAs for biodiversity conservation will generally be larger than those planned for fish stock protection and enhanced recruitment. In terms of fisheries, as MPA size increases, the potential fisheries benefit from spillover and larval recruitment will increase, but only to a certain point, and only if those targeted species are protected. General MPA size principles that apply to the entire MPA network are provided in the following recommendations:

- Aim for 10-20 km in diameter, across MPA minimum width.
- In terms of biodiversity protection, fewer large MPAs are preferable to a greater number of smaller ones.
- To meet both fishery and conservation goals, intermediate sizes of MPAs, and a variation of sizes within a network may be ideal.
- Consider feasibility of management. A smaller MPA is easier to enforce, and the monitoring efforts are less demanding. Larger MPAs take longer to establish and implement, and require greater financial support.

No-take Areas

Coral bleaching events have demonstrated that replenishment is an important consideration for reef survival, regardless of the management objective. The effects of bleaching cannot be lessened by MPA zones, boundaries, regulations, or management efforts. Therefore, MPAs should be designed specifically to meet the requirements for reef survival. MPAs need to be large enough to be self-replenishing and sustainable. The optimal size of an MPA is designed around a strictly protected, no-take zone, or 'core zone', which encompasses sufficient target coral areas to be self-replenishing. To support self-replenishing MPAs, the following no-take zone guidelines are recommended:

- The no-take area should be selected to encompass a diverse range of reef habitats.
- The no-take area should be as large as possible to preserve a high diversity of reef biota.
- Large reefs may be self-replenishing, because their size allows portions of reefs damaged by bleaching, slumping (collapse of the reef slope), storm surges, freshwater flooding, or other stresses, to be replenished by recruits from undamaged parts of the same reef.
- To ensure self-seeding, the MPA should be as large as the mean larval dispersal distance of the target species.

Optimal Spacing

The exchange of larvae and adult organisms among MPAs is the fundamental biological rationale for MPA networks. To function as an effective network, the MPAs should be spaced to facilitate the connectivity between one another. Spacing of individual MPAs within the network is critical to maximize recruitment outside the MPAs. The design of the network of MPAs should: (1) accommodate the long distance dispersal of larvae; (2) capture the biogeographic range of variation in habitats and species.

Movement out of, into and between MPAs by adults, juveniles, larvae, eggs, or spores of marine organisms depends on their dispersal distance, and guides spacing aspects of MPA network design. In general, the lower the effective larval dispersal of a species, the

closer the MPAs will have to be to provide benefits to unprotected areas. MPAs that are more closely spaced are more likely to be ecologically connected and serve to protect a greater number of species through movement of young and increased recruitment from other MPAs. Therefore, MPAs should be spaced appropriately to capture the broadest range of dispersal distances as possible.

MPA spacing is habitat dependent. Habitat distribution patterns should influence where the MPAs are placed and how they are spaced. Within an MPA network, what matters is not spacing to the next MPA, but spacing to the next MPA that offers suitable habitat for the target species (or range of target species). Based on the habitat distribution or larval dispersal of the target species, spacing between MPAs can be established.

In general, the following spacing guidelines are recommended:

- To facilitate dispersal and promote connectivity between MPAs, MPAs should be placed appropriately to capture the middle range of dispersal distances. It is recommended that MPAs should be placed within 10 - 20 km of one another to capture effective connectivity.
- MPAs should be spaced to capture the biogeographic range of variation in habitat and species.
- Variable spacing is better than fixed spacing when there are several small reserves rather than a few large reserves (as long as they are within this 10-20km range)

Shape Matters

There are two components of shape to consider in the design of an MPA: edge effects and enforceability.

Edge Effects: In the design of an MPA, it is important to consider the ratio of edge habitat versus core interior habitat, as the edges (or perimeter boundary line) of MPAs are often extensively fished, and therefore do not offer the same refuge to fish species as the interior protected areas do. Juvenile and adult spillover from the MPA is edge-dependent, and as the amount of edge of an MPA increases, faster export is expected, relative to the total protected area. It is important to **minimize edge habitat and maximize interior protected area.**

Enforceability: The shape of an MPA is also a critical factor in effective delineation and enforcement. A shape that allows for clear marking of boundaries for both resource users and enforcement personnel may increase effectiveness. MPAs with boundaries that conform to natural habitat edges offer fuller protection than MPAs with boundaries that cross reef habitat types and zones. However, the ease of compliance and enforcement capabilities need to be taken into account.

- MPAs should be contiguous, compact and easily delineated.
- Consider obvious, easy GPS reference points, such as landmarks and distinct habitat types.
- Regular MPA **shapes of squares or rectangles are preferable** because they can be delineated by lines of latitude and longitude, and therefore more easily identified by user groups.



On-the-Web

Reef Resilience Toolkit:

http://reefresilience.org/Toolkit_Coral/C5d0_SizeSpacing.html



Publications and References

Gaines, S.D., Gaylord, B., and Largier, J.L. 2003. Avoiding current oversights in marine reserve design. *Ecological Applications* 13(sp1): 32-46

Green, A., Lokani, P., Sheppard, S., Almany, J., Keu, S., Aitsi, J., Warku Karvon, J., Hamilton, R. and Lipsett-Moore G. 2007. Scientific design of a resilient network of Marine Protected Areas. Kimbe Bay, West New Britain, Papua New Guinea. TNC Pacific Island Countries Report No. 2/07.

http://www.reefresilience.org/pdf/Kimbe_Complete_Report.pdf

Halpern, B. 2003. The Impact of Marine Reserves: Do Reserves Work and Does Reserve Size Matter? *Ecological Applications* 13(1): S117-S137

http://www.nceas.ucsb.edu/~halpern/pdf/Halpern_EA_2003.pdf

Halpern, B.S., Regan, H.M., Possingham, H.P., and McCarthy, M.A. 2006. Accounting for uncertainty in marine reserve design. *Ecology Letters* 9(1): 2-11.

http://www.nceas.ucsb.edu/~halpern/pdf/Halpern_etal_2006_EL_entire_set.pdf

Sala, E., Aburto-Oropeza, O., Paredes, G., Parra, I., Barrera, J.C., and Dayton, P.K. 2002. A General Model for Designing Networks of Marine Reserves. *Science* 298: 1991-1993.

http://www.physics.mun.ca/~bdeyoung/Connectivity/sala_marine_reserves_science_2002.pdf

Shanks, A. L., B. A. Grantham and M. H. Carr (2003). Propagule Dispersal Distance and the Size and Spacing of Marine Reserves. *Ecological Applications* 13(1): S159-S169.

Section 5: Socioeconomic Criteria

Lesson Objectives

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

- ② Identify the main sectors that socioeconomic efforts tend to focus
- ② Describe ecosystem services and identify the four main groups of services
- ② List the ecosystem services that should be considered and how to measure them for MPA planning

Background

Social and economic criteria should always be considered when creating a resilient MPA network. The challenge is how to integrate requirements of natural systems with needs of the people who depend upon them. An effectively managed, resilient MPA network is one way to address this challenge. MPA creation can help move from single sector management to a more holistic approach, including human and ecosystem interactions, and cumulative impacts. This multiple-objective approach can create a foundation that transforms the way people address conflicts between the environment and the economy.

Although all social and economic factors, including the costs and benefits to humans and the environment, should be considered in creating an MPA network, the majority of efforts tend to focus on:

Tourism: Often a majority of income, especially in developing countries, comes from tourism. It is important to create tourism industries with limited biodiversity impacts, local knowledge that is used for tours and management, and buy-in from the local community to be stewards for their natural resources.

Fisheries: Commercial and some artisanal fishing can have the largest impacts, and be most impacted by MPA networks. Local fishers may have to learn new trades or fish with alternative gear to ensure their livelihoods are secure. Support and buy-in from the local community, stakeholders, and government is imperative to a successful and sustainable MPA network.

Other (climate change, ports/marinas, coastal development): Creating a successful resilient MPA network depends on accounting for the many effects of climate change, some of which are addressed in this toolkit. In addition, there will always be multiple uses in or near an MPA. Working with the community and multiple stakeholders to create a win-win situation for everyone is key.

Ecosystem Services

What are Ecosystem Services?

1. Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are defined as “ecosystem services” and include products like clean drinking water, and processes like the decomposition of wastes. The Millennium Assessment has identified four groups of ecosystem services: Provisioning (e.g., subsistence and commercial fisheries attained from healthy reefs)
2. Regulating (protection of beaches and coastlines from storm surges and waves)
3. Cultural (tourism and recreation)
4. Supporting (nursery habitats)

Ecosystem services are distinct from other ecosystem products and functions, because there is human demand for these natural assets.

As human populations grow, so do resource demands imposed on ecosystems and impacts of our global footprint. For many years, people have assumed that these ecosystem services are free and infinitely available. However, impacts of anthropogenic use and abuse are becoming more apparent, especially around coral reefs: oceans are being overfished, invasive species are extending beyond their historical boundaries, and deforestation is eliminating flood control around human settlements. Consequently, society is now realizing that ecosystem services are not only threatened and limited, but that the need to evaluate trade-offs between immediate and long-term human needs is urgent.

To help inform decision-makers, economic value is increasingly associated with many ecosystem services, and often based on the cost of replacing these services with human derived alternatives, such as installing a breakwater where the natural system that used to provide a barrier has been destroyed. The on-going challenge of prescribing economic value to nature is prompting shifts in how we recognize and manage the environment, social responsibility, business opportunities, and our future as a species.

What Services Should Be Considered?

Since there are many ecosystem services that benefit humans it is important to include them in management plans. These services have been well reviewed and defined in the Millennium Assessment, and the other links on this page.

Often the provisioning and cultural services of fisheries and tourism, respectively, are considered in MPA management plans. However, regulating and supporting services should also be reviewed, valued if possible, and represented in any resilient MPA network. A healthy reef will be able to provide multiple services to the community that

depends on it; including the services the reef provides in management plans is one way to ensure reef health.

Measuring Ecosystem Services

There are many methods by which to measure ecosystem services. However, it should be noted that the values that are determined from these methods, whether in dollars, number of jobs, or tons of fish, should be kept in perspective and evaluated within the larger context of how they will contribute to reef health.

Using Ecosystem Services Information

Once services have been measured, or at least accounted for, managers can use this information to:

- Prioritize which areas should be protected/restored
- Balance between extractive and conservation uses
- Balance between sustainable harvesting and ensuring healthy reefs for biodiversity and tourism goals



On-the-Web

Reef Resilience Toolkit:

http://reefresilience.org/Toolkit_Coral/C5e0_Socioeconomic.html

Kimbe Bay Case Study: http://www.reefresilience.org/Toolkit_Coral/C8_Kimbe.html

NOAA Coasts: <http://www.noaa.gov/coasts.html>

Biodiversity of Economics: <http://pdf.wri.org/cesardegradationreport100203.pdf>

SOCMON: http://www.reefbase.org/socmon/default.asp?redirect=home_04



Publications and References

The Economics of Worldwide Coral Reef Degradation (links to many MPA papers):

<http://pdf.wri.org/cesardegradationreport100203.pdf>



Activity: Part 2: MPA Design: Zoning

Purpose: Using information developed in the reef classification exercise, identify representative and resilient reefs and replicates for selection for MPAs/zoning schematic. This preliminary work can be used to begin the process of designation or consideration of zones in existing managed areas with stakeholders at your site(s).

Group Exercise

Instructions:

Based on the information you developed in the classification exercise and the criteria listed below, choose a portfolio of MPA sites for your country or zoning scheme for your site. This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. Record your decision-making process in the notes section so that you may return to this activity in the future.

Step 1: Review criteria below to further describe your area

- Good example of reef or habitat type
- Good condition
- High biodiversity
- Low level of threat
- Survived bleaching
- Recovering well from bleaching mortality or disturbance
- High habitat complexity
- Replicates of the above at regular intervals (20 km where possible) by Latitude/Longitude

Step 2: Identify Critical Areas

Step 3: Choose a portfolio of MPA sites for your country or zoning scheme for your site using what you've learned about resilience and rules of thumbs for connectivity, critical areas, size, shape, spacing, and socioeconomic criteria

Step 4: Peer review your work within your group (if more than one country)– prepare to report back in a 30 minute poster session at end of exercise

Output: Country map with MPA or MPA network design/zoning scheme

Rules of Thumb Checklist for MPA/Network Design

Representation & Replication

- Good representation of habitat types, structure, function, physical conditions
- Minimum of 3 replicates of each habitat type/condition (classified area)

Critical Areas

- Inclusion of important nesting, breeding, and nursery grounds
- Inclusion of special areas (e.g., likely resilience/resistance to bleaching, ecologically sensitive areas)

Connectivity

- Inclusion of known 'source' areas
- Protection of habitat linkages (e.g., reef to seagrass to mangrove)

Size, Spacing, Shape

- 10-20 km diameter at minimum width
- Fewer large better than many small
- 10-20 km between core zones or MPAs
- Regular shapes easy to delineate and enforce (e.g., squares, rectangles, straight lines)

Socioeconomics

- Consider locations away from industrial areas or other high impact land use areas
- Consider existing activities that may be impacted or have negative impact on MPA (e.g., traditional use, commercial use, recreational use)
- Consider user conflicts to minimize future problems

Tips for Facilitating this Training Session

Module 4 – Early Warning Systems: Predicting Mass Coral Bleaching

Focus

An early warning system for predicting and identifying mass bleaching is a key element in a manager's bleaching response plan. An early warning system provides information to communicate to media, government, and stakeholders. Early warning systems also identify the potential location, extent, and severity of bleaching to focus monitoring response.

Estimated Time

45 minutes – Presentation

30 minutes – Activity

Seating Arrangement/Group Size

Full session, maximum of 25 students; group activity splits the participants into 4 teams

Learning Objectives

By the end of this module you will:

- ④ Understand the importance of early warning systems in predicting mass bleaching.
- ④ Be familiar with how satellites measure sea surface temperature.
- ④ Know about NOAA products that warn when reefs are at risk from high temperature and their strengths and limitations.
- ④ Understand the role of community monitoring in an early warning system and as a response to a mass coral bleaching event, disease outbreak, etc.
- ④ Understand the components, strengths, and weaknesses of community monitoring.
- ④ See examples of community-based monitoring programs.
- ④ Understand the role of ReefBase.

Recommended Reading to Prepare for This Discussion

NOAA Coral Reef Watch online tutorial:

<http://coralreefwatch.noaa.gov/satellite/education/tutorial/welcome.html>

Also review one of the community-based monitoring websites below

Materials Needed

- PowerPoint Presentation from DVD for Module 4
- Student Workbook for Module 4
- Flip charts and pens to record any discussion following the presentation

Handouts Needed (on CD)

- Printout of scenarios for “You make the call” group exercise

General Guidance for Carrying Out a 45-minute session

- Introduction: Introduce yourself and the topic
- Three main presentation sections:

- overview of sources of early-warning information
- introduction to NOAA's satellite tools
- description of community-based monitoring
- Hands-on exercise
 - Purpose: to integrate information from many sources to determine bleaching risk: weather, sea surface temperature, and local conditions. The exercise simulates a three-week event.
 - Instructor divides participants up into four groups. Each group will receive a piece of paper with basic information about the reef.
 - Each group receives current conditions for the first week: recent weather, satellite bleaching alert status, bleaching observations, and other events. The group is asked to determine risk for coral bleaching.
 - Updated information for week 2 and then week 3 will be passed out. Based on changes in weather, satellite bleaching alert status, etc. participants will be asked to revise their threat level over time.
 - Participants report back to describe their 3-week bleaching event.
- Discussion: Engage the full session in a discussion after the exercise (5 minutes)

Notes to the Instructor

- It is very important that the instructor have a good understanding of the NOAA tools before teaching this session. If the presenter lacks confidence, the remote sensing may seem hard to understand and less useful. The concepts are really not difficult, but it is crucial to present them clearly.
- The section on community-based monitoring programs uses the Florida Keys as an example. If there is a monitoring network in your region, it would be great to change the presentation to use a local example instead.
- The challenge in discussing Early Warning Systems is in illustrating the usefulness of the products, while not getting bogged down in the technical details. However, you have to understand and present enough of the technical details so that managers understand the products, their limitations, and how they can be used as tools in reef management.
- History: Originally, remote sensing scientists with NOAA Coral Reef Watch presented a 3-day workshop focused solely on these satellite products and the technique of remote sensing. The idea was to give managers a background on remote sensing and the limits of what satellites can measure, in-depth details on each of the products, and hands-on exercises to cement the concepts. The workshops were successful overall and some managers with a technical background were very interested in this level of detail. However, the realization that most reef managers just don't need that level of detail in order to USE the satellite products in their daily work grew out of this workshop series. We have pared this module down to the essential concepts that can be presented in about 45 minutes. This module is important in the R2CC workshop because it gives managers a concrete set of products that provide early warning when bleaching conditions are ramping up and a very important FREE global system that pinpoints where bleaching is likely right now.

- **What works:** When discussing Early Warning Systems, start with the bottom line: why are these products useful tools for managers. Then give some background on remote sensing and the various products, especially the online resources that are available for further training. It's also important to give concrete examples of how and when the products can be used as part of a bleaching response plan, ending with a hands-on exercise to show how multiple sources of early warning information can be taken together to give a comprehensive picture of the current local threat for bleaching. It is also important to show managers where SBAs are available, and encourage them to sign up for the several stations that are close to their reef area. One concern that we hear expressed is that the 50km resolution products are on a scale too large to be indicative of what is happening on a reef. It is important to emphasize that these tools give a broad perspective on what's going on in the region, and that local knowledge of conditions that might exacerbate or mitigate coral bleaching locally are extremely important. It is therefore vital that managers incorporate their local knowledge, do their own monitoring with SST loggers, buoys, and *in situ* surveys to interject local conditions and observations along with higher resolution remote sensing information into their early warning system.
- **Biggest challenge:** Understanding the products well enough to present them clearly and confidently. The DHW concept can be a bit hard to explain, so it's good to refresh your memory with the online tutorial before teaching this section. If the teacher is not comfortable with the concepts, the students won't understand what's going on and the satellite tools will seem intimidating and incomprehensible. The concepts are not complicated if they're explained clearly.

Additional Resources

Alternative hands-on exercise; could be done individually by students in the class, or by the instructor as a concept review before teaching this module: "A Classroom Activity Using Satellite Sea Surface Temperatures to Predict Coral Bleaching." Free download: <http://www.tos.org/hands-on/index.html>

Community-based program websites:

Florida Keys: <http://isurus.mote.org/Keys/bleaching.phtml>

Great Barrier Reef:

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

Western Indian Ocean: <http://www.cordioea.org/bleachingalert/>

Mesoamerican Barrier Reef (Mexico, Belize, and Honduras):

<http://www.marcoralwatch.net/en/home.php>

Hawaii: <http://www.reefcheckhawaii.org/eyesofthereef.htm>

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Module 4: Early Warning Systems

Section 1: Tools to Predict Mass Bleaching

Learning Objectives

By the end of this lesson you will have:

- ④ An understanding of the importance of early warning systems in predicting mass bleaching events.
- ④ A basic understanding of remote sensing and how satellites measure sea surface temperature (SST).
- ④ The ability to access and interpret SST and SST anomaly data on the NOAA website.
- ④ A knowledge of the methodology Coral Reef Watch uses to predict bleaching from satellite measurements of sea surface temperature.
- ④ A suite of tools that will warn managers when their reefs might be at risk from elevated temperatures.

Background

A manager's response to bleaching has three major components: An early warning system for predicting and identifying mass bleaching events, an assessment and monitoring program to measure the impacts of bleaching, and a communication program. An early warning system provides information for managers to communicate to the media, government and stakeholders about the likelihood of bleaching events. Early warning systems also allow managers to identify the location and potential extent and severity of bleaching events to be able to mobilize an assessment and monitoring response.

Prediction of bleaching serves three main purposes: It allows managers to predict whether a bleaching event is likely to occur and how severe the impacts might be, it helps managers prepare for an impending bleaching event in order to monitor and manage impacts, and it also helps managers identify where the greatest impact is likely to be and therefore where to focus management, assessment and monitoring efforts. Mass coral bleaching is preceded by environmental conditions that can be tracked to provide managers with an effective early warning system for bleaching events.

An understanding of the factors that influence sea temperature has the potential to enable managers to predict the probability of occurrence and severity of a bleaching event. In theory, the relationship between climate patterns, seawater heating, and mass bleaching should provide a mechanism for such predictions. In particular, the weather patterns associated with phenomena such as the El Niño Southern Oscillation or the Pacific Decadal Oscillation can be

associated with regional and local warming sea temperatures. Weather patterns also provide a useful indication of whether bleaching risk is increasing or decreasing. Longer-term predictions, such as seasonal forecasts, can be used to assess the probability of weather conditions that contribute to increasing sea temperatures occurring over timescales of weeks to months. For example, seasonal outlooks for the hot season that predict above-average air temperatures and decreased storm activity indicate that there is an increased probability of conditions that can lead to stressful sea temperatures.

Shorter-term predictions, such as weekly weather forecasts, indicate whether sea temperatures will increase or decrease in coming days and weeks. The risk of mass bleaching is higher when forecasts are for high air temperatures and extended periods of clear skies, low wind and neap tides. In contrast, forecasts for stormy conditions with cooler air temperatures, high cloud cover and strong winds indicate that sea temperatures may stabilize or decrease over the coming week. Once atmospheric conditions suggest the development of unusually warm conditions, measurements of sea temperatures provide a more direct indication of the potential for mass coral bleaching. Temperature stress can be monitored using satellite imagery and in-water instruments.

Sea surface temperature (SST) is known to be variable in both space and time. Fortunately, we can measure this temperature globally and in near-real-time, from the polar-orbiting satellites that NOAA deploys. This technique is known as remote sensing.

What is remote sensing?

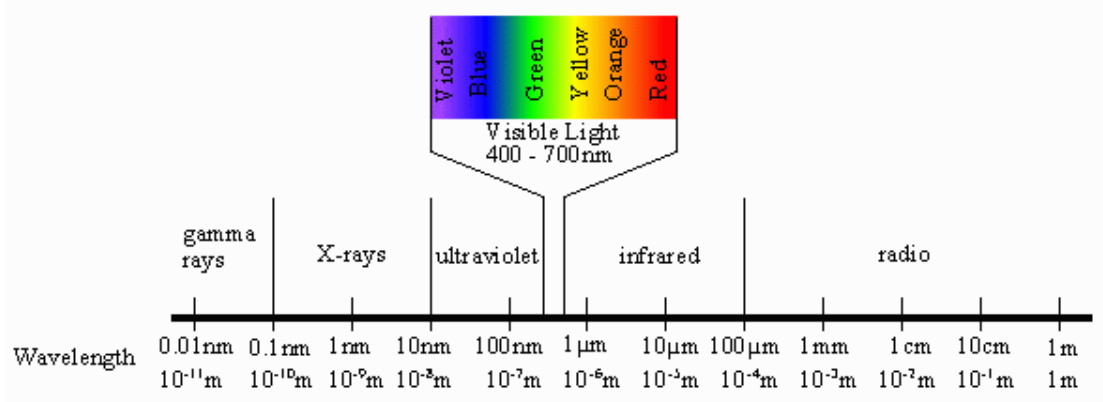
Basically, remote sensing means measuring some property of an object without actually touching it. Usually, we add some interpretation to this measurement to draw conclusions about the object we are sensing.

For example, our eyes and ears are remote sensing instruments, and in fact humans are all skilled remote sensors. Let's take an example. How can you tell if the burner on an electric stove is hot, without touching the surface and burning your hand? There are actually two ways that you use remote sensing to tell whether the burner is cool or hot. The first way is to look at the color of the burner. If it is red, you can interpret that color to mean that the burner is very hot. But if the color is black, the stove still may be quite hot. What other sense can you use to detect if the burner is warm?

Answer: If you put your hand close to the burner, you can feel the heat without touching the surface. Your skin is actually sensing the infrared radiation from the stove. As you will see, this is similar to the way satellites measure the temperature of the ocean's surface.

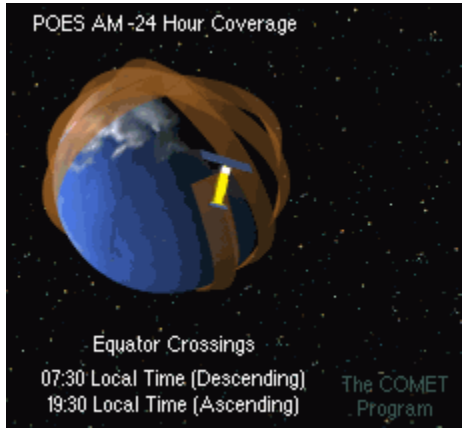
Remote sensing uses sensors that measure parts of the electromagnetic spectrum. This "spectrum" is a way of talking about natural energy: from x-rays and ultra-violet light (UV), through visible light, to infrared (IR) and microwaves. At the right are high-energy waves like gamma rays, which pass right through physical matter. In the center is a narrow band of energy

that our eyes are tuned to detect—visible light, from higher-energy blue light to the lower-energy red. The next section of this spectrum is called infrared. This is energy that we can feel as heat, like what comes off the hot burner on your stove. All the way at the lower (left) end are radio waves, which have low energy and long wavelengths. Many of these forms of energy are used in remote sensing.



Satellite remote sensing

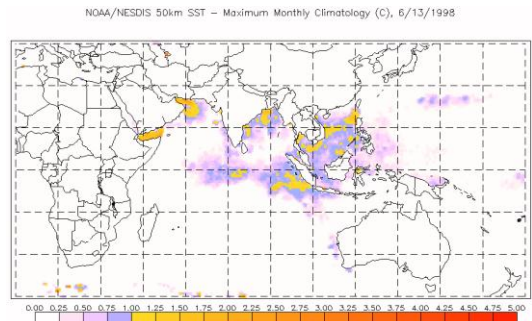
NOAA operates two different types of satellites that carry remote sensing instruments. Geostationary satellites stay in the same position relative to Earth, so they can take frequent measurements of an area throughout the day and night. However, each satellite can only see a fraction of the Earth’s surface. Because coral reefs are located all around the world, the Coral Reef Watch program uses NOAA’s polar-orbiting satellites. Although they can only measure a given area once or twice a day, they have the advantage of getting measurements around the entire planet.



There are only 4 properties of the ocean that a satellite can directly measure:

- How far away is the water surface?
- How rough is the surface?
- What color is the water?
- What is the temperature of the water?

It is this last property that can be directly used in monitoring for bleaching conditions.



The Coral Reef Watch program has customized NOAA's satellite SST measurements into trusted data products that highlight areas that are currently at risk for coral bleaching. HotSpot maps (Strong et al. 1997) show SSTs that are currently above the monthly mean temperature we expect to see in the hottest month. The mapped HotSpots are updated twice each week, and have proven to be a very reliable indicator of current temperature stress in coral reef areas. However, we also know that the duration of the heat stress is also important in predicting the severity of coral bleaching. Coral Reef Watch therefore also produce Degree Heating Week (DHW) maps that combine the HotSpot intensity of the temperature anomaly with the duration of exposure, providing a composite picture of cumulative thermal stress over the last 12 weeks. One DHW is equivalent to one week of SST at 1 °C greater than the expected summertime maximum. Two DHWs are equivalent to two weeks at 1 °C above the expected maximum or one week of 2 °C above the expected maximum. At DHWs over 4, the Coral Reef Watch program issues a Coral Bleaching Alert that mass bleaching is likely to be occurring.



Worksheet or Activity

Activity: "You Make the Call"

Purpose: The purpose of the "You Make the Call" exercise is to integrate information from many different sources to determine if the reef you are managing is at risk for bleaching. The exercise spans three weeks, and participants will consider how changing weather, sea surface temperature, and local conditions might change the threat of bleaching.

Instructions: Instructor will divide participants up into four groups based on their location in the room. Your group will receive a piece of paper with a type of reef and basic information about the reef. The information will include:

- Reef type
- Tidal range
- Important information about adjacent landscape features, uses, etc.
- Current Conditions
 - Recent Weather
 - Satellite Bleaching Alert Status
 - Bleaching Observations
 - Other Relevant Events

Based on current conditions for this first week including recent weather, satellite bleaching alert status, bleaching observations and other events you will be asked to determine how great a threat your reef is for widespread coral bleaching. Once the threat level is determined for week 1, updated information for week 2 and then week 3 will be passed out. Based on changes in

weather, satellite bleaching alert status, etc. participants will be asked to revise their threat level over time.



On-the-Web

NOAA Coral Reef Watch:

Homepage: <http://coralreefwatch.noaa.gov/satellite>

Tutorial on our data products:

<http://coralreefwatch.noaa.gov/satellite/education/tutorial/welcome.html>

Sign up for free Satellite Bleaching Alert e-mails: <http://coralreefwatch-satops.noaa.gov/SBA.html>

Florida Keys BleachWatch program:

<http://isurus.mote.org/Keys/bleaching.phtml>

Florida Keys Current Conditions Reports:

http://isurus.mote.org/Keys/current_conditions.phtml

Great Barrier Reef Current Conditions Reports:

http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change/management_responses/current_condition_reports/

GBRMPA Bleachwatch Program:

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

ReefTemp: (Australian high-resolution satellite bleaching tools)

<http://www.cmar.csiro.au/remotesensing/gbrmpa/ReefTemp.htm>

Mesoamerican Coral Reef Watch Program:

<http://mesoamericanreefwatch.net/en/bleachwatch/bleachwatch.php>

Other key links:

NOAA Coral Reef Conservation Program, with info on all of NOAA's coral reef activities:

<http://www.coralreef.noaa.gov/>

Submit a bleaching report to ReefBase: <http://www.reefbase.org/contribute/bleachingreport.aspx>



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Hoegh-Guldberg, Fine, Skirving, Johnstone, Dove, and Strong, Coral bleaching following wintry weather, *Limnol. & Oceanogr.*, 50(1), 265–271, 2005.

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IPCC (2001). *Climate Change 2001: The Scientific Basis*. Published for the Intergovernmental Panel on Climate Change by the Cambridge University Press, Cambridge, United Kingdom.

Strong, A. E., C. B. Barrientos, C. Duda, and J. Sapper (1997). Improved satellite techniques for monitoring coral reef bleaching. *Proc 8th International Coral Reef Symposium*, Panama City, Panama, p 1495-1498.

Strong, A. E., F. Arzayus, W. Skirving, and S. F. Heron. Identifying coral bleaching remotely via Coral Reef Watch – improved integration and implications for climate change. Chapter 9 in *Coral Reefs and Climate Change: Science and Management*, J. T. Phinney, O. Hoegh-Guldberg, J. Kleypas, W. Skirving, and A. E. Strong (Co-Eds), American Geophysical Union, 2006.

Section 2 Community-based Monitoring

Learning Objectives

By the end of this lesson you will:

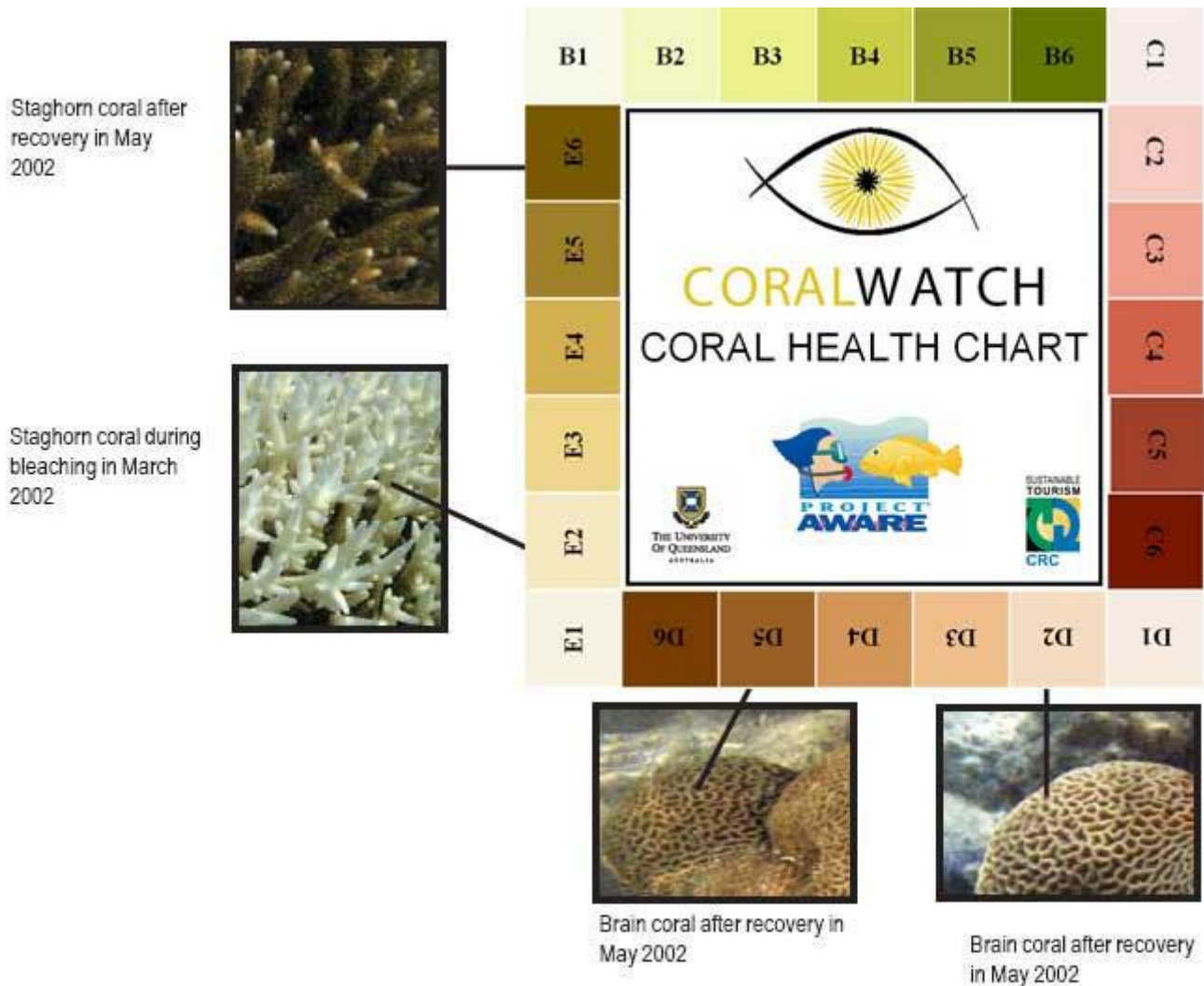
- ② Understand the role of community or citizen monitoring in an Early Warning System and as a component of a management response to a mass coral bleaching event, disease outbreak, etc.
- ② Understand the components of community-based monitoring and its strengths and weaknesses.
- ② See examples of a number of community-based monitoring programs.
- ② Understand the role of ReefBase.

Background

One of the first community-based monitoring programs was established on the Great Barrier Reef by the University of Queensland. The following information was taken from their website (<http://www.coralwatch.org/ProjectDetails/default.aspx>).

Current attempts to monitor coral bleaching often involve costly satellite-borne technologies, are restricted to locations researcher are working in and often require sampling of live tissue for physiological analysis. Our coral reef monitoring approach using color charts is the first attempt to provide useful data on a relatively large scale with the help of an inexpensive, 'user friendly' and non-invasive device. At the University of Queensland, Australia we have developed a method of coral health monitoring which uses simple color charts, like paint color matching charts. This is a result of the unusual union between world leading vision and color experts at VTHRC (Vision, Touch and Hearing Research Centre) and world leading coral experts at CMS (Centre for Marine Studies). The color charts can be used by anyone, scientists, school children, tourists and politicians. Perhaps most importantly, the opportunity for everyone to participate in a global reef-monitoring project removes the sense of hopelessness felt by many in the face of outcomes predicted from global warming. With this monitoring program we also aim to educate the public about coral bleaching and its devastating effect on coral reefs.

This is how it works: The color charts are based on the actual colors of bleached and healthy corals. Each color square corresponds to a concentration of symbionts contained in the coral tissue. The concentration of symbionts is directly linked to the health of the coral. All you have to do is match the color of the coral with one of the colors in the coral health monitoring chart. You then record the matching color codes, along with coral type (species if possible), on the website data sheet (www.coralwatch.org).



Why we need your help: Little is known about trends of coral bleaching on a global scale, though as these bleaching episodes increase in frequency we are learning more. Currently coral health monitoring mainly occurs around a few reefs that are regularly visited by scientists. There are many questions that will have to be answered in order to try and save the reefs. This is where you can help! If many people around the world, like you, participate in the monitoring program we will be able to answer questions such as:

1. Large and small-scale pattern of coral bleaching: Based on water temperature measurements and knowledge of currents, it is possible to predict which areas will be affected by bleaching. We hope to answer several questions within this. Do all reefs bleach during every El Niño event, or are there some reefs/zones of reef that never bleach? Does the same reef bleach every time?
2. Duration and severity of coral bleaching: How long are different reefs affected by bleaching events? How severely are different reefs around the world affected? Is the severity and duration dependent on whether or not a reef has bleached before? Does the overall health of the reef get worse from one bleaching event to another?

3. Large and small scale pattern of recovery: To date most research has concentrated on the onset of bleaching rather than recovery. With your help it will be possible to measure recovery - how long after the drop in water temperature do different reefs recover? How long does recovery take? Is it variable between different reefs and different coral types?

With your help it will be possible to monitor coral health throughout the year, not just during bleaching events. It is important to measure the small natural fluctuations in the coloration of healthy corals, which do happen seasonally, so that we can immediately identify if there is a color change outside the normal range. In this way it will be possible to find out if there are other factors that may influence coral health throughout the year. (Source <http://www.coralwatch.org>)

Using this sentinel community-based monitoring program as a template, many other such programs have been developed around the world. We will discuss some of those projects as well as their many levels of usefulness to scientists and managers.



Worksheet or Activity

Activity: Take your Coral Watch kit out to the reef and practice being part of a citizen monitoring program.

Activity: Explore the ReefBase website on your own (www.reefbase.org).

Worksheet: “Monitoring and Reporting Bleaching Conditions” in your Bleaching Response Plan

MONITORING AND REPORTING BLEACHING CONDITIONS

The activities in the right-hand column are examples of activities related to monitoring and reporting bleaching conditions. Please modify these as is appropriate for your site. It is important to identify these activities and who will be responsible for conducting them. Choose a back-up who is not likely to be on travel or vacation at the same time as the primary person. Determine the timing of these activities. The Great Barrier Reef Marine Park Authority table of activities is provided on the back of this sheet as an example.

Frequency (e.g. weekly)	Timing (e.g. every Monday)	Person Responsible (also provide back-up)	Activity (modify and fill in other activities as needed)
Routine tasks:			
			Check the NOAA Seasonal Bleaching Outlook
			Check NOAA HotSpot & DHW maps on web
			Receive and review Coral Reef Watch Satellite Bleaching Alert updates
			Review weekly weather summary (e.g., air temp, cloud cover and wind from NOAA NWS)
			Review Coral Reef Watch reports and update maps
			Make use of traditional Hawaiian seasonal prediction tools
			Brief senior management team on weather and heating conditions
			(optional: if you publish bleaching conditions on your website): Summarize weather, sea and coral conditions and draft bleaching risk current conditions report for website. Include recent images. Announce web update and send brief report.
			Monitor extent of bleaching using existing information channels and evaluate for trends
			Advise senior management if dramatic worsening of conditions is evident
			Others:
Responsive tasks:			
			Actively solicit confirmatory bleaching reports from reliable sources, including community monitoring participants, field scientists, tourist/dive operators, etc.
			Alert relevant project coordinators and managers
			Brief senior management
			Brief elected officials
			Prepare media position, draft statement and consult with media coordinator and executive
			Brief all staff, stakeholders and collaborators
			Release media statement
			Actively promote and solicit submissions to online bleaching reports to provide wide spatial coverage
			Implement Bleaching Assessment and Monitoring component
			Others:

MONITORING AND REPORTING BLEACHING CONDITIONS

EXAMPLE: From GBRMPA Bleaching Response Plan

Frequency	Timing	Person Responsible (back-up)	Activity
weekly	Monday		Check GBRMPA ReefTemp and NOAA HotSpot maps on web
			Receive updated Great Barrier Reef sea temperature graphs from AIMS
			Review weekly weather summary, for example air temp, cloud cover and wind from Bureau of Meteorology
			Review BleachWatch (including BleachWatch Aerial) reports and update maps
			Print out ReefTemp and NOAA HotSpot maps for GBRMPA Climate Change Group Director to brief senior management team
Weekly/ fortnightly	Tuesday		Summarise weather, sea and coral conditions and draft bleaching risk current conditions report for website. Include recent images.
Weekly/ fortnightly	Wednes- day		Have updated current conditions report reviewed, approved and published on external web
			Announce web update and send brief report
Weekly/ fortnightly	Constant		Monitor extent of bleaching using existing information channels and evaluate for trends (ie change in bleaching extent)
			Advise GBRMPA senior management team and the Minister for the Environment, Heritage and the Arts if dramatic worsening of conditions is evident
Event- based	High bleaching risk		Actively solicit confirmatory bleaching reports from reliable sources, including BleachWatch participants, Day-to-Day Management field officers, AIMS, other researchers, etc.
			Alert relevant project coordinators and managers
			Brief GBRMPA senior management team
Event- based	Moderate bleaching event detected		Brief GBRMPA executive and the Minister for the Environment, Heritage and the Arts
			Prepare media position, draft statement and consult with GBRMPA media coordinator and executive
			Brief all GBRMPA staff, stakeholders and collaborators
			Release media statement
			Actively promote and solicit submissions to online bleaching reports to provide wide spatial coverage
			Implement Bleaching Assessment and Monitoring component



On-the-Web

Coral Watch (University of Queensland):

www.coralwatch.org

Bleach Watch (Great Barrier Reef Marine Park Authority):

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

Eyes on the Reef, Reef Check Hawaii:

<http://www.reefcheckhawaii.org/eyesofthereef.htm>

Florida Keys Bleach Watch:

<http://isurus.mote.org/Keys/bleaching.phtml>

MesoAmerican Coral Reef Watch Program:

<http://www.marcoralwatch.net/>

Tips for Facilitating this Training Session

Module 5 – Bleaching Response

Focus

This session focuses on monitoring bleaching events and the importance of having a bleaching or disturbance response plan. The presentation includes information about monitoring bleaching, some of the challenges, and protocols available. It also highlights important considerations in developing a bleaching response plan. There are several additional presentations and workbook sections that go further into the various types of monitoring. These are included for your use as appropriate at your site.

Estimated Time

50 minutes – Powerpoint Presentation: Bleaching Response

20 minutes - Discussion

2-3 hours - Group Activity: Developing a Bleaching Response Plan

Seating Arrangement/Group Size

Group Activity – 4-5 students per group max with coach – can group students by geography or mixed – either way works well

Full Session – Up to 25 students (absolute max is 30)

Learning Objectives

By the end of this module students will be able to:

- ④ Understand why we need to assess the ecological impacts of mass coral bleaching.
- ④ Identify bleached corals.
- ④ Assess the geographic extent and severity of a mass bleaching event.
- ④ Understand how bleaching assessments differ to normal monitoring.
- ④ Be prepared to develop a bleaching response plan for their site.

Recommended Reading to Prepare for This Discussion

Read the following sections of the Reef Resilience Toolkit:

- All sections and subsections of *Bleaching Monitoring*
http://www.reefresilience.org/Toolkit_Coral/C6c0_Monitor.html
- *Rapid Response* and associated resources
http://www.reefresilience.org/Toolkit_Coral/C6c2_RapidResp.html
- *A Reef Managers Guide to Coral Bleaching* (in Toolkit and on workshop CDs)
- Supporting resources listed at the bottom of each of the Toolkit pages for these sections

Materials Needed

- Powerpoint Presentation Module 5 (from DVD)
- Student Workbook for Module 5 (from DVD)
- Multi-color markers (5 colors minimum) 1 pack per group
- Flip charts
- Notepad and pen to record decisions made during activity

Handouts Needed (CD)

Monitoring and Reporting Bleaching Conditions
Socioeconomic Considerations
Communications Strategy

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation
- Facilitate a discussion about bleaching monitoring and response plans
- Do group activity – develop bleaching response plan

Activity Instructions: Integrated Response Plan

Instructions: Develop a bleaching response plan for a coral reef area under your management (*i.e.*, the area managed by one group member). You may use the GBRMPA bleaching response plan as a model or create an entirely new approach.

Goal: To begin drafting a bleaching response plan for the participants' area.

Purpose: Pre-planning before a bleaching event allows managers to quickly respond when bleaching happens. It is critical to plan ahead for staffing, funding, communications, monitoring, etc. Having a plan in place should also help managers to gain credibility and political support with reef users and decision-makers.

Think about how you will:

- Predict mass bleaching events
- Set thresholds for declaring mass bleaching
- Assess the ecological impacts of mass bleaching
- Monitor pre-and post-bleaching to identify resilient reef areas
- Assess the socio-economic impacts of mass bleaching
- Communicate about mass bleaching before, during and after the event
- Implement management interventions to increase coral survival during events
- Fund activities called for in the plan
- Staff activities called for in the plan
- Gain support for the plan
- Will your plan address more than bleaching (disease outbreaks, crown-of-thorns, invasive species, storm events, etc.)? If so the same sort of questions as above should be considered for each event.

Record your decision-making process in the notes section so that you can return to this activity in the future. Refer back to the worksheets that you have filled out throughout the workshop to help you through the activity (Monitoring and Reporting Bleaching Conditions, Socioeconomic Considerations, Communication Strategies).

OUTPUT: Draft Bleaching/Crisis Response Plan

****If a current Bleaching or Integrated Response Plan exists, revisit your plan and consider opportunities to integrate information you learned in the workshop to update the plan.**

Guiding Questions:

1. Early Warning System:
 - a. How often should NOAA satellite products be checked?
 - b. Are there Virtual Stations close by, and are you signed up for e-mail alerts?
 - c. Are there volunteers, dive operators, etc. who could be organized for a citizen monitoring system? What about pilots who fly over the reef regularly?
2. Assessment and Monitoring
 - a. Can you do monitoring to try to identify resilient sites ahead of time?
 - b. Who will be responsible for monitoring the extent & severity of bleaching?
 - c. How will the extra monitoring be paid for, or can it be part of regular summer surveys?
3. Communications
 - a. How to do pro-active communications before bleaching occurs—briefing decision-makers, press, etc.—so these groups will be on board if bleaching does happen. Any creative ideas on this from the communications/skit activity?
 - b. What audiences should be contacted at the beginning of the bleaching season?
 - c. What audiences should be contacted if bleaching does occur?
4. Routine Tasks during the bleaching season
 - a. Who will be responsible for keeping an eye on the early warning system?
 - b. Who to communicate with?
 - c. What would trigger a shift to active bleaching response?
5. Responsive tasks if bleaching does occur
 - a. Who will coordinate and carry out monitoring?
 - b. Who to communicate with?
 - c. Are there resources for follow-up surveys to assess mortality, months after the bleaching event?
 - d. Who will analyze the monitoring data to look for resilient areas or places that are more vulnerable to bleaching?

Notes to the Instructor

- Depending on what you are trying to achieve with this module, consider covering it last since the development of a bleaching response plan works best once you have thought through the other pieces (e.g., communication).
- There are several monitoring presentations associated with this training including: Assessing the Ecological Impacts of Mass Bleaching, Assessing Reef Resilience, and Assessing Socioeconomic Impacts. Depending on your needs, you can use any of these. The presentations and workbook sections are provided and you can include or exclude as you see fit.

- For the exercise – depending on your audience and purpose, you can use this to begin developing an actual plan for your geography. If you have the right stakeholders present – you could actually take advantage of this opportunity to get something done. Instead of every group working on a separate plan – consider dividing the group to focus on different aspects of one shared plan.
- The worksheets included here may or may not be filled out previous to this module (depending on the order in which you present the information). If not, then ask participants to review them and fill out prior to developing the plan as many of the pieces of information that would go into a plan are gathered in these worksheets.

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Module 5: Bleaching Response: Assessing Mass Coral Bleaching, Resilience, and Socioeconomic Impacts

Section 1: Assessing the Ecological Impacts of Mass Coral Bleaching

Learning Objectives

By the end of this module you will have:

- ④ An understanding of why we need to assess the ecological impacts of mass coral bleaching.
- ④ The ability to identify bleached corals.
- ④ The ability to assess the geographic extent and severity of a mass bleaching event.
- ④ An understanding of how bleaching assessments differ to normal monitoring.
- ④ In-water experience carrying out a bleaching impact assessment.

Background

In previous modules, you learned about the impacts of climate change to coral reefs and what resilience is and how to identify factors that confer resilience. This module will provide a overview of how to assess the ecological and socioeconomic impacts of mass coral bleaching and how to incorporate resilience into monitoring programs. This section deals with one of the first steps in a response strategy that managers should take when a mass bleaching event occurs. When mass bleaching occurs, managers must rapidly assess the extent and severity of bleaching in order to make timely and effective management decisions and communicate the situation to stakeholders, managers, government departments and the media.

One goal of this section is to provide managers with the skills and knowledge necessary to assess the impacts of bleaching on coral communities and ecosystem processes. Certain reef areas may escape bleaching or may recover rapidly from bleaching due to underlying physical characteristics of the local reef environment or physiological attributes of the coral community present. The occurrence of a mass bleaching event provides managers with an opportunity to identify resilient reef areas, gain an understanding of the underlying causes of resilience, and incorporate these factors into management planning. To that end, another goal of this section is to provide managers with the ability to identify resilient reef areas and incorporate resilience monitoring into bleaching assessment protocols.

When a mass bleaching event occurs, reef users, other stakeholders, the media, and senior government officials will want to know: *'How bad is it? What are the impacts to the reef?'* and *'What will it mean for the local stakeholder community?'* Managers must

rapidly assess the extent and severity of mass bleaching in order to make timely and effective management decisions and communicate the situation to others. This section details a range of methods that can be used by managers, scientists and community members to identify bleaching and assess the extent and severity of a mass bleaching event. Since mass bleaching is transitory in nature, the decision about when to conduct a rapid assessment of bleaching impacts, including which protocol can be best mobilized and used, may have significant implications for the survey results and for any conclusions made from those results.

Experience from around the world during previous bleaching events has led to the development of standard set of strategies that can help with monitoring-related decisions. The World Wildlife Fund (WWF), the WorldFish Centre, and the Great Barrier Reef Marine Park Authority (GBRMPA) have compiled these experiences into *A Global Protocol for Assessment and Monitoring of Coral Bleaching* (can be downloaded from the ReefBase website: www.reefbase.org). The *Protocol* aims to provide detailed guidance for planning and implementing bleaching assessments under a range of resource settings, while ensuring that data are useful and readily integrated into a global database of coral bleaching impacts. These techniques will allow managers to gather sufficient information to report to concerned stakeholders, managers, decision makers, media and the general public.

Ongoing monitoring is also required to document the long-term ecological impacts of mass bleaching and other major disturbances on reef ecosystems. It is necessary to track changes in reef communities over longer timeframes (several years to decades) in order to estimate the probability and rate of recovery, increase the ability to determine the cause of changes in reef condition, and evaluate the effectiveness of management strategies. Maintenance of long-term monitoring programs will enable managers to detect gradual changes in coral community structure that may occur because of bleaching and mortality and to maximize their ability to attribute chronic impacts to particular stresses, including coral bleaching. Monitoring on an annual or semi-annual basis should be complemented with additional surveys timed to detect the occurrence and impact of coral bleaching at long-term monitoring sites. The data from such targeted surveys will help managers determine the relative influence of coral bleaching on the long-term dynamics of coral reef ecosystems.

Coral reef monitoring protocols have been developed for a wide range of skill levels, ranging from *Reef Check* for volunteers, to the comprehensive *Survey Manual for Tropical Marine Resources* developed by the Australian Institute of Marine Science (AIMS) and the Global Coral Reef Monitoring Network for reef scientists and managers. Rather than dictate to managers which assessment protocols should be used, this section highlights the relative benefits and weaknesses of a range of assessment approaches so that managers can make the best choice of methods to be included in a bleaching response plan.



On-the-Web

Bleaching assessment protocols:

Great Barrier Reef Marine Park Authority Coral Bleaching Response Plan:

http://www.gbrmpa.gov.au/data/assets/pdf_file/0020/13169/Coral_Bleaching_Response_Plan_2006-07_Final.pdf

Reef Check Bleaching Monitoring Protocol:

http://reefcheck.org/ecoaction/Monitoring_Instruction.php

Australian Institute of Marine Science – coral bleaching index:

<http://www.aims.gov.au/pages/search/search-coral-bleaching.html>

TNC Florida Reef Resilience Program, Expert Response Protocols

<http://www.nature.org/wherewework/northamerica/states/florida/preserves/art17499.html>

Information and databases:

ReefBase global database on bleaching threats:

http://www.reefbase.org/global_database/default.aspx?section=t4



Publications and References

Oliver, J, P. Marshall, N. Setiasih and L. Hansen 2004 *A Global Protocol for Assessment and Monitoring of Coral Bleaching*. WorldFish Center, Penang, Malaysia and WWF Indonesia, Jakarta. 35 pp.

Siebeck, U. E., Marshall, N. J., Klüter, A. and Hoegh-Guldberg O., 2006 *Monitoring coral bleaching using a colour reference card*. *Coral Reefs* 25: 453-460.

Hansen, L.J., J.L. Biringer and J.R. Hoffman . 2003 *Buying Time: A User's Manual to Building Resistance and Resilience to Climate Change in Natural Systems*.

http://www.panda.org/news_facts/publications/index.cfm?uNewsID=8678

Section 2: Assessing Reef Resilience

Learning Objectives

- 🌐 Knowledge of the reef characteristics that may promote resilience to bleaching.
- 🌐 The ability to use bleaching events to identify resilient reef areas.
- 🌐 Understand resilience protocols that are available for you to use and modify
- 🌐 Understand the importance of incorporating resilience monitoring into your traditional monitoring practices.

Background

The severity of bleaching responses varies between reefs during mass bleaching events. Identification of areas that have historically had high resilience to bleaching provides the basis for a network of refuges to underpin resilience-based management of the reef ecosystem. Refuges serve as a seed bank to facilitate the recovery of areas with lower natural resilience, and will play a central role in networks of protected areas designed to maximize ecosystem resilience. The identification of resilient areas as an ecosystem management strategy is already being applied in various locations around the world. The experiences gained from these initiatives will help to refine knowledge and develop additional protocols for the identification of resilient areas. The outcomes of these early tests of resilience management strategies will also provide important information about the extent to which the factors that confer resilience on an area will remain consistent over time. As managers, you too can contribute to this knowledge through incorporating resilience monitoring into bleaching monitoring protocols.

Recently the IUCN has been working on a rapid resilience assessment protocol. The following information comes from the *IUCN Resilience Assessment of Coral Reefs: Rapid assessment protocol for coral reefs focusing on coral bleaching and thermal stress*. The need for rapid methodologies for measuring coral reef resilience and their application in assessing the effectiveness of coral reef conservation management measures is becoming increasingly acute, and especially so in the developing world. It is therefore crucial to develop monitoring and assessment protocols to build an understanding of bleaching resistance and resilience indicators for application in management, and to determine how MPA management actions can influence resilience and resistance. The IUCN Resilience Assessment Methodology is designed to provide a rapid assessment of coral bleaching resistance and resilience at an individual site level. This is intended to facilitate assessment of any past management actions in maintaining the resilience of coral reefs, and the making of new management decisions against local MPA objectives.

Specifically, the protocol is intended to:

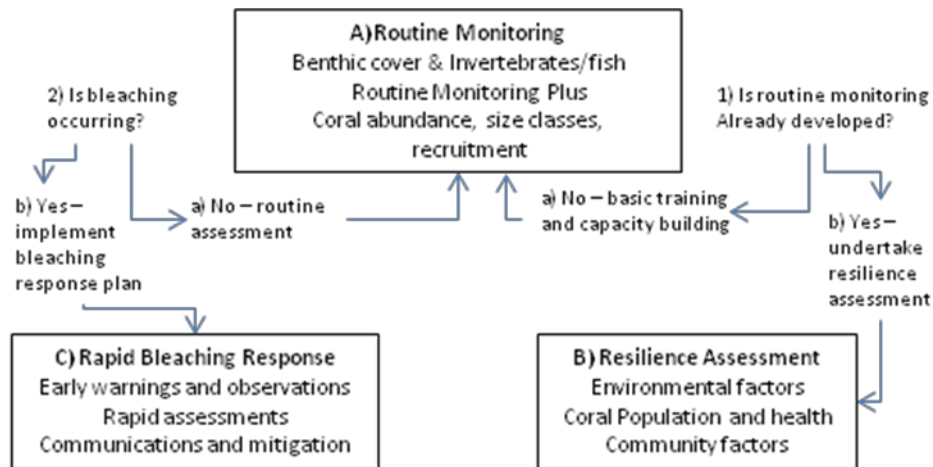
- 1) Assess the factors affecting coral bleaching during a bleaching event (resistance factors).
- 2) To assess the factors affecting coral and reef recovery following a bleaching event (resilience factors).
- 3) Enable between-site comparisons at a local area/region/MPA (network) level.
- 4) Enable inter-regional comparisons at larger scales.

In a management context, the protocol should facilitate:

- 5) Building an understanding of bleaching resistance and resilience factors that can be addressed by MPA design and management.
- 6) Assessing whether MPA design and management practices to date have addressed bleaching resistance and resilience.
- 7) Designing networks of MPAs based on bleaching resistance/resilience characteristics.
- 8) Providing information to adaptively manage coral reefs in response to bleaching events and reef resilience.

While the assessment protocol can be undertaken as an independent study, it is most useful in an adaptive management structure that already incorporates annual or routine monitoring. Thus routine monitoring (A) provides background time series information on a limited set of variables that track coral reef status and function over time. Where the concern is about the effects of coral bleaching, this resilience assessment is designed to be undertaken to increase understanding of the resistance and resilience of reefs to bleaching, whether a bleaching event has occurred in the past or not (B).

This need be done only once, then again after a long period (e.g. 5 years) or after a major event (e.g. bleaching, or other major pulse stress such as a cyclone, COTs outbreak, etc.) to determine whether the reef has been shifted into another phase. During a bleaching event, a separate monitoring approach is applied focused just on bleaching variables, designed to be repeated over short periods of time (e.g. monthly) to track the actual event (C).



Nested approach to monitoring resilience, building additional resilience indicators onto routine monitoring approaches (step 1b). During a bleaching event (step 2b) a subset of resilience indicators would be included in bleaching assessment protocols (Oliver et al. 2004). (Source: *IUCN Resilience Assessment of Coral Reefs: Rapid assessment protocol for coral reefs focusing on coral bleaching and thermal stress*)

The Resilience Assessment Methodology will be available in a publication from IUCN which includes survey design, field methods to assess coral condition, algae, fish and resilience factors and well as data management and analysis.

The IUCN is just one protocol of many that is available. In the Caribbean region the Atlantic and Gulf Rapid Reef Assessment (AGRRRA) protocol is widely used and there may be other protocols designed for your areas.

The Nature Conservancy Reef Resilience (R²) Toolkit, on which portions of this workshop are based, provides a good review of the resilience principles for and incorporating resilience into coral reef management. We will discuss the incorporation of resilient areas and into MPA design in a later module. Broader guidance beyond MPA design for increasing reef resilience can also be found in the Tropical Marine chapter of *Buying Time* which can be found at <http://assets.panda.org/downloads/6chapter6.pdf>.



On-the-Web

Florida Reef Resilience Program: www.frrp.org/

TNC Reef Resilience Toolkit: www.reefresilience.org

Atlantic and Gulf Rapid Reef Assessment Protocol: www.aggra.org

IUCN Resilience Assessment of Coral Reefs:

http://cmsdata.iucn.org/downloads/resilience_assessment_final.pdf



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Nyström, M., and Folke, C. 2001. Spatial resilience of coral reefs. *Ecosystems* 4: 406–417.

Section 3: Assessing and Predicting Socioeconomic Impacts of Climate Change

Learning Objectives

- ④ An understanding of the why we need to assess the socioeconomic impacts of mass coral bleaching and climate change.
- ④ An understanding of the potential socioeconomic impacts of coral bleaching and mortality, as well as other impacts from climate change.
- ④ The ability to identify impacted populations.
- ④ An understanding of the steps necessary to undertake a socioeconomic assessment.
- ④ An understanding of developing and using scenarios in vulnerability and adaptation assessment
- ④ Heard about several case studies to illustrate results of previous socioeconomic assessments in Philippines, Palau, American Samoa, Bonaire, Barbados, and the Western Indian Ocean.

Background

Climate change impacts on coral reef ecosystems may also have subsequent flow-on effects for coastal communities who depend on reefs for a range of ecosystem goods and services. When corals bleach, impacts occur not only to ecological communities but also to the human communities who depend upon coral reefs for income, food from fisheries, revenue generation from tourism, recreation, cultural traditions, and educational opportunities. If corals recover from bleaching events, these impacts may be temporary. However, if corals die as a result of bleaching, impacts may be longer-term and more severe. Ironically, social, cultural, and economic impacts can also occur as a result of management interventions aimed at promoting coral reef resilience to climate change.

Managers need to understand the relationship of the communities with the coastal and marine resources. At the same time, they need to find out how climate change and management decisions related to climate change will impact the socioeconomic aspects of communities who depend upon reefs so that they can design and implement strategies that will meet both environmental and socioeconomic needs. This section aims to provide managers with basic knowledge of the components of a socioeconomic assessment and ways to perform assessments. In the following section we will discuss some specific manuals available that outline the steps for socioeconomic assessment, and for developing of socioeconomic scenarios for vulnerability and adaptive assessments. Several case studies have been provided to illustrate how other communities have undertaken such assessments and the outcomes of these assessments. These case studies show how difficult it can be to separate out the socioeconomic impacts of bleaching from impacts from concurrent events, such as regional economic downturns, weather events, or

other stresses on corals. This section aims to incorporate socioeconomic monitoring into bleaching assessment protocols.

Reef managers, policy-makers, and communities that understand the relationships people have with the adjacent coral reefs will be able to better identify both the impacts of a mass bleaching event and any impacts associated with management strategies. This knowledge can be used to design management strategies that maximize environmental outcomes while minimizing negative impacts on people. Specifically, impact assessments can:

- Identify the potential social and economic impacts of mass bleaching;
- Integrate local knowledge with technical expert knowledge;
- Evaluate the social and economic costs and benefits of various coral bleaching management strategies; and
- Increase public involvement in the monitoring of coral bleaching.

Given how difficult it can be to separate the socioeconomic impacts of bleaching from impacts from concurrent events, some communities may wish to undertake general economic valuation studies for their coral reefs, which could be used to derive impacts from bleaching with a small amount of additional data collection. These valuation studies can also be used as a baseline from which to measure socioeconomic impacts of bleaching and other damaging events.

In addition to impacts from coral bleaching, climate change and variability will catalyze other impacts as well. In the Pacific island region, the current most visible impacts from climate change also include sea level rise, inundation, salt water intrusion, and coastal erosion. Climate change is having increasingly impacts on livelihood, food security, infrastructure, human health, and the most important economic bases of the Pacific islands, namely fishery, agriculture and tourism. Quantification of these impacts to the tourism industry has been attempted in several cases, with significant economic consequences predicted for climate change.

Worksheet or Activity

Worksheet: Socioeconomic Considerations in your Bleaching Response Plan

Activity 3: Selecting Socioeconomic Indicators

SOCIOECONOMIC CONSIDERATIONS

It is important to consider the impacts to human users of coral reefs from climate change and coral bleaching. These will have both direct impacts, from the bleaching itself, especially when there is coral mortality, and indirect impacts from management measures intended.

Use this table to identify populations who may be affected by major coral bleaching events. These impacts will be important to report to the media and to elected officials. It is also important to understand up front the economic impacts of certain management measures (e.g. dredging bans during bleaching events).

Type of event	Populations who may be affected by bleaching (e.g. dive operators, fishermen, women harvesting at low tide)	Type of impact (social, cultural, economic)	Actions that may lessen impacts (examples: pre-bleaching warnings, economic mitigation, etc)
Direct impacts			
Moderate bleaching	1.		
	2.		
	3.		
Severe bleaching	1.		
	2.		
	3.		
Post-bleaching coral mortality	1.		
	2.		
	3.		
Indirect impacts			
Fishing restrictions	1.		
	2.		
Recreational use restrictions	1.		
	2.		
Restrictions on coastal development/ dredging	1.		
	2.		
Other:			

Activity 3: Defining socioeconomic assessment objectives and selecting relevant socioeconomic indicators

Given scenario: A coastal community of 10,000 people experiencing the following impacts:

- Climate: Rising sea surface temperature
- Biological impacts: Mass coral bleaching, coral mortality, decreasing abundance and availability of fish stocks
- Physical impacts: Weaken reef structure, more exposure for coastal erosion during storm surge events

Your tasks:

1. Define your socioeconomic assessment objectives:

2. From the examples of socioeconomic indicators presented in the Powerpoint presentation, select ones that are relevant and appropriate for the above objectives. Propose a data collecting method for each of the selected indicators. The methods include secondary sources, household survey, key informant interview, focus group discussion, and observation.



Socioeconomic assessment tools:

Global Socioeconomic Monitoring Initiative (SocMon):

<http://www.reefbase.org/socmon/>

Locally Managed Marine Areas Network (L MMA): <http://www.lmmanetwork.org>

Malone, Elizabeth L., Joel B. Smith, Antoinette L. Brenkert, Brian Hurd, Richard H. Moss, and Daniel Bouille. 2004. Developing Socioeconomic Scenarios for Use in Vulnerability and Adaptation Assessments. New York: UNDP.

<http://ncsp.undp.org/docs/653.pdf>.

Mersai, Charlene T and Craig J. Severance. No date. Introductory Handbook for Biological and Social Monitoring of MPAs in Palau. Koror: Palau International Coral Reef Center.

Nakalevu, Taito. 2006. CV&A : A Guide to Community Vulnerability and Adaptation Assessment and Action. Apia, Samoa : South Pacific Regional Environment Programme (SPREP). http://www.sprep.org/att/publication/000437_cvaguidee.pdf

Wongbusarakum, S. and R. Pomeroy. 2008. Socioeconomic Monitoring Guidelines for Coastal Managers in Pacific Island Countries. Silver Spring: National Oceanic and Atmospheric Administration; and Apia, Samoa: Secretariat of Pacific Regional Environment Programme. http://www.reefbase.org/socmon/pdf/SocMon_Pacific.pdf

World Wildlife Fund. 2007. Climate Witness Community Toolkit. Suva, Fiji: World Wildlife Fund-South Pacific Programme.

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<http://marineeconomics.noaa.gov/Reefs/HICesar.pdf> Accessed on April 24, 2008.

Socioeconomic Monitoring Program for the Florida Keys National Marine Sanctuary - Recreation/Tourism: <http://marineeconomics.noaa.gov/SocmonFK/Linking.html>

Valuing the Environment in Small Islands - An Environmental Economics Toolkit

<http://www.incc.gov.uk/page-4065>

World Resources Institute (WRI) Economic Valuation of Coastal Ecosystems in the Caribbean: <http://www.wri.org/project/valuation-caribbean-reefs>



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United States Agency for International Development. 2007. *Adapting to Climate Variability and Change: A Guidance Manual for Development Planning*. Washington D.C.
http://www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamannual.pdf

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Van Beukering, P., editor. *The economic value of the coral reefs of Saipan, Commonwealth of the Northern Mariana Islands*. February 2006. Prepared by Cesar Environmental Economics Consulting under contract to the National Oceanic and Atmospheric Administration.

Van Beukering, P., editor. *The economic value of Guam's coral reefs*. March 2007. University of Guam Marine Laboratory Technical Report No. 116.

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Section 4: Developing a Bleaching/Crisis Response Plan

Learning Objectives

In this module you will be developing bleaching response plans for your reef that will enable you to:

- ② Predict Mass Bleaching
- ② Set thresholds for declaring mass bleaching
- ② Assess the ecological impacts of mass bleaching
- ② Assess the socioeconomic impacts of mass bleaching
- ② Communication about mass bleaching before, during, and after the event
- ② Implement management interventions to increase coral survival during events
- ② Fund activities called for in the plan
- ② Staff activities called for in the plan
- ② Gain support for the plan you have developed

Background

In order to respond effectively and quickly to mass bleaching events and the impacts of climate change, managers need a plan. At its most basic level, the plan should identify the goal of the response, specific steps that will be taken to meet the goal, and resources required to implement the response. Plans should also take into account available resources, staff capacity, management authority, and the characteristics of local reef systems. The Great Barrier Reef Marine Park Authority (GBRMPA) Bleaching Response Plan provides a good example. The plan includes procedures for prediction, ecological assessment, and communication of mass bleaching impacts.

Routine tasks occur throughout the summer, whether or not there is bleaching. For example, routine tasks include monitoring environmental conditions and frequently assessing the bleaching risk. Responsive tasks are only implemented if a bleaching event occurs. Responsive tasks include rapid assessment of ecological impacts and increased communication with senior managers and the media. Because it can be difficult to decide exactly when a bleaching event has started, the GBRMPA plan outlines specific thresholds that trigger each type of responsive task. For example, when bleaching thresholds are exceeded at multiple sites, an aerial survey is undertaken to determine the extent and severity of bleaching. Strategic tasks may be taken at any time to strengthen a bleaching response or support long-term coral reef resilience. Strategic activities can include: building capacity, securing funding, raising awareness, developing professional networks to exchange information, establishing policies that support bleaching response, or protecting/restoring factors that confer resilience to the system.



Activity

Activity 5: Developing a Bleaching Response Plan

Developing Bleaching/Crisis Response Plans

Develop a bleaching response plan for a coral reef area under your management (*i.e.*, the area managed by one group member). You may use the GBRMPA bleaching response plan as a model or create an entirely new approach. Use the worksheets that you have been filling out through out the workshop to help you with the different components of the plan.

- *Work in groups of approximately four people*
- *Use flipcharts*
- *You have a set amount of time to develop the plan*
- *You will be reporting back to the main group at the end of the exercise*

Think about how you will:

- Predict mass bleaching events
- Setting thresholds for declaring mass bleaching
- Assess the ecological impacts of mass bleaching
- Assess the socio-economic impacts of mass bleaching
- Communicate about mass bleaching before, during and after the event
- Implement management interventions to increase coral survival during events
- Fund activities called for in the plan
- Staff activities called for in the plan
- Gain support for the plan

Sharing Bleaching/Crisis Response Plans

In this exercise, you will share your bleaching response plans that you have developed with the rest of the workshop group.



On-the-Web

Great Barrier Reef Marine Park Authority Bleaching Response Plan:

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



Publications and References

Maynard, J.A., J.E. Johnson, P.A. Marshall, C.M. Eakin, G. Goby, H. Schuttenberg, and C.M. Spillman. A Strategic Framework for Responding to Coral Bleaching Events in a Changing Climate. *Environmental Management* DOI 10.1007/s00267-009-9295-7.

Woodley, C.M., Bruckner, A.W., McLendon, A.L., Higgins, J.L., Galloway, S.B. and Nicholson, J.H. 2008. *Field Manual for Investigating Coral Disease Outbreaks*. NOAA Technical Memorandum NOS NCCOS 80 and CRCP 6. National Oceanic and Atmospheric Administration, Silver Spring, MD 85pp.

Tips for Facilitating this Training Session

Module 6 – Management

Focus

The most fundamental piece of the Reef Resilience model is effective management. Maintaining healthy coral reef communities is the first line of defense against any major or minor disturbance. Corals that are already under stress are at a greater disadvantage when facing additional stressful conditions, such as elevated sea temperatures. Therefore, if managers are faced with limited choices in terms of steps to take in the face of rising sea temperatures, reducing all other threats should be the priority.

Estimated Time

45 Minutes – Powerpoint Presentation

100 minutes – Resilience Management Group Activity

Seating Arrangement/Group Size

Full session, maximum of 25-30 students

Group Activity – 4-6 students

Learning Objectives

By the end of this module you will:

- ② Review and discuss resilience-based management action options
- ② Understand the mechanics of a resilience assessment and how to use the results to prioritize and target action options.
- ② Understand the term socio-ecological resilience
- ② Be able to incorporate resilience monitoring into a bleaching response plan
- ② Learn how to incorporate the concept of socio-ecological resilience into coral reef management
- ② Heard about examples of integrating social-ecological resilience into management in Marshalls, American Samoa, Kenya and Papua New Guinea.
- ② Understand that managers can do something locally to respond to mass bleaching events
- ② Understand coral reef “triage” and restoration options available for MPA managers to implement in response to severe mass coral bleaching
- ② Understand a range of short-term, local strategies for coral bleaching management:
- ② Understanding of the considerations for assessing whether restoration intervention is a viable strategy.
- ② Understand a range of options for restoration intervention

Recommended Reading to Prepare for This Discussion

http://www.refresilience.org/Toolkit_Coral/C6_Managing.html

Materials Needed

- Powerpoint Presentation from CD for Module 6
- Student Workbook for Module 6
- Flip charts and pens to record any discussion following the presentation

Handouts Needed (on CD)

- Participant Worksheet for Resilience Management Activity

General Guidance for Carrying Out a 45-minute session

- Introduction: Introduce yourself and the topic starting with describing how we move from learning about social and ecological resilience to integrating them into management practice
- Discussion: Engage the full session in a discussion. Write down on a flipchart the participants definitions of 'socio-ecological' resilience. Then ask them to give you definitions for the two components and record them on the chart. Ask them if social and ecological resilience are linked in any way. Finally, ask them to come up with one definition that covers both social and ecological resilience.

Additional Resources

-Reef Resilience Toolkit:

http://www.reefresilience.org/Toolkit_Coral/C1b0_DefResil.html

-'Reef Restoration Concepts and Guidelines: Making sensible management choices in the face of uncertainty.' World Bank Report (www.gefcoral.com)

Activity Instructions- Resilience Management Activity: Resilience and coral reef management decision-making

PART 1: IDENTIFYING ACTION OPTIONS (50 MINS)

Activity Description

- Give the participants 5 minutes to brainstorm on their worksheet
- Ask your group to identify the sorts of actions that managers can take to support the natural resilience of reef systems.
- Work to help them identify the high-level actions
- Almost all of the actions they'll identify will fall into one of the following categories but few groups will identify all of these so you'll need to guide discussions somewhat and ask questions that trigger people to mention any of these they didn't say before you prompted them.

Below are some questions to help guide the group if needed:

1. *When designing a marine park you can consider representation and replication, critical areas as well as connectivity, and once the park is established you can work to manage it effectively (the TNC resilience model).*

Explore with your group why this is so important in a climate change context – uncertainty is the key to the answer.

2. *High resilience sites are likely to be critical areas (they'll recover fastest and can be sources of larvae to other disturbed sites) so managers can preferentially protect these sites when designing parks.*

Your group will recognize this requires being able to identify those sites but you'll review that with them.

3. *You can target an action to a site that has high resilience (to any site, really) but is being impacted by an anthropogenic stressor that managers can work to reduce.*

This also requires an assessment of differences in relative resilience as well as local knowledge of where each type of human stressor is most severe and how likely it will be (politically/socially) that an action could be implemented at a site. There will always be the political and social considerations so don't feel you need to over-simplify this; let the discussion evolve and encourage people to recognize that identifying resilient sites needs to be paired with an assessment of anthropogenic stress in an area. From there (and this is not included in the activity below), it's useful to think about feasibility. The stressor reducing resilience that's feasible for managers to address (because of the legislation or because it won't anger certain stakeholders) represents a key priority.

4. *You can implement an action that reduces a stress of all of the sites in the area.*

A case study of great relevance that you can discuss here is the RWQPP of 2003 in the GBR. Water quality will be the key stressor here, but it might be useful to turn discussions towards tourism once you touch on water quality. Tourism is rife on the reefs throughout much of the Florida Reef tract. How tourism is managed can affect reef health at many sites in the same way that water quality does.

5. You can communicate about the concept of resilience in ways that changes people's behavior either in the managed area (while visiting reefs) or at home.

We will discuss more on communication later this afternoon. Including people in resilience assessments can be useful; as we know from engaging with industry in the Keppel Islands. Communication efforts that connect people – like the ‘living on the reef’ campaign done by GBRMPA can also engage and empower people to take some action themselves.

6. You can use the coral reef plight to agitate for policy change on emissions.

In the arena of communicating about climate change impacts on ecosystems, no other system has had the profile that coral reefs have enjoyed these last 10 years. Many in your groups may mention that it hasn't made a difference, which is really only partly true. We all need to continue to raise awareness of what our actions (i.e., our polluting ways) mean for the environments we live in, love, and depend on. Without an increased (and ongoing) understanding of the consequences of inaction, no formative action will ever be taken at the scale required to either stabilize or reduce emissions outputs.

This list is not necessarily exhaustive and it's certainly true that not all managers or management agencies/authorities will have all of the options listed above available to them. Management groups in different location (i.e., reef regions) would prioritize the action options differently.

PART 2: ASSESSMENT, PRIORITIZING AND TARGETING ACTIONS (50 MINS)

General Notes:

First, stress up-front that you don't need a guaranteed path to implementation (i.e. implementing any of the sorts of actions described above) in order to justify undertaking a resilience assessment.

Background on resilience assessments: In short, people need to understand that resilience 'scores' are the result of the measurement and assessment of a list of factors that are linked to components of resilience, namely resistance and recovery. Scores for these factors are averaged to produce the resilience score and sites are ranked from highest to lowest score. Turn people onto West and Salm (2003), Obura and Grimsditch (2009) and Maynard et al. (2010) [references below] for further reading on this topic. Hopefully, at this point in the workshop all have learned that there's been a lot of recent movement in this working area and that new/revised protocols to assess coral reef resilience are forthcoming.

Activity Description:

Explain to your group that they'll review a mock resilience assessment which shows the resilience score for 10 fictional reefs, and pairs the resilience scores for those sites with an assessment of anthropogenic stress

Good scores for stress means low stress, shown in green; low scores means high stress, shown in red.

Having this knowledge ensures managers can implement actions categorized as numbers 2, 3 and 4 above (participants may number them differently so re-stress the sorts of actions managers will be able to implement with this knowledge in hand).

It's critical to highlight the divergence between reef condition (e.g., coral cover) and reef resilience (recovery potential). Reef condition or state, depending on when the site was last disturbed, may tell you very little about a site's resilience.

Ask your group to use their worksheet and review the matrix and the map.

Ask them the Activity questions (see all questions and answers on following pages)

Notes that could help guide discussions:

We have learned that people's first reaction is often to try to tear apart the map and matrix, as if it's something that needs to be criticized. It's *fictional* and developed solely as a conceptual example that builds capacity. Ask them to focus on the questions primarily and then to take the discussion from there and apply it to their own work. Also, you may have to explain to people that this mock system is like many reef systems in the world in that it is assumed reliable information on connectivity is not available.

However, people could draw some arrows on their maps and discuss amongst themselves how (/whether) their decisions would be different if information became available on connectivity. The most useful potential example is that a medium resilience site is very well connected 6 or 7 of the 10 sites but the highest resilience site is completely isolated (this is actually possible the way resilience scores are calculated). If this were the case you may de-prioritize the high resilience sites. But, of course, if you do go down this road people will make clear that there might be something about that site that make it unique or otherwise give it conservation significance (so maybe it would still be prioritized). All of that is food for thought and coaches should keep it in mind but every

group's discussion will be slightly different and not all will want to drive it down the road of thinking about what connectivity would mean for the mock assessment.

Questions:

1. How many sites have high, medium, and low resilience, according to this assessment?

Four high, four medium, and four low.

2. What action could be taken that would increase the resilience of all sites?

All sites have either a high or medium score for water quality so water quality could be improved at all sites.

3. If only two sites could be protected, which two would you choose?

There will be differing perspectives here and people may start to steer away from resilience; i.e., what information isn't in this table that could be important (stakeholder use, cultural significance, level of endemism, biodiversity, etc.)? That question is coming up so stick with resilience at first. Most of this brief discussion should focus on protecting the sites with high resilience, either the two sites with the highest resilience could be protected or, better, the sites ranking 1st and 3rd could be protected since a no-take area won't fix the sedimentation problem at the site ranked 2nd – *this illustrates the importance of identifying sites where management actions can make a difference to resilience.*

Some may argue that it would be better to protect the two low resilience sites. This is a very interesting debate but it certainly has the potential to confuse people. There are some notes here so that all coaches can guide this discussion but if it doesn't go this way then this might be too much detail (or too confusing) for some participants.

Eddie Game and some others from the lab where he did his PhD (Game et al. 2008) came up with a useful stats-based approach to determining 'whether to protect the strong or the weak'. The long and short of their recommendations is this, and assumes your objective is to maximize the number of healthy sites in your management area:

You protect the strong sites if you expect your sites to spend most of your time in a degraded state.

You protect the weak sites if you expect your sites to spend most of your time in a healthy state.

So, for some types of management actions (where you hope to see results in 10-15 years) you might 'protect' (this could mean a lot of things) weak sites. But, evidence is increasing that it takes a long time for the benefits of MPAs to be reaped. And, we expect coral reefs to become increasingly degraded towards the middle of this century.

So, in light of that, there's a stronger case to protect the high resilience sites than the low resilience sites.

4. If the four sites with high resilience are already protected as no-take areas, what could managers do to further increase the resilience of these sites?

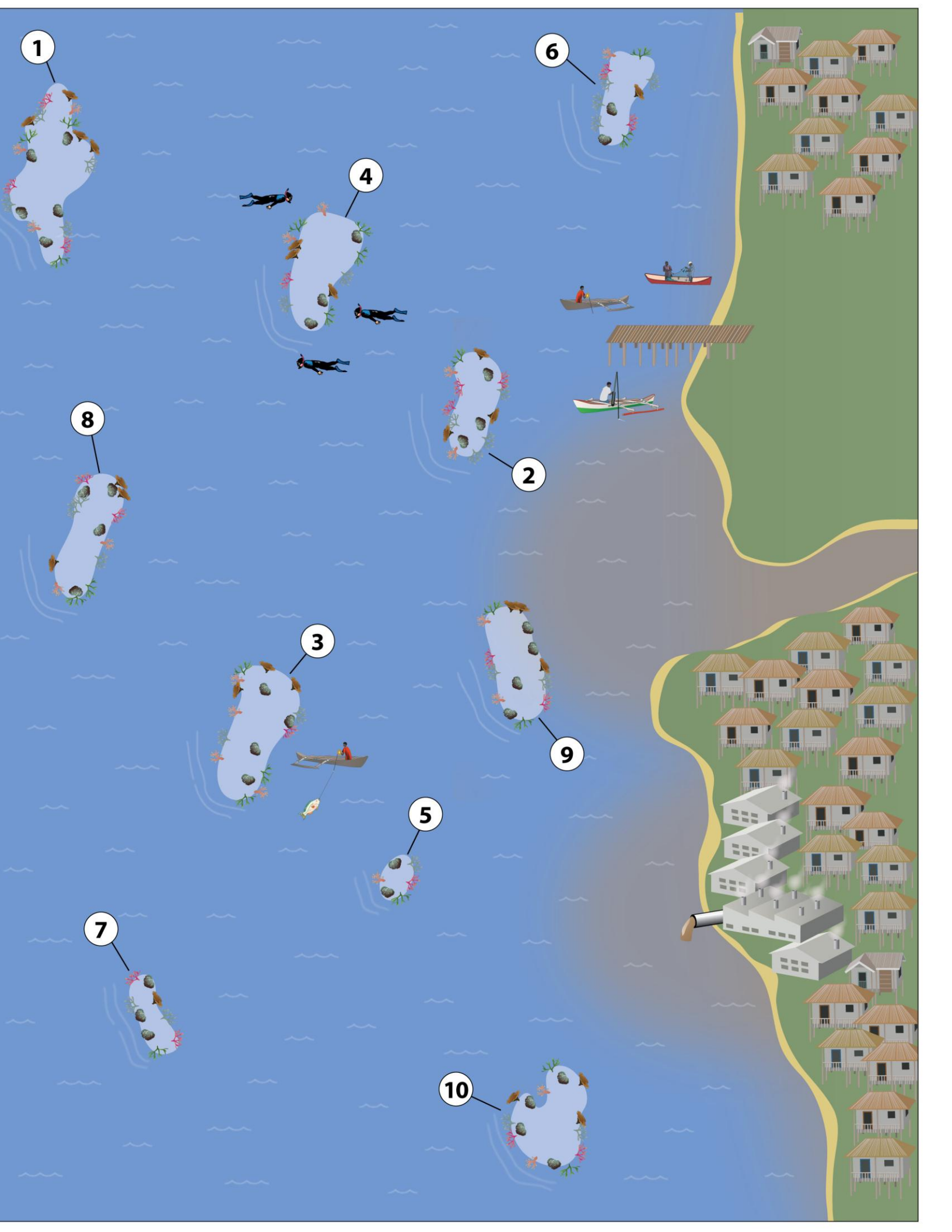
Each of these four sites has a stressor that managers could potentially reduce by either limiting or changing the nature of resource use. Coastal development could be limited near one site to reduce sedimentation (Rose Reef), one might have an acute water quality problem (Plumeria Reef), herbivores are being targeted at one site (Lily Reef), and anchoring damage is severe at another (Tulip Reef). Spend a few minutes talking about Tulip Reef. Make the case that this site is really valuable to tourism operators as it is beautiful and close to a major port. Anchoring impacts there could be preventable...perhaps sites like this can be managed better? All participants will know of sites in their area where that story is relevant. Sunscreen use and fin damage may also come up in discussions with regulations and snorkel trails being potential remedies.

5. What important descriptors of a site's conservation value are ignored by a resilience assessment like the one presented? How could or should this information be included in the decision to protect some of these sites?

Biodiversity, high density of endemics, cultural value, or high commercial value of some sort – those should be at least some of the answers to the first question just above. The second is trickier; it depends on local politics. The general thrust of the discussion should be that resilience provides an extremely useful framework upon which to make reef management decisions but it isn't the only important information. Resilience has to be considered in light of other values and goals of the management group. And, community/stakeholder interests and perspectives are always going to be critical to consider when making decisions that affect resource use.

	Rank	Resilience Score	Water quality	Anchoring	Herbivore abundance	Fishing pressure	Sedimentation	Anthropogenic stress score
Plumeria Reef	1	4.2	2	5	4	5	5	4.2
Rose Reef	2	4.05	3	4	4	4	1	3.2
Lily Reef	3	3.72	2	4	2	2	4	2.8
Tulip Reef	4	3.65	3	1	4	4	4	3.2
Iris Reef	5	3.39	1	4	5	4	4	3.6
Gerbera Reef	6	3.24	3	3	3	2	3	2.8
Violet Reef	7	3.17	2	2	2	3	5	2.8
Poinsettia Reef	8	2.89	3	3	3	3	4	3.2
Orchid Reef	9	2.56	2	1	1	2	3	1.8
Daisy Reef	10	2.12	2	3	2	3	4	2.8

Sites are ranked by resilience score. The resilience assessment suggests that the sites with high scores are likely to be more resilient to disturbances than other sites. The resilience score *does not* include the stressors to reefs that managers can reduce by implementing actions/strategies that either limit or change the nature of resource use (*these are considered separately*). Importantly though, those stressors related to human activities (which are averaged to produce the anthropogenic stress score) are reducing each site's resilience (if scores for the stressor are low). Cells are green if the resilience score is high or if the score for a human impact is high (either a 4 or 5), which means that impact is limited or does not occur at the site. Yellow and red refer to medium (3) or low (1 or 2) scores meaning that a site is being impacted by a human activity.



1

6

4

8

2

3

9

5

7

10

Notes for coaches on the map: The numbers labeling the reefs match the resilience rankings from the matrix. The matrix and the map mostly overlap nicely – reefs close to communities are heavily fished, reefs very close to the river have sedimentation issues, anchoring occurs at the tourism site, and there aren't many herbivores at the site where you can see a bloke pulling a parrot out of the water. Participants may find it confusing that water quality in this mock assessment isn't only driven by the port, river and industry. There are no high scores for water quality. The high resilience site has poorer water quality than sites nearer to shore. That might feel unrealistic to some but discourage people from focusing on that; there are many local-scale drivers of water quality that you don't get a handle on by determining the proximity of sites to point-source type pollution (like a lack of local mixing). Above all, what you want people to see is that each reef in this example has a different resilience score and a different myriad of human-related stressors – **that** is very realistic.

References

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- Maynard JA, Marshall PA, Johnson JE, and S Harman (2010) Building resilience into practical conservation: identifying local management responses to global climate change in the southern Great Barrier Reef. *Coral Reefs* 29(2): 381-391.
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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:

- ② Understand the term socio-ecological resilience
- ② Be able to incorporate resilience monitoring into a bleaching response plan
- ② Learn how to incorporate the concept of socio-ecological resilience into coral reef management
- ② 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 managers perceive that these concepts may work in their respective regions.



On-the-Web

Reef Resilience R² Toolkit: <http://www.reefresilience.org/>



Publications and References

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International Coral Reef Initiative Statement on Coral Reefs and Climate Change
http://www.icriforum.org/library/Reso_CC_Tokyo_0407.pdf

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management: key findings & recommendations. Conference proceedings of the International Tropical Marine Ecosystem Management Symposium 2006, Cozumel, Mexico. http://www.itmems.org/itmems3/pr_resilience.html

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<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:

- ② Understand that managers can do something locally to respond to mass bleaching events
- ② Understand coral reef “triage” and restoration options available for MPA managers to implement in response to severe mass coral bleaching
- ② 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
- ② Understanding of the considerations for assessing whether restoration intervention is a viable strategy.
- ② 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



Publications and References

Edwards, A.J. Gomez, E.D. (2007). *Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty*. Coral Reef Targeted Research & Capacity Building for Management Programme: St. Lucia, Australia. iv + 38 pp.

(www.gefcoral.org)

Precht, William F. 2007. *Coral Reef Restoration Handbook*. Taylor & Francis Group, U.S.A.; 2006. 384 p. (ISBN 0849320739)

Contact: George Kenney, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Boca Raton, FL 33487; Phone: 561-998-2544, Fax: 561-998-9784,

george.kenney@taylorandfrancis.com

Causey, Billy D. Ph.D. 2007. **Climate Change: What Can Coral Reef Managers Do To Address Coral Bleaching?** Draft manuscript in review, (Clive Wilkinson). Florida Keys National Marine Sanctuary, 33 East Quay Road, Key West, FL 33040, USA.

billy.causey@noaa.gov

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Okamoto, Mineo; Satoshi Nojima, Yasuo Furushima and William C. Phoel. 2005. *A basic experiment of coral culture using sexual reproduction in the open sea*. Fisheries Science, 71:263-27

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

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

Wilkinson, C., Souter, D. (2008). *Status of Caribbean Coral Reefs after bleaching and hurricanes in 2005*. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, 152 p. (ISSN 1447 6185)

Available for download from:

http://www.coris.noaa.gov/activities/caribbean_rpt/
www.gcrmn.org

Tips for Facilitating this Training Session

Module 7 – Communicating Climate Change, Coral Bleaching, and Resilience

Focus

This session focuses on how to communicate complex problems such as climate change and coral bleaching, as well as how to explain reef resilience and the need for a resilience-based approach. It highlights the communication challenges and some rules of thumb that will improve your communication approach. The presentation includes options for examples that you can choose according to your audience. It also includes options for hands-on activities to best suit your group.

Estimated Time

40 minutes – Powerpoint Presentation: Communicating Climate Change, Coral Bleaching, and Resilience

20 minutes - Discussion

90 minutes - Group Activity: Communication Campaign or Communication Plan

30 minutes – Group Presentations (if Communication Campaign option is chosen)

Seating Arrangement/Group Size

Group Activity – 4-5 students per group max with coach – can group students by geography or mixed – either way works well

Full Session – Up to 25 students (absolute max is 30)

Learning Objectives

By the end of this module students will be able to:

- ② Understand why we need to communicate about the impacts of climate change to coral reef ecosystems
- ② Identify different audiences and think about how to tailor communication strategies to target each audience
- ② Identify innovative ways others are communicating to the public and stakeholders

Recommended Reading to Prepare for This Discussion

Read the following sections of the Reef Resilience Toolkit:

- All sections and subsections of *Communicating Resilience*
http://www.reefresilience.org/Toolkit_Coral/C7_Communicating.html
- Supporting resources listed at the bottom of each of the Toolkit pages for these sections
- Communication Examples for:
Papua New Guinea
http://www.reefresilience.org/Toolkit_Coral/C7d1_Example1.html
Guam http://www.reefresilience.org/Toolkit_Coral/C7d2_Example2.html
Australia http://www.reefresilience.org/Toolkit_Coral/C7d3_Example3.html

Materials Needed

- Powerpoint Presentation Module 7 (from DVD)
- Student Workbook for Module 7 (from DVD)
- Multi-color markers (5 colors minimum) 1 pack per group
- Flip charts
- Colored construction paper
- Tape & scissors
- Notepad and pen to record decisions made during activity

Handouts Needed (on CD)

Communications in your Bleaching Response Plan
Resilience Communication Worksheet

General Guidance for Carrying Out this Session

- Give Powerpoint Presentation
- Facilitate a discussion about communication challenges and examples
- Do group activity – either communication campaign or go through worksheets to begin a communication plan
- Group presentations of communication campaigns (only if you choose this option)

Activity Instructions

Communication Campaign

Goal/Purpose: To develop a communication campaign that is appropriate for your problem and place

Guidelines: In this exercise, you are going to begin to develop a communication campaign that is specific to the issues of resilience, climate change, or bleaching that will assist you in your management strategies. Your main message or theme can be delivered in a variety of ways including advertising campaigns, school programs, a radio show, a puppet show, a video, a song for radio – the possibilities are endless. The most important thing is to make sure it is focused and outcome oriented.

Group Exercise

Instructions:

1. Identify issue or message
2. Identify communication goal
3. Identify key/target audiences
4. Identify best method of delivery (skit! song & dance!)
5. Identify concerns/emotions of stakeholders
6. Develop campaign that is audience appropriate
7. Pitch it to us

Output: Communication campaign framework developed

Notes to the Instructor

- This is a very straightforward presentation that doesn't present difficult concepts – they are somewhat obvious, but people often miss the importance of this aspect of their work. So it is important to emphasize the value of focusing on how you communicate, being prepared with information in the case of a serious event and a solid communication strategy.
- There are two options listed as examples – however, you can use any great example you've seen. If you'd like more information about the examples given, please contact us. (resilience@tnc.org)
- The Big Mamma Song and campaign materials can be downloaded on the website for anyone interested (also available on the toolkit).

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Module 7: Communications

Section 1: Communicating Climate Change, Coral Bleaching, and Resilience

Learning Objectives

By the end of this module you will have:

- ② An understanding of why we need to communicate about the impacts of climate change to coral reef ecosystems.
- ② Identify different audience and think about how to tailor communication strategies to target each audience.
- ② Heard about innovative ways others are communicating to the public and stakeholders.

Background

Effective Management can mean so many different things. When you break it down to the bare issues, you discover that it is all about **People** and how they relate to their **Environment**. Instead of focusing on one particular approach to managing reefs effectively, this section focuses on the fundamental component to any effective management strategy: **COMMUNICATION**. Paying attention to how you communicate information and to who is the first step to becoming more effective. Add to that some creative spark, and you might be on to something that advances your efforts substantially.

In this section, we want you to ‘think outside the box’ and work together to come up with a communication strategy that you can take home with you. We will tie together several of the previous sections to discuss the importance of communicating about mass bleaching and management strategies to various audiences. It is crucial to communicate the ecological and socioeconomic impacts of coral bleaching in order to raise awareness, impact decision makers, change behavior, and raise funds for future research. It is also important to realize that managing for resilience does not always look like traditional management, so communicating this will be very important. This brief module examines how to identify various audiences and how to tailor messages to each audience for maximum impact.

Mass coral bleaching is an issue that attracts strong interest from the public, the media, and policy/decision-makers and it is an issue we can take advantage of to communicate about the causes and impacts of climate change, resilience, management strategies, etc. In response, managers will want to provide up-to-date and informative answers to important questions about mass bleaching events and related impacts.

- A communication strategy for responding to mass bleaching might have three aims:
- (1) Gain support from supervisors and constituencies to respond to mass bleaching in the short and long term
 - (2) Engage stakeholders in a two-way communication about the extent and severity of bleaching and actions that can be taken to build reef resilience
 - (3) To work with the media to raise awareness of mass bleaching events and their impacts among the general public.

In working with any audience, managers are advised to take an approach that is clear and well thought out, proactive, solution-oriented, balanced, and respectful of political constraints. In communicating about mass bleaching, it is important that managers maintain the trust of their supervisors and the credibility of their reputation. Managers should be aware of political and social sensitivities and operate within organizational constraints. Managers also need to resist temptations to over-dramatize issues or events in order to meet the expectations of the press. This is of particular importance when bleaching is patchy and tourism operators are wary of the condition of their frequently visited sites becoming highlighted in the media. Lost credibility due to exaggeration of facts or presentation of premature conclusions can be costly and, sometimes, impossible to regain.



Worksheet or Activity

Worksheet: Communications in your Bleaching Response Plan

Worksheet: Resilience Communication Worksheet

Activity: Communications Campaign

COMMUNICATIONS IN YOUR BLEACHING RESPONSE PLAN

The following provides a briefing schedule to senior management, the governor or other elected official, the press and the message to be conveyed according to the risk or severity of bleaching. Fill in dates and triggers that are appropriate to your site. Think about the message that should be conveyed in each of these cases. The Great Barrier Reef Marine Park Authority table of activities is provided on the back of this sheet as an example.

Approx. date (adjust per your site)	Trigger ₁	Briefings				Examples of messages (tailor to your own site):
		Senior Management	Elected official	Stakeholders and partners	The media	
1 June						Summer approaching; bleaching risk period; we are prepared
	High bleaching risk					Temperatures unusually high; coral bleaching event probable
	Moderate bleaching					High temperatures recorded; moderate bleaching observed; areas worst affected
	Severe bleaching					Very high temperatures recorded; severe bleaching observed; areas worst affected; mortality likely
15 July						Temperature trends for first half of summer; summary of reports of coral bleaching
15 September	No bleaching					Summer concluding; bleaching risk period over; no significant bleaching observed
	Moderate or severe bleaching					High water temperatures recorded during summer; bleaching observed; preliminary assessment of extent and severity; detailed surveys underway
15 October	Moderate or severe bleaching					Summary of full extent and severity of bleaching; implications for the reef
Monthly						Updates on temperature trends and coral condition; also publish to web and email to all staff

EXAMPLE: GREAT BARRIER REEF MARINE PARK AUTHORITY COMMUNICATIONS STRATEGY

Approx. date	Trigger1	Briefings			Message
		Senior Management	Minister	Stakeholders	
1 Dec		^	^	^	Summer approaching; bleaching risk period; GBRMPA prepared
20 Dec		^			Temperature trends for December; plans for Christmas break
	High bleaching risk	^	^		Temperatures unusually high; coral bleaching event probable
	Moderate bleaching	^	^	^	High temperatures recorded; moderate bleaching observed; areas worst affected
	Severe bleaching2	^	^	^	Very high temperatures recorded; severe bleaching observed; areas worst affected; mortality likely
15 Feb3		^			Temperature trends for first half of summer; summary of reports of coral bleaching
31 March	No bleaching	^	^	^	Summer concluding; bleaching risk period over; no significant bleaching observed
	Moderate or severe bleaching	^	^	^	High water temperatures recorded during summer; bleaching observed; preliminary assessment of extent and severity; detailed surveys underway
31 April	Moderate or severe bleaching	^	^	^	Summary of full extent and severity of bleaching; implications for Great Barrier Reef
Monthly4		^			Updates on temperature trends and coral condition; also publish to web and email to all staff

Resilience Communication Worksheet

Instructions: In this exercise, you are going to begin to develop a communication plan that is specific to Resilience that will assist you in your management strategies. Your main message or theme can be delivered in a variety of ways including advertising campaigns, school programs, radio show, a video – the possibilities are endless. The most important thing is to make sure it is focused and outcome oriented. Follow the steps in the Resilience Communication Worksheet to complete this exercise.

OUTPUT: Communication campaign plan outlined

Try This At Home: To have a well developed effective communication campaign, it requires a dedicated staff person to make sure it is implemented. Working with community volunteers and available resources can produce a great product that gets attention.

Step 1. What is your goal for your communication strategy? (see examples below)

GOAL: _____

Examples of types of goals:

- To raise awareness
- To increase cooperation or compliance
- To gain political support
- To get young people involved
- To change behaviors of resource users

Step 2. Identify Resilience issue of concern (see helpful questions below)

Resilience Issue of Concern: _____

??Helpful Questions??

1. What aspect of the resilience principles would resonate most with your target audience?
2. Does your issue of concern have a practical application?
3. Does it have an emotional element that people would respond to?

Step 3. Identify your target audience and secondary audiences for your communication plan* (See helpful questions below)

**Note that the audience refers to the group you are trying to influence. You will be able to identify groups that can HELP you with this later in the exercise.*

??Helpful Questions??

1. Who is your primary audience?
2. What other audiences might be interested or relate to this message?
3. Which audiences have the most political influence?
4. Which audiences have the most social influence?
5. Who will be most positively affected by any management actions?
6. Who has the potential to be negatively affected by any management actions?
7. Who will be involved in the implementation of management actions?
8. Who usually causes confusion or trouble when information is distributed to the public or your key audience?

Please fill out this table

Primary Audience	Description	Rationale

Please fill out this table

Secondary Audience	Description	Rationale

Step 4. Identify and rank most effective methods of communication or message delivery (see helpful questions below)

Helpful Questions

1. How do people usually get information where you live? (TV, radio, newspaper, friends, religious gatherings, local shop, village meetings, etc.)
2. Which medium seems to be most powerful or influential?
3. Do people respond to visual images?
4. Are people interested in local politics and decisions?
5. Do people read the news regularly?

For Ranking:

6. What is the least expensive way to communicate with people?
7. Do you have existing resources or education programs that you could build on?
8. Are there specific education or outreach campaigns/programs that you can expand?
9. Are there resources in your community to help you implement your plan/strategy?

Please fill out this table

Method of Communication	Feasibility Ranking (1-5) 5 = most feasible	Notes

Step 4. Identify who should have primary responsibility for implementation

Person/Agency Responsible: _____

Step 5. Identify individuals, organized groups, or institutions that can help or support implementation

Helper	Description of Potential Contribution

Step 6. Identify resources available to you currently (see helpful questions below)

Staff	Schools	Events	Other
e.g. Public Relations Specialist	e.g. Ocean studies course	e.g. National Holiday Celebration	

Helpful Questions

1. Are there existing outreach or communication programs in your area or for your site?
2. Are there school programs that have environment or ocean classroom modules in place?
3. Are there particular teachers in your community with an interest in developing such programs?
4. Do you have TV or radio shows that highlight or discuss local issues?
5. Are there annual events that most of the community participates in? (e.g., agriculture exhibits, weekly markets, social events, religious events)

Step 7. Identify additional needs for you or your organization to successfully implement this plan/strategy

Potential Needs	Yes/No	Notes
Funding		
Expertise		
Materials		
Other		

Step 8. Layout a preliminary timeline for activity or program implementation

Timeframe (by quarter)	Activity Description	Milestones	Outcomes
Example: 1st Quarter	Conduct community survey on current perceptions about status of reefs	1. Develop survey; 2. Implement survey; 3. Analyze survey	Report on current perceptions to be used to shape message or info distributed



Activity

Application Exercise: Communication Campaign

Goal: To develop a communication campaign that is appropriate for your problem and place

Guidelines: In this exercise, you are going to begin to develop a communication campaign that is specific to the issues of resilience, climate change, or bleaching that will assist you in your management strategies. Your main message or theme can be delivered in a variety of ways including advertising campaigns, school programs, a radio show, a puppet show, a video, a song for radio – the possibilities are endless. The most important thing is to make sure it is focused and outcome oriented.

Group Exercise

Instructions:

1. Identify issue or message
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3. Identify key/target audiences
4. Identify best method of delivery (skit! song & dance!)
5. Identify concerns/emotions of stakeholders
6. Develop campaign that is audience appropriate
7. Pitch it to us

Output: Communication campaign framework developed

Try This At Home: To have a well developed effective communication campaign, it requires a dedicated staff person to make sure it is implemented. Working with community volunteers and available resources can produce a great product that gets positive attention.



On-the-Web

Great Barrier Reef Marine Park Authority Education Unit: <http://www.reefed.edu.au/>

The Nature Conservancy Reef Resiliency Toolkit: www.reefresilience.org

The Reef Environmental Education Foundation: <http://www.reef.org/>
Coral Reef Alliance-International Coral Reef Information Network Library
www.coralreefalliance.org

ReefBase: www.reefbase.org

NOAA's Coral Reef Conservation Program – Outreach and Education Program
<http://www.coralreef.noaa.gov/outreach/welcome.html>

Florida Keys National Marine Sanctuary Website:
<http://www.fknms.nos.noaa.gov/edu/welcome.html>



Definitions

Acclimatization: Acclimatization refers to phenotypic changes by an organism to stresses in the natural environment that result in the readjustment of the organism's tolerance.

Accretion: Growth by external addition of new matter.

Adaptive Management: The process of changing a management strategy in response to measuring its success.

Agricultural Run-off: The drainage of water from agricultural land.

AVHRR: Advanced Very High Resolution Radiometer, a sensor that is used to measure sea surface temperature from satellites.

Bathymetry: Measurement of the depth of the sea floor below sea level.

Belt Transect: A unit of data collection using transect lines of a fixed width.

Biodiversity: The number of different species present in a given environment (species diversity). Or, the number of different ecosystems present in a given environment (ecological diversity).

Bioerosion: Erosion caused by living organisms.

Biogeographic: Refers to the distribution of biodiversity over space. A biogeographic region is a geographic area with similar dominant plants, organisms and prevailing climate conditions.

Biota: Living organisms.

BOFFF: The abbreviation for Big Old Fat Fertile Female. BOFFFs are more biologically valuable due to their age and reproductive abilities, and removing them from the system is more detrimental than removing younger, non-reproductive fish.

Bleaching: See Coral bleaching.

Bleaching threshold: The temperature above which corals experience thermal stress that can lead to bleaching; defined as 1°C above the maximum monthly mean.

Catchment: An area that catches water.

Calcium Carbonate: The mineral laid down by a coral to create the hard structure surrounding the organism.

Clades: A clade is a term used to distinguish a taxonomic group that consists of a common ancestor and all descendents (cladograms are graphical depictions of these relationships; see [Phylogenetic](#)).

Climate: Long-term characteristics of weather.

Climate Change: The long-term fluctuations in temperature, precipitation, wind, and all other aspects of the Earth's climate. It is also defined by the United Nations Convention on Climate Change as "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Colony Integration: Influences the degree to which a whole colony responds to thermal stress. Characteristics of colony integration include polyp dimorphism, intra-tentacular budding and complex colony morphology. Species with high colony integration are predicted to

result in a greater whole-colony response to increased temperatures than species with low colony integration.

Connectivity: Natural linkages among reefs including ocean currents, larval dispersal, spawning patterns, and movements of adult fishes. Connectivity is an important part of dispersal and the replenishment of biodiversity on reefs damaged by natural or human related agents.

Contiguous: Touching area.

Contiguous Habitats: Habitats that share a boundary.

Cooling: Local oceanographic conditions such as vertical mixing of heated surface waters with cooler deeper water that can reduce temperature stress.

Coral bleaching: The paling of corals resulting from a loss of symbiotic algae. Bleaching occurs in response to physiological shock in response to abrupt changes in temperatures, salinity and turbidity. (see also Mass coral bleaching).

Coral Recruit: Settlement of a coral larvae to a permanent location.

Corallivorous: Organisms that consume coral.

Cryptic: Hidden or difficult to see.

CPUE: Catch Per Unit Effort, the number of fish caught per unit time/effort.

Deforestation: The act of cutting down trees within a given forested habitat.

Desiccation: To dry out.

Destructive Fishing: Using cyanide, dynamite, or other methods that cause coral breakage to kill all reef life (including corals, other invertebrates, as well as unmarketable species).

DHW (Degree Heating Weeks): A measurement that combines the intensity and duration of thermal stress in order to predict coral bleaching.

Distant Linked Habitats: Non contiguous habitats linked by connectivity.

Ecoregion: An area that contains a distinct assemblage of communities and species.

Ecosystem Resilience: The ability of an ecosystem to maintain key functions and processes in the face of stresses or pressures by either resisting or adapting to change.

Ecotourism: Responsible travel to natural areas that conserves the environment and sustains the well-being of local people. (The International Ecotourism Society)

Eddy: A current, as of water or air, moving contrary to the direction of the main current, especially in a circular motion.

Electromagnetic Spectrum: Energy that travels through space in the form of waves. The highest frequencies in the spectrum of electromagnetic radiation are gamma-rays; the lowest frequencies are radio waves. All electromagnetic radiation travels at the speed of light. Shorter wavelength radiation (e.g., ultraviolet) carries more energy and is likely to be more harmful to living tissue.

El Niño: An irregular variation of ocean current that from January to March flows off the west coast of South America, carrying warm, low-salinity, nutrient-poor water to the south. It is associated with the Southern Oscillation. These two effects are known as the El Niño Southern Oscillation (ENSO).

Eddy: A current, as of water or air, moving contrary to the direction of the main current, especially in a circular motion.

Energy Regime: Refers to the level of energy that characterizes a location. For example, a site on the leeward side of an island would have a lower energy regime because the influence of the wind on a daily basis is minimal.

Exposure: Describes the level of being exposed to physical forces such as high wave energy, wind, and strong currents. If an area is surrounded by islands with limited influence from waves, wind, and currents, its level of exposure is minimal.

Extractive (Non-Extractive): Taking something out of an environment versus leaving it in place. For example, food fishing is extractive, but catch and release fishing, snorkeling and diving, which leave the fishes in the environment, are non-extractive.

Fecundity: Refers to the potential reproductive capacity of an organism.

Functionally linked habitats Connected environments that are intended to conserve "all" biodiversity in an area- typically large and usually include both aquatic and terrestrial targets.

GBRMPA: Great Barrier Reef Marine Park Authority

Genetic Diversity: Genetic variation within a species.

GOES (Geostationary Operational Environmental Satellite): Geostationary satellites operated by NOAA. Hover at an altitude of about 36,000 km to give continuous data for one fixed area of the Earth's surface and lower parts of a given surface.

GPS: Global Positioning System; An electronic unit that receives satellite signals that tell your specific position in latitude and longitude.

HotSpot: A satellite product that highlights areas where the current sea surface temperature is above the mean temperature for the warmest month. May indicate a risk for coral bleaching.

Infrared Radiation: The part of the electromagnetic spectrum that has energy levels just below visible light. This is felt as radiant heat, and is sensed by the AVHRR sensor on NOAA's satellites.

Integrated Coastal Management: A continuous and dynamic process by which decisions are taken for the sustainable use, development, and protection of coastal and marine areas and resources.

La Niña: A phenomenon characterized by unusually cold ocean temperatures in the eastern Equatorial Pacific, compared to El Niño, which is characterized by unusually warm ocean temperatures in the eastern Equatorial Pacific.

Larval Duration: Pelagic larval duration refers to the amount of time the larvae spend in the open ocean before settlement on the reef.

Local Extinction: The complete loss of an organism in a specific part of its range.

Marine Protected Area(MPA): Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment (IUCN definition).

Marine Protected Area Network: An MPA network can include zones that are designed for different levels of use and extraction. For example, within the MPA network, no-take zones can be strategically placed to prohibit harvest. Multiple-use MPA zoning, including no-take areas, provides a way to accommodate multiple uses (e.g., recreational fishing, commercial fishing, tourism, etc.) and balances the trade-offs between sustainable use and conservation.

Marine Tenure: Locally specified entitlements to marine territories and resources claimed and exercised by the 'guardians' of those territories and resources.

MARXAN: Computer software available at no charge that provides decision support for those designing marine reserves or networks of reserves. It has become the most utilized conservation planning tool in the world.

Mass coral bleaching: (See also coral bleaching) Coral bleaching extending over large distances (often affecting reef systems spanning tens to hundreds of kilometres) as a result of anomalously high water temperatures.

Migration Corridors: Many large marine animals (i.e., whales, predatory fish, turtles, etc.) follow set routes when they migrate (for feeding, nesting, birthing, or breeding purposes) from one area to another. These routes are referred to as migration corridors.

MMM (Maximum Monthly Mean) Temperature: in other words, the average temperature for the warmest month of the year.

Mortality: The rate at which a particular species or population dies.

Mutualistic Relationships: Biological interaction between two species where each derives a benefit from the other.

NGO: Non-Governmental Organization.

NOAA: The U.S. National Oceanic and Atmospheric Administration.

Ocean Acidification: The declining pH (increased acidification) of the oceans due to increased CO₂ emissions globally.

Ocean Neighborhood: The area centered on a set of parents that is large enough to retain most of the offspring of those parents.

Pathogen: An organism which causes disease within another organism.

Pelagic Planktonic Larvae: Larvae of planktonic organisms that are located in the open ocean.

Phenotypic Plasticity: Refers to non-genetic variation in organisms in response to environmental factors.

Photosynthetically Active Radiation: Electromagnetic radiation in the wavelengths $\lambda = 400-700$ nm (the visible wavelengths and the spectrum used by plants for photosynthesis) that is absorbed by the chlorophyll molecule.

Phylogenetic: Pertains to the evolutionary development of an organism.

Pigment: A compound that gives color to tissue.

Planktivorous: Organisms that consume plankton.

POES (Polar Operational Environmental Satellite): Polar-orbiting satellites operated by NOAA. Orbit the earth at an altitude of about 850km to give global coverage every day and lower parts of a given surface.

Pond-Effect: Wide temperature fluctuations in back-reef lagoons, especially shallow lagoons behind fringing reefs.

Promontory: A high ridge of land or rock jutting out into a body of water.

Refugia: 1. An area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat for relict species. 2. An area of relatively unaltered climate that is inhabited by plants and animals during a period of continental climatic change (e.g., glaciation) and remains as a center of relict forms from which a new dispersion and speciation may take place after climatic readjustment. 3. Secure areas that are protected by natural factors and human intervention from a variety of stresses. They function as reliable sources of seed.

Relief (High or Low, Mapped): The differences between elevation and slope of higher and lower parts of a given surface.

Remote Sensing: Measuring some property of an object from a distance, without touching the object itself.

Replication: The process by which multiple samples of any habitat types are secured in a network of protected areas. Replication helps to spread the risk of any large-scale event destroying all protected examples of any habitat type.

Representation: The inclusion of a full range of habitat types into a protected area system. Representation of all habitat types helps to ensure that the full complement of species for that habitat type is protected.

Resilience to bleaching: Coral colonies bleach and partially or entirely die, but the coral community recovers rapidly to its former state. Resilient reefs should be managed to maintain conditions that facilitate successful coral recruitment and recovery.

Resistance: The capacity of an organism or a tissue to withstand the effects of a harmful environmental agent. Resistance to bleaching is exhibited when coral colonies do not bleach, or bleach but don't die. This may vary among different parts of a reef and between different reef communities.

Resistance to bleaching: Coral colonies don't bleach or bleach but don't die. Resistant reefs play a critical role in reef survival by providing a reliable source of larvae which can recruit to and enable recovery of affected areas.

Salinity: Measure of salt per unit of water usually measured in parts per thousand (seawater is generally around 35 parts per thousand).

Satellite: An object that goes around (orbits) a larger object, such as a planet.

SBA (Satellite Bleaching Alert): These free automatic e-mails are sent by NOAA to warn of elevated temperatures that may lead to coral bleaching.

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

Sediment: Soil or particulate organic and inorganic matter carried in the water.

Sedimentation: The settling of particulate matter.

Shading: Reduced exposure to the harmful effects of sunlight. Examples include high island shadow or overhanging vegetation.

Sink Area: The area to which eggs and larvae disperse and settle.

Site Conservation Planning: Planning methodology which places sites in their larger ecological context; setting conservation priorities and strategies to conserve both single and multiple conservation areas, taking direct conservation action; and measuring conservation success.

SocMon Guidelines: A set of guidelines for establishing a socioeconomic monitoring program at a coastal management site. The guidelines provide a prioritized list of socioeconomic variables useful to managers, questions for data collection, and tables for data analysis.

Social Resilience: The resilience of communities to adapt to and withstand institutional, environmental and economic changes in their particular geography. Often these changes take the form of policies or regulations, with more resilient communities more likely to comply and sustain change.

Source Area: The area from which eggs and larvae originate to supplement populations down current.

Species Diversity: The number of different species present in a given environment.

Spillover: Spillover from an MPA accounts for two types of movements outside the MPA: (1) adults and juvenile animals swim into adjacent areas, and (2) young animals and eggs can drift out from the MPA into the surrounding waters.

Spur and Groove: The series of gullies divided by higher spurs that cross reefs at right angles below the reef crest.

SST: Sea surface temperature.

SST Anomaly: The difference between the current sea surface temperature and a long-term average.

Stakeholder: Any person with a vested interest in the natural resources of concern (e.g., coral reefs).

Stress Tolerance: The response of organisms to stressful conditions that have been repeatedly exposed to a stress, such as an exposed reef flat exposed to warm waters, that may result in a natural tolerance against bleaching.

Stressor: A physical, chemical or biological factor that adversely affects organisms; an agent, condition or similar stimulus that causes stress to an organism.

Stress Tolerance: The response of organisms to stressful conditions that have been repeatedly exposed to a stress, such as an exposed reef flat exposed to warm waters that may result in a natural tolerance against bleaching.

Susceptibility to bleaching: How easily corals are influenced or affected by bleaching.

Symbiotic Algae: Zooxanthellae are tiny symbiotic algae that provide food and oxygen to the coral, allowing their host to direct more energy toward constructing its calcium carbonate skeleton. Bleached corals lose their zooxanthellae and turn white (see also Zooxanthellae).

Synergistic: Producing a combined effect greater than the same agents used separately.

Thermal Stress: Adverse stress caused to an organism by elevated temperature.

Thermohaline Circulation (THC): Large-scale ocean circulation patterns that are driven by global density gradients that result from both temperature (thermo) and freshwater inputs that alters the salinity of the water (haline).

Tolerance (Thermal, Stress): The ability to survive and grow in the presence of normally toxic conditions (i.e. Heat)

Topographical: The characteristics describing the physical features of the environment.

Transect: Typically a straight line across an area along which ecological measurements are taken.

Trophic Structure: The relationship of an organism to other organisms in the context of a food web (trophic refers to an organisms assignment to different trophic levels, i.e., consumers, producers, decomposers, etc.).

Turbid (or turbidity): Limited visibility due to particulate matter suspended in the water; murky.

Turbulence: Small-scale non-directional water movements.

Upwelling: Movement toward the surface of deeper waters, bringing cooler waters with nutrients to the surface.

UTM (Coordinates): Universal Transverse Mercator (UTM) Coordinates measure in meters east and north from two perpendicular reference baselines.

Waypoint: A point of latitude and longitude given when using a GPS unit to map an area.

Zooxanthellae: Symbiotic algae (in the dinoflagellate genus *Symbiodinium*) that lives in the tissues of coral polyps and other host animals. The tiny photosynthetic organisms provide both nutrients and oxygen to the corals and other host animals in which they live (see also symbiotic algae).

****Also See NOAA's CoRIS coral reef glossary for more definitions:***

<http://coris.noaa.gov/glossary/>